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

—The Publisher
Preface

I suppose there is always a question regarding the reception a first edition of any text will receive before its publication. The response and enthusiasm for the first edition of this text have been rewarding and exceeded my optimistic expectations. Inasmuch as imitation is a form of flattery, I am also pleased with the development of multiple other titles in the Netter’s Concise series that were based on the format of this text. Despite this encouragement, it quickly became clear that the first edition of this text, written predominantly while I was a medical student, was in need of an update. Although the anatomy is a constant, our understanding of it, our terminology, and its clinical application continue to advance.

I received considerable feedback, both positive and negative, on the first edition. Much of it was constructive, and I am grateful for all of it. The revision has been both challenging and rewarding. Formatting this enormous volume of material was a painstaking process, and I would like to thank John Casey, the production team, and all of those at Elsevier for their patience, hard work, and professionalism. With their help I was able to develop my vision of this project. It has been a pleasure to work with them.

In this revision, I have tried to strike a balance between being thorough and yet concise while staying true to the original concept of the text, which was to allow the incomparable Netter artwork to do a majority of the teaching. Knowing it’s impossible to please everyone, I look forward to hearing how well the balance was or was not achieved.

In this second edition, every table, both anatomic and clinical, was updated or revised. We were also able to enhance the text with radiographs, additional sections, and new artwork including additional surgical approaches. In the preface to the first edition I noted that the text embodied the book that I unsuccessfully tried to find on the shelves of medical bookstores as a medical student. That failed search originally prompted me to write the text. With the above-mentioned updates and additions, I feel that statement should be amended. This edition is, in fact, the text for which I had originally searched and fulfills the vision of the initial undertaking that began over 10 years ago. I hope the readers find it so.

Jon C. Thompson, MD
About the Author

Jon C. Thompson, MD, received his undergraduate degree from Dartmouth College and his medical degree from the Uniformed Services University of the Health Sciences in Bethesda, Maryland. Having recently completed his orthopaedic residency at Brooke Army Medical Center in San Antonio, Texas, he is now board certified in orthopaedic surgery and sports medicine. He is currently continuing his military service at Irwin Army Community Hospital, Fort Riley, Kansas. Dr. Thompson is glad to no longer have to answer questions regarding why he published an orthopaedic text before doing any formal orthopaedic training, as well as being able to spend more time with his family. His wife and four young children, though very supportive, are not looking forward to Dr. Thompson’s future publishing projects.

To the men and women of the armed forces
who bravely serve our country

To the readers
whose enthusiasm for the text has
motivated me to do better

To my children,
Taylor, Turner, Jax, and Judson,
constant and perfect reminders
of the truly important and joyful aspects of life

To my wife,
Tiffany, the foundation
of every good thing in my life
About the Artists

**Frank H. Netter, MD**
Frank H. Netter was born in 1906, in New York City. He studied art at the Art Student’s League and the National Academy of Design before entering medical school at New York University, where he received his medical degree in 1931. During his student years, Dr. Netter’s notebook sketches attracted the attention of the medical faculty and other physicians, allowing him to augment his income by illustrating articles and textbooks. He continued illustrating as a sideline after establishing a surgical practice in 1933, but he ultimately opted to give up his practice in favor of a full-time commitment to art. After service in the United States Army during World War II, Dr. Netter began his long collaboration with the CIBA Pharmaceutical Company (now Novartis Pharmaceuticals). This 45-year partnership resulted in the production of the extraordinary collection of medical art so familiar to physicians and other medical professionals worldwide.

In 2005, Elsevier, Inc., purchased the Netter Collection and all publications from Icon Learning Systems. There are now over 50 publications featuring the art of Dr. Netter available through Elsevier, Inc. (in the US: www.us.elsevierhealth.com/Netter and outside the US: www.elsevierhealth.com)

Dr. Netter’s works are among the finest examples of the use of illustration in the teaching of medical concepts. The 13-volume *Netter Collection of Medical Illustrations*, which includes the greater part of the more than 20,000 paintings created by Dr. Netter, became and remains one of the most famous medical works ever published. *The Netter Atlas of Human Anatomy*, first published in 1989, presents the anatomical paintings from the Netter Collection. Now translated into 16 languages, it is the anatomy atlas of choice among medical and health professions students the world over.

The Netter illustrations are appreciated not only for their aesthetic qualities, but also, more important, for their intellectual content. As Dr. Netter wrote in 1949, “... clarification of a subject is the aim and goal of illustration. No matter how beautifully painted, how delicately and subtly rendered a subject may be, it is of little value as a medical illustration if it does not serve to make clear some medical point.” Dr. Netter’s planning, conception, point of view, and approach are what inform his paintings and what makes them so intellectually valuable.


Learn more about the physician-artist whose work has inspired the Netter Reference collection:

http://www.netterimages.com/artist/netter.htm
Carlos Machado, MD

Carlos Machado was chosen by Novartis to be Dr. Netter’s successor. He continues to be the main artist who contributes to the Netter collection of medical illustrations.

Self-taught in medical illustration, cardiologist Carlos Machado has contributed meticulous updates to some of Dr. Netter’s original plates and has created many paintings of his own in the style of Netter as an extension of the Netter collection. Dr. Machado’s photorealistic expertise and his keen insight into the physician/patient relationship informs his vivid and unforgettable visual style. His dedication to researching each topic and subject he paints places him among the premier medical illustrators at work today.

Learn more about his background and see more of his art at:

http://www.netterimages.com/artist/machado.htm
Introduction

*Netter’s Concise Orthopaedic Anatomy* is an easy-to-use reference and compact atlas of orthopaedic anatomy for students and clinicians. Using images from both the *Atlas of Human Anatomy* and the 13-volume *Netter Collection of Medical Illustrations*, this book brings over 450 Netter images together.

Tables are used to highlight the Netter images and offer key information on bones, joints, muscles, nerves, and surgical approaches. Clinical material is presented in a clear and straightforward manner with emphasis on trauma, minor procedures, history and physical exam, and disorders.

Users will appreciate the unique color-coding system that makes information look-up even easier. Key material is presented in black, red, and green to provide quick access to clinically relevant information.

**BLACK:** standard text

**GREEN:** key/testable information

**RED:** key information that if missed could result in morbidity or mortality
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bones</td>
<td>2</td>
</tr>
<tr>
<td>Joints</td>
<td>16</td>
</tr>
<tr>
<td>Nerves</td>
<td>22</td>
</tr>
<tr>
<td>Muscles</td>
<td>24</td>
</tr>
</tbody>
</table>
BONES

**Function**
- Serves as attachment sites for muscles
- Protection for organs (e.g., cranium, ribs, pelvis)
- Reservoir for minerals in the body: 99% of body's calcium stored as hydroxyapatite crystals
- Hematopoiesis site

**BONE FORMS**
- Long bones:
  - Form by enchondral ossification (except clavicle): primary (in shaft) and secondary growth centers
  - Have physis ("growth plates") at each end where it grows in length (metacarpals, metatarsals, and phalanges of hand and feet typically have only one physis)
  - 3 parts of long bone:
    - **Diaphysis**: shaft, made of thick cortical bone, filled with bone marrow
    - **Metaphysis**: widening of bone near the end, typically made of cancellous bone
    - **Epiphysis**: end (usually articular) of bone, forms from secondary ossification centers
- Flat bones:
  - Form by intramembranous ossification (e.g., pelvis, scapula)

**MICROSCOPIC BONE TYPES**
- Woven:
  - Immature or pathologic bone; poorly organized, not stress oriented
  - Examples: Immature—bones in infants, fracture callus; Pathologic—tumors
- Lamellar:
  - Mature bone; highly organized with stress orientation
  - Mature (>4y.o.) cortical and cancellous bone are both made up of lamellar bone
**Structure of Cortical (Compact) Bone**

- **Subperiosteal outer circumferential lamellae**
- **Periosteum**
- **Interstitial lamellae**
- **Capillaries in haversian canals**
- **Periosteal vessels**
- **Central (haversian) canal** containing capillary, nerve fiber, and perivascular (progenitor) cells and lined with osteoblasts
- **Interstitial lamellae** (not part of the osteon)
- **Diagram of osteon (haversian system) with 6 concentric lamellae (greatly enlarged)**

### STRUCTURAL BONE TYPES

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>COMMENT</th>
</tr>
</thead>
</table>
| **Cortical (compact)**     | • Strong, dense bone, makes up 80% of the skeleton  
• Composed of multiple osteons (haversian systems) with intervening interstitial lamellae  
• **Osteons** are made up of concentric bone lamellae with a central canal (haversian canal) containing osteoblasts (new bone formation) and an arteriole supplying the osteon. Lamellae are connected by canaliculi. **Cement lines** mark outer limit of osteon (bone resorption ended).  
• Volkmann’s canals: radially oriented, have arteriole, and connect adjacent osteons  
• Thick cortical bone is found in the diaphysis of long bones |
| **Cancellous (spongy/trabecular)** | • Crossed lattice structure, makes up 20% of the skeleton  
• High bone turnover rate. Bone is resorbed by osteoclasts in Howship’s lacunae and formed on the opposite side of the trabeculae by osteoblasts.  
• **Osteoporosis** is common in cancellous bone, making it susceptible to fractures (e.g., vertebral bodies, femoral neck, distal radius, tibial plateau).  
• Commonly found in the metaphysis and epiphysis of long bones |
### Bone Composition

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bone</strong></td>
<td>Bone is composed of multiple components: 1. Organic phase (“matrix:” proteins, macromolecules, cells); 2. Inorganic phase (minerals, e.g., Ca(^{++})); 3. Water</td>
</tr>
</tbody>
</table>

#### Inorganic phase
- **Calcium hydroxyapatite**
  - Approximately 60% of bone weight
  - \(\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2\). Primary mineral in bone. Adds compressive strength.
- **Osteocalcium phosphate**
  - “Brushite” is a secondary/minor mineral in bone.

#### Organic phase
- **Collagen**
  - Type 1 collagen gives tensile strength and is 90% of organic phase. Mineralization occurs at ends (hole zones) and along sides (pores) of the collagen fibers.
- **Proteoglycans**
  - Macromolecules made up of a hyaluronic backbone w/ multiple glycosaminoglycans
  - Glycosaminoglycans (GAG): made of core protein w/ chondroitin & keratin branches
  - Gives bone compressive strength
- **Noncollagen proteins**
  - Osteocalcin #1, is indicator of increased bone turnover (e.g., Paget’s disease)
  - Others: osteonectin, osteopontin
- **Cells**
  - Osteoblasts, osteocytes, osteoclasts

#### Water
- Approximately 5% of bone weight (varies with age and location)

*Periosteum surrounds the bone, is thicker in children, and responsible for the growing diameter (width) of long bones.*
Four Mechanisms of Bone Regulation

1. Stimulation of deposition
   - Weight-bearing activity
   - Growth
   - Fluoride
   - Electricity
   - More (or more active) osteoblasts (B)

2. Inhibition of deposition
   - Lack of weight-bearing activity
   - Chronic malnutrition
   - Alcoholism
   - Chronic disease
   - Normal aging
   - Hypercortisolism
   - Fewer (or less active) osteoblasts

3. Inhibition of withdrawal
   - Weight-bearing activity
   - Estrogen
   - Testosterone
   - Calcitonin
   - Adequate vitamin D intake
   - Adequate calcium intake (mg/day)
     - Child: 400–700
     - Adolescent: 1,000–1,500
     - Adult: 750–1,000
     - Pregnancy: 1,500
     - Lactation: 2,000
     - Postmenopause: 1,500
   - Fewer (or less active) osteoclasts

4. Stimulation of withdrawal
   - More (or more active) osteoclasts
   - Lack of weight-bearing activity (disuse)
   - Space travel (weightlessness)
   - Hyperparathyroidism
   - Hypercortisolism
   - Hyperthyroidism
   - Estrogen deficiency (menopause)
   - Testosterone deficiency
   - Acidosis
   - Myeloma
   - Lymphoma
   - Inadequate calcium intake
   - Normal aging
   - Net decrease in bone mass

<table>
<thead>
<tr>
<th>CELL</th>
<th>COMMENT</th>
</tr>
</thead>
</table>
| Osteoblasts           | • Function: produce bone matrix (“osteoid”). Make type 1 collagen and other matrix proteins  
                       • Line new bone surfaces and follow osteoclasts in cutting cones  
                       • Receptors: PTH (parathyroid hormone), vitamin D, glucosteroids, estrogen, PGs, ILs |
| Osteocytes            | • Osteoblast surrounded by bone matrix. Represent 90% of all bone cells  
                       • Function: maintain & preserve bone. Long cell processes communicate via canaliculi.  
                       • Receptors: calcitonin (do not release calcium) |
| Osteoclasts           | • Large, multinucleated cells derived from the same line of cells as monocytes & macrophages  
                       • Function: when active, use a “ruffled border” to resorb bone; found in Howship’s lacunae  
                       • Receptors: calcitonin, estrogen, IL-1, RANK L. Inhibited by bisphosphonates |
Bone formation (ossification) occurs in 3 different ways: enchondral, intramembranous, appositional.

**Enchondral**
- Bone replaces a cartilage anlage (template). Osteoclasts remove the cartilage, and osteoblasts make the new bone matrix, which is then mineralized.
- Typical in long bones (except clavicle).
- Primary ossification centers (in shaft) typically develop in prenatal period.
- Secondary ossification centers occur at various times after birth, usually in the epiphysis.
- Longitudinal growth at the physis also occurs by enchondral ossification.
- Also found in fracture callus

**Intramembranous**
- Bone develops directly from mesenchymal cells without a cartilage anlage.
- Mesenchymal cells differentiate into osteoblasts, which produce bone.
- Examples: flat bones (e.g., the cranium) and clavicle

**Appositional**
- Osteoblasts make new matrix/bone on top of existing bone.
- Example: periosteal-mediated bone diameter (width) growth in long bones
### ANATOMY OF THE PHYYSIS

<table>
<thead>
<tr>
<th>Structure</th>
<th>Comment</th>
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</thead>
<tbody>
<tr>
<td><strong>Reserve zone</strong></td>
<td>- Loosely organized cells produce abundant matrix and store metabolites.</td>
</tr>
</tbody>
</table>
| **Proliferative zone**            | - **Longitudinal growth** occurs here as chondrocytes divide and stack into columns.  
- **Achondroplasia** is result of dysfunction of this zone. |
| **Hypertrophic zone**             | - Has 3 subzones. Function is to prepare the matrix for calcification and calcify it.  
- Cells (chondrocytes) mature and enlarge 5-10x in size.  
- Chondrocytes die, proteoglycans are degraded, allowing for mineralization of matrix.  
- Released calcium mineralizes the cartilage matrix (radiographically dense zone). |
| **Metaphysis**                    | - Osteoblasts make immature (woven) bone on the calcified cartilage.  
- Osteoclasts remove cartilage & immature bone; osteoblasts make new (lamellar) bone. |
| **Other**                         | - Peripheral chondrocytes allow for widening/growth of the physis.  
- AKA “perichondral ring of La Croix.” Provides peripheral support for cartilaginous physis. |
Normal Calcium and Phosphate Metabolism

**Calcium**
- Calcium (Ca^{++}) plays a critical role in cardiac, skeletal muscle, and nerve function.
- Normal dietary requirement: 500-1300mg. More is required during pregnancy, lactation, fractures.
- 99% of body's stored calcium is in the bone.
- Calcium levels directly regulated by PTH and Vitamin D 1,25.

**Phosphate**
- Important component of bone mineral (hydroxyapatite) and body metabolic functions.
- 85% of body's stored phosphate is in the bone.

**MINERAL** | **COMMENT**
--- | ---
**BONE METABOLISM** | Bone plays a critical role in maintaining proper serum calcium and phosphate levels.

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<table>
<thead>
<tr>
<th>MINERAL</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
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</tr>
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<td>Important component of bone mineral (hydroxyapatite) and body metabolic functions. 85% of body’s stored phosphate is in the bone.</td>
</tr>
</tbody>
</table>
### Regulation of Calcium and Phosphate Metabolism

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parathyroid hormone (PTH)</strong></td>
<td>- Low serum calcium triggers PTH release. PTH binds 1. osteoblasts (which stimulate osteoclasts to resorb bone), 2. osteocytes (to release Ca(^{++})), 3. kidney (increase Ca(^{++}) reabsorption)</td>
</tr>
</tbody>
</table>
| **Vitamin D 1,25 (OH)**  | - Vitamin D from skin (UV light) or diet is hydroxylated twice ([1-liver], [25-kidney])  
- Vit. D 1,25 triggered by low serum Ca\(^{++}\) stimulates uptake in intestine and bone resorption |
| **Calcitonin**    | - Released when serum Ca\(^{++}\) is elevated. Directly inhibits osteoclasts (bone resorption) and increases urinary excretion from kidneys, thus lowering serum levels |
| **Other hormones** | - Estrogen, corticosteroids, thyroid hormone, insulin, growth hormone |
Dynamics of Bone Homeostasis

**Active osteocytes maintain bone**
- Lining cells (inactive osteocytes)
- Osteoid (hypomineralized matrix)
- Osteoblasts form osteoid (bone matrix)
- Weight-bearing activity and use of antigravity muscles

**Periosteum**
- Weight-bearing activity and use of antigravity muscles
- Lack of weight-bearing activity or decreased use of antigravity muscles

**Endosteum**
- Lining cells (inactive osteocytes)

**Osteoclasts resorb bone**
- Promote net bone resorption (osteoclastic bone resorption > osteoblastic bone formation)
- Adrenal cortex
  - Glucocorticoids (decrease Ca++ absorption from intestine)
  - Excess hormone
    - Thyroid
    - Parathyroids
    - Acidosis

**Osteoblasts form osteoid (bone matrix)**
- 1,25(OH)2D promotes Ca++ absorption
- Promote net bone formation (osteoblastic bone formation > osteoclastic bone resorption)

**Blood and tissue fluid**
- Adequate intake and absorption of Ca++ needed to maintain blood and tissue-fluid levels.
- Levels regulated by PTH, 1,25(OH)2D, and calcitonin
- Amino acids (adequate intake and absorption of protein needed for bone matrix formation)

**Intake**
- 800 mg/day
- 500 mg/day absorbed
- 300 mg/day returned to intestine
- 7,800 mg/day reabsorbed
- 200 mg/day lost in urine
- 600 mg/day lost in stool

**Intestine**
- Adequate intake and absorption of Ca++ needed to maintain blood and tissue-fluid levels.
- Levels regulated by PTH, 1,25(OH)2D, and calcitonin
- Amino acids (adequate intake and absorption of protein needed for bone matrix formation)

**Renal tubule**
- 800 mg/day filtered
- 500 mg/day absorbed

**CONDITION**

**Hypercalcemia**
- 1° Hyperparathyroidism
  - Symptoms: constipation, nausea, abdominal pain, confusion, stupor, coma
  - Typically from parathyroid adenoma and/or overproduction of PTH hormone
  - “Brown tumors” form. Labs: increased serum calcium, decreased serum phosphate
- 2° Hyperparathyroidism
  - Malignancy (lung CA produces PTH-like protein), MEN syndromes

**Hypocalcemia**
- Hypoparathyroidism
  - Symptoms: hyperreflexia, tetany, +Chvostek’s/Trousseau sign(s), papilledema
  - Due to decreased PTH production, results in decreased serum calcium levels
  - Can occur after thyroidectomy with inadvertent excision of parathyroid glands
  - Due to one of many diseases resulting in chronic renal failure
  - Failure to properly mineralize the bone matrix (qualitative problem)
  - Due to Vitamin D deficiency (nutritional) or receptor defect (usually hereditary)

**Renal osteodystrophy**
- Rickets/osteomalacia

**METABOLIC DISORDERS**

**COMMENT**

**Hypercalcemia**
- 1° Hyperparathyroidism
  - Symptoms: constipation, nausea, abdominal pain, confusion, stupor, coma
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## Comparison of Osteoporosis and Osteomalacia

<table>
<thead>
<tr>
<th>Definition</th>
<th>Osteoporosis</th>
<th>Osteomalacia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unmineralized matrix</td>
<td>Mineralized matrix</td>
<td>Unmineralized matrix</td>
</tr>
<tr>
<td>Bone mass decreased, mineralization normal</td>
<td>Bone mass variable, mineralization decreased</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age at onset</th>
<th>Osteoporosis</th>
<th>Osteomalacia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generally elderly, postmenopause</td>
<td>Any age</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Osteoporosis</th>
<th>Osteomalacia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endocrine abnormality, age, idiopathic, inactivity, disease, alcoholism, calcium deficiency</td>
<td>Vitamin D deficiency, abnormality of vitamin D pathway, hypophosphatemic syndromes, renal tubular acidosis, hypophosphatasia</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symptomatology</th>
<th>Osteoporosis</th>
<th>Osteomalacia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain referable to fracture site</td>
<td>Generalized bone pain</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Signs</th>
<th>Osteoporosis</th>
<th>Osteomalacia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenderness at fracture site</td>
<td>Tenderness at fracture site and generalized tenderness</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Radiographic features</th>
<th>Osteoporosis</th>
<th>Osteomalacia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial predominance</td>
<td>Appendicular predominance</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Laboratory findings</th>
<th>Osteoporosis</th>
<th>Osteomalacia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum Ca²⁺</td>
<td>Normal</td>
<td>Low or normal (high in hypophosphatasia)</td>
</tr>
<tr>
<td>Serum P₁</td>
<td>Normal</td>
<td>Low or normal</td>
</tr>
<tr>
<td>Ca²⁺ x P₁ &gt; 30</td>
<td>Normal</td>
<td>Elevated, except in hypophosphatasia</td>
</tr>
<tr>
<td>Alkaline phosphatase</td>
<td>Normal</td>
<td>Normal or low (high in hypophosphatasia)</td>
</tr>
<tr>
<td>Urinary Ca²⁺</td>
<td>High or normal</td>
<td></td>
</tr>
<tr>
<td>Bone biopsy</td>
<td>Tetracycline labels normal</td>
<td>Tetracycline labels abnormal</td>
</tr>
</tbody>
</table>

### METABOLIC DISORDERS

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>COMMENT</th>
</tr>
</thead>
</table>
| Osteoporosis | • Decrease in bone mass (quantitative problem). Most common in elderly patients  
• 2 types: Type 1: most common, affects cancellous bone (femoral neck, vertebral body, etc); Type 2: age related, >70y.o. Both cancellous and cortical bone mass are deficient.  
• DEXA scan is standard for evaluation. Hormone replacement or bisphosphonates may be used. |
| Scurvy | • Vitamin C deficiency leads to defective collagen, resulting in a constellation of symptoms. |
| Osteopetrosis | • “Marble bone disease”. Osteoclast dysfunction results in too much bone density. |
| Paget’s disease | • Simultaneous osteoblast & osteoclast activity results in dense, but brittle bones. |
Type I. Wound <1 cm long. No evidence of deep contamination

Type II. Wound >1 cm long. No extensive soft tissue damage

Type IIIA. Large wound. Good soft tissue coverage

Type IIIB. Large wound. Exposed bone fragments, extensive stripping of periosteum. Needs coverage

Type IIIC. Large wound with major arterial injury

Compression fracture

Pathologic fracture (tumor or bone disease)

Greenstick fracture

Torus (buckle) fracture

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FRACTURES</strong></td>
<td></td>
</tr>
<tr>
<td>Type/description</td>
<td>Transverse, oblique, spiral, comminuted, segmental, impacted, avulsion</td>
</tr>
<tr>
<td>Displacement</td>
<td>Nondisplaced, minimally displaced, displaced</td>
</tr>
<tr>
<td>Angulation</td>
<td>Direction of distal fragment (e.g., dorsal displacement) or direction of apex (e.g., apex volar)</td>
</tr>
<tr>
<td>Open vs closed</td>
<td>Open if bone penetrated skin resulting in open wound (surgical emergency for infection risk)</td>
</tr>
<tr>
<td></td>
<td>Gustilo &amp; Anderson classification of open fractures (I, II, III a,b,c) is commonly used</td>
</tr>
<tr>
<td>Other</td>
<td>Compression: failure of bone due to compressive load.</td>
</tr>
<tr>
<td></td>
<td>Salter-Harris: pediatric fracture involving an open physis (growth plate)</td>
</tr>
<tr>
<td></td>
<td>Greenstick: pediatric fracture with disruption of a single cortex</td>
</tr>
<tr>
<td></td>
<td>Buckle/torus: pediatric fracture involving an impacted cortex</td>
</tr>
<tr>
<td></td>
<td>Pathologic: fracture resulting from a diseased bone/bone tumor</td>
</tr>
</tbody>
</table>
1. Complete separation of epiphysis from shaft through calcified cartilage (growth zone) of growth plate. No bone actually fractured; periosteum may remain intact. Most common in newborns and young children.

2. Most common. Line of separation extends partially across deep layer of growth plate and extends through metaphysis, leaving triangular portion of metaphysis attached to epiphyseal fragment.


4. Fracture line extends from articular surface through epiphysis, growth plate, and metaphysis. If fractured segment not perfectly realigned with open reduction, osseous bridge across growth plate may occur, resulting in partial growth arrest and joint angulation.

5. Severe crushing force transmitted across epiphysis to portion of growth plate by abduction or adduction stress or axial load. Minimal or no displacement makes radiographic diagnosis difficult; growth plate may nevertheless be damaged, resulting in partial growth arrest or shortening and angular deformity.

6. Portion of growth plate sheared or cut off. Raw surface heals by forming bone bridge across growth plate, limiting growth on injured side and resulting in angular deformity.
Periosteum Hemorrhage

Healing of fracture

Inflammation
A hematoma forms as the result of disruption of intraosseous and surrounding vessels. Bone at the edges of the fracture dies. Bone necrosis is greater with larger amounts of soft tissue disruption. Inflammatory cells are followed by fibroblasts, chondroblasts, and osteoprogenitor cells. Low pO2 at the fracture site promotes angiogenesis.

Endosteum

Osteoblasts

Cartilage

Osteoid Organized hematoma

Repair of soft callus formation
Soft callus forms, initially composed of collagen; this is followed by progressive cartilage and osteoid formation.

Remodeling
Osteoclastic and osteoblastic activity converts woven bone to lamellar bone with true haversian systems. Normal bone contours are restored; even angulation may be partially or completely corrected.

Fiber bone

Repair of hard callus formation
Osteoid and cartilage of external, periosteal, and medullary soft callus become mineralized as they are converted to woven bone (hard callus).

<table>
<thead>
<tr>
<th>STAGE</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FRACTURE HEALING</strong></td>
<td></td>
</tr>
<tr>
<td>Fracture healing occurs as a continuum with three stages: inflammation, repair (callus formation), remodeling.</td>
<td></td>
</tr>
<tr>
<td>• To heal, most fractures require good blood supply (most important) and stability.</td>
<td></td>
</tr>
<tr>
<td>• Callus formation does not occur after rigid fixation of fractures (ORIF); instead primary/direct healing occurs.</td>
<td></td>
</tr>
<tr>
<td>• Smoking and NSAIDs both inhibit bone/fracture healing.</td>
<td></td>
</tr>
<tr>
<td><strong>Inflammation</strong></td>
<td>• Hematoma develops &amp; supplies hematopoietic/osteoprogenitor cells. Granulation tissue forms.</td>
</tr>
<tr>
<td><strong>Repair</strong></td>
<td>• Soft callus: cells produce a cartilage (soft) callus that bridges the bone ends (bridging callus)</td>
</tr>
<tr>
<td></td>
<td>• Hard callus: replacement of soft callus into immature (woven) bone (enchondral ossification)</td>
</tr>
<tr>
<td><strong>Remodeling</strong></td>
<td>• Immature (woven) bone is replaced by mature (lamellar) bone</td>
</tr>
</tbody>
</table>
Factors That Promote or Delay Bone Healing

**Factors that promote**
- Growth hormone
- Pituitary
- Thyroid hormones
- Calcitonin
- Thyroid
- Insulin
- Pancreas
- Anabolic hormones
- Adrenal cortex
- Gonads
- Normal absorption of nutrients
- GI tract
- Electric stimulation of bone
- Vitamin D
- Vitamin C, retinoic acid, TGF-β, BMP
- Exercise, weight bearing
- Promotion of calcification
- Youth
- Rapid bone growth

**Factors that delay**
- Corticosteroids
- NSAIDs
- Adrenal cortex
- Diabetes mellitus
- Pancreas
- Deficiency of sex hormone
- Gonads
- Poor oxygenation
- Anemia
- Deficiency of Vitamin D or its conversion to 1,25(OH)2D
- Osteomalacia
- Excessive bone gap or motion
- Large bone defect or interposition of soft tissue
- Impaired bone nutrition or vitality
- Loss of soft tissue, vascular injury, x-ray irradiation
- Bone damage
- Infection, neoplasm
- Synovial fluid fibrolysin
- Intraarticular fracture
- Deficiency or abnormality of bone substance
- Osteoporosis, Paget disease of bone
- Slow bone growth
- Advanced age
Synovial joints

- Patella (cut)
- Synovium covering femur
- Cut edge of synovium
- Cut edge of capsule
- Articular surface of femur
- Cruciate ligaments covered by synovium
- Articulating surfaces of medial and lateral menisci
- Synovium covering tibia
- Articular surface of tibia
- Synovium lining joint capsule
- Articular surface of patella

Cartilage (blue) covers articular surfaces; synovial membrane (orange) covers interior of joint capsule and ligaments, traversing joint space. Dynamic and static stability of joint and relative congruity of articulating surfaces maintained by ligaments and muscles acting across joint.

---

### JOINTS

<table>
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<tr>
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<tbody>
<tr>
<td>Synovial (diarthrodial) joints are found at the ends of two adjacent bones that articulate.</td>
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</tr>
</tbody>
</table>
| Articular cartilage | • Extremely smooth (nearly frictionless) covering of the bone ends that glide on each other  
• It can be injured leading to pain, degeneration, or dysfunction |
| Subchondral bone | • Dense bone that supports and is found directly beneath the articular cartilage  
• Appears radiodense on plain film x-rays and has low signal (black) on MR |
| Synovium | • Inner membrane lines the joint capsule  
• “Makes” (filters plasma to produce) synovial fluid  
• Synovial folds (plica) form normally but occasionally can be pathologic |
| Capsule | • Outer layer, surrounds and supports the ends of two bones in proper orientation  
• Thickening of the capsule (capsular ligaments) maintain stability of the joint |
| Synovial fluid | • Ultrafiltrate of plasma (synovium filters it)  
• Composed of hyaluronic acid, lubricin, proteinase, and collagenases. Viscosupplementation therapy aims to replace hyaluronic acid in the joint  
• Function: 1. Lubrication of joint. 2. Nutrition to articular cartilage (and menisci/TFCC, etc)  
• Laboratory evaluation is important part of workup of intraarticular processes |
| Other | • Joints often have additional structures within them, including ligaments (e.g., ACL, PCL), tendons (e.g., biceps, popliteus), supporting structures (e.g., meniscus, TFCC, articular discs) |

### CARTILAGE

- Hyaline | • Found in articular cartilage of synovial joints and cartilage in physes  
• Contains type II collagen |
- Fibrocartilage | • Found in meniscus, TFCC, vertebral disc, articular disc (e.g., acromioclavicular joint)  
• Contains type I collagen |
Typical synovial joints exhibit congruent articular cartilage surfaces supported by subchondral and metaphyseal bone and stabilized by joint capsule and ligaments. Inner surfaces, except for articular cartilage, covered by synovial membrane (synovium).

Degrees of sprain

Grade I. Stretching of ligament with minimal disruption of fibers

Grade II. Tearing of up to 50% of ligament fibers; small hematoma. Hemarthrosis may be present

Grade III. Complete tear of ligament and separation of ends, hematoma, and hemarthrosis

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<td><strong>LIGAMENTS</strong></td>
<td></td>
</tr>
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</table>
| Function | • Attach two bones to each other (usually at a joint [ACL] or b/w 2 prominences [suprascapular])
• Ligaments provide stability to a joint allowing for physiologic range of motion |
| Types | • Ligaments can be discrete structures (e.g., ACL or PCL)
• Many ligaments are thickenings of the fibrous joint capsule (e.g., ATFL in ankle) |
| Insertion | • 1. Ligamentous tissue (primarily type 1 collagen) attaches to fibrocartilage
• 2. Fibrocartilage attaches to calcified fibrocartilage (most injuries occur here)
• 3. Calcified fibrocartilage (Sharpey’s fibers) attaches to bone/periosteum |
| Injury | • Ligament injuries are termed “sprains” and are graded 1-3
○ Grade 1: stretching of ligament.
○ Grade 2: partial tear of ligament
○ Grade 3: complete tear of ligament
• Adults tend to have midsubstance injuries; children have more avulsion injuries |
| Treatment | • Depending on ligament: 1. immobilization, 2. therapy, 3. surgical repair, 4. surgical reconstruction |
| Ligament strength | • Pediatrics: ligament is stronger than physis, so physis usually injured. Sprains are less common.
• Adults: ligament is weakest portion of joint, so sprains are common.
• Geriatrics: ligament is stronger than weaker bone, so fracture more common than sprain.
Gliding surface

Articular cartilage matrix with regional organization based on chondrocyte proximity and matrix composition (high power)

Superficial zone (fibers parallel to surface)
Middle zone (random fibers)
Deep zone (fibers perpendicular to surface)
Tidemark (calcification line)
Calcified zone
Subchondral bone
Cancellous bone

Collagen fibrils form structural framework for articular cartilage and provide support for chondrocytes and proteoglycan aggregates

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<td><strong>ARTICULAR CARTILAGE</strong></td>
<td></td>
</tr>
<tr>
<td>Hyaline cartilage covering of intraarticular ends of bones.</td>
<td></td>
</tr>
</tbody>
</table>
| Function           | • Smooth (nearly frictionless) surface covering the ends of articulating bones  
• Allows for pain-free range of motion  
• Avascular (nutrition from synovial fluid), aneural, alymphatic |
| Composition        | • Water: up to 80% of weight. Changes with load/compression; decr. with age, increases with OA  
• Collagen: 90-95% is type II (also types V, VI, IX, X, XI); gives tensile strength  
• Proteoglycans: gives compressive strength; decreases with age and allows softening  
• Chondrocytes: maintains cartilage, produces collagen and proteoglycans |
| Zones (layers)     | • Superficial: thin layer, fibers have tangential orientation (parallel to surface), resists shear  
• Middle: moderate-sized layer, fibers are randomly/obliquely oriented  
• Deep: thick layer, fibers are vertical (perpendicular to surface), resists compression  
• Tidemark: ultrathin line separating deep zone from calcified zone  
• Calcified zone: transitional zone that attaches cartilage to subchondral bone |
| Injury & healing   | • Articular cartilage is avascular; limited healing capacity, making treatment of injuries problematic  
• Injuries extending deep to the tidemark may heal with fibrocartilage (not hyaline)  
• Microfracture surgery is based on stimulating the differentiation of mesenchymal cells within the bone into chondrocytes to produce fibrocartilage healing of articular cartilage injuries |
Early degenerative changes

- Surface fibrillation of articular cartilage
- Early disruption of matrix-molecular framework (increased water content and decreased proteoglycans)
- Superficial fissures
- Sclerosis (thickening) of subchondral bone early sign of degeneration
- Narrowing of upper portion of joint space with early degeneration of articular cartilage

Advanced degenerative changes

- Release of fibrillated cartilage into joint space
- Loss of cartilage and narrowing of joint space
- Enzymatic degradation and thinning of articular cartilage
- Osteophytes
- Reactive synovitis

End-stage degenerative changes

- Exposed articular surface of subchondral bone
- Loss of articular cartilage, (bone-on-bone articular surface)
- Subchondral cysts
- Capsular fibrosis
- Articular cartilage lost and joint space narrowed. Bone shows remodeling osteophyte and subchondral cysts.

**OSTEOARTHRITIS**

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Pathophysiology</td>
<td>• Diffuse wear, erosion, or degeneration of articular cartilage</td>
</tr>
<tr>
<td></td>
<td>• Microscopically: Increase in water content, disorganized collagen, proteoglycan breakdown</td>
</tr>
<tr>
<td>Etiology</td>
<td>• Primary: idiopathic, no other identifiable cause; common in elderly patient population</td>
</tr>
<tr>
<td></td>
<td>• Secondary: due to other underlying condition (e.g., posttraumatic, joint dysplasia, etc)</td>
</tr>
<tr>
<td>Incidence</td>
<td>• Most common type of arthritis</td>
</tr>
<tr>
<td></td>
<td>• Common in weight-bearing joints (knee #1, hip), also in spine, DIPJ, PIPJ, &amp; thumb CMCJ</td>
</tr>
<tr>
<td>Symptoms</td>
<td>• Worsening pain and disability (cartilage loss allows bones to directly articulate on each other)</td>
</tr>
<tr>
<td>Radiographs</td>
<td>• 1. Joint space narrowing, 2. osteophytes, 3. subchondral sclerosis, 4. subchondral cysts</td>
</tr>
<tr>
<td>Treatment</td>
<td>• Rest, activity modification, NSAIDs, therapy (ROM), steroid injection, arthrodesis or arthroplasty</td>
</tr>
</tbody>
</table>
Analysis

A. Normal. Clear to pale yellow, transparent. WBC < 200

B. Osteoarthritis. Slightly deeper yellow, transparent. WBC < 2,000

C. Inflammatory. Darker yellow, cloudy, translucent (type blurred or obscured). WBC < 80,000

D. Septic. Purulent, dense, opaque. WBC > 80,000

E. Hemarthrosis. Red, opaque. Must be differentiated from traumatic tap.

The clarity of the fluid is assessed by expressing a small amount of fluid out of the plastic syringe into a glass tube. Printed words viewed through normal and noninflammatory joint fluid can be read easily.

Viscosity. Drop of normal or noninflammatory fluid expressed from needle will string out 1 in or more, indicative of high viscosity. Inflammatory fluid evidences little or no stringing. Viscosity may also be tested between gloved thumb and forefinger.

Synovial fluid analysis

<table>
<thead>
<tr>
<th>TYPE</th>
<th>COMMENT</th>
</tr>
</thead>
</table>
| Rheumatoid arthritis | • Autoimmune disorder targeting the joint synovium  
• Chronic synovitis and pannus formation lead to articular surface degeneration and eventually joint destruction  
• Women 3:1; Labs: +RF, HLA-DR4; monocytes mediate the disease effect  
• Multiple extraarticular manifestations: ocular, skin nodules, vasculitis  
• Characterized by warm, painful joints with progressive deformity (e.g., ulnar deviation of fingers)  
• Radiographic findings: 1. joint space narrowing, 2. osteopenia, 3. bone/joint erosion  
• Treatment: primarily medical until advanced stages necessitate surgical reconstruction |
| Gout           | • Monosodium urate crystal deposition in joint/synovium  
• Labs: elevated serum uric acid; synovial analysis: negatively birefringent crystals  
• Typical presentation: monoarticular arthritis (1st MTPJ #1 site); symptoms can be self-limiting  
• Treatment consists of indomethacin (NSAID) & colchicine |
| Pseudogout     | • Deposition of calcium pyrophosphate dihydrate crystals (CPPD) in the joint  
• Chondrocalcinosis (calcification of cartilage) can also occur (e.g., calcification of meniscus)  
• Monoarticular arthritis in older patient is typical presentation; women > men  
• Synovial analysis shows weakly positive birefringent crystals |
| Reiter’s syndrome | • Triad: urethritis, conjunctivitis, arthritis. Labs: +HLA-B27 |
**Anatomy of Peripheral Nerve**

**Compression**
- Longitudinal vessels
- Outer epineurium
- Inner epineurium

**Traction**
- Fascicle
- Nerve fiber bundles
- Epineurial coat provides some protection against compression. Spiral configuration of nerve fiber bundles within fascicles provides some protection from traction.

**Neural Fiber Types**

**Myelinated nerve fiber**
- Schwann cell
- Node of Ranvier
- Nerve cell axon
- Axonal transport
- Microtubules within axoplasm allow transport of cell products (anterograde and retrograde). Compression may inhibit axonal transport.

**Unmyelinated nerve fiber**
- Schwann cell
- Nerve fibers

**NERVES • Basic Science**

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuron</td>
<td>A nerve cell made up of cell body (in dorsal root ganglion [DRG] for afferent fibers, in ventral horn for efferent fibers), dendrites (receive signal), axon (transmit signal), presynaptic terminal</td>
</tr>
<tr>
<td>Glial cells</td>
<td>Schwann cell produces myelin to cover the axon; myelin increases conduction speed</td>
</tr>
<tr>
<td>Node of Ranvier</td>
<td>Gap between Schwann cells; facilitates conduction of action potentials/impulse signals</td>
</tr>
<tr>
<td>Nerve fiber</td>
<td>A single axon. 3 types: large/myelinated fibers are fast, small/unmyelinated are slow. Efferent fibers (axons) transmit motor signals from CNS via ventral horn to peripheral muscles</td>
</tr>
<tr>
<td></td>
<td>Afferent fibers (axons) transmit sensory signals from peripheral receptor via DRG to CNS</td>
</tr>
<tr>
<td>Fascicle</td>
<td>A group of nerve fibers surrounded by perineurium. Fascicles unite and divide (form plexi) continuously along the course of the nerve</td>
</tr>
<tr>
<td>Peripheral nerve</td>
<td>One or more fascicles surrounded by epineurium. Most peripheral nerves have both motor and sensory fascicles</td>
</tr>
<tr>
<td>Epineurium</td>
<td>Surrounds all fascicles of peripheral nerve; protects and nourishes fascicles</td>
</tr>
<tr>
<td>Perineurium</td>
<td>Surrounds individual fascicles; provides tensile strength to peripheral nerve</td>
</tr>
<tr>
<td>Endoneurium</td>
<td>Surrounds nerve fibers (axons); protects and nourishes nerve fibers</td>
</tr>
<tr>
<td>Blood supply</td>
<td>Intrinsic: vascular plexus within the endoneurium, perineurium, and epineurium. Extrinsic: vessels that enter the epineurium along its course</td>
</tr>
</tbody>
</table>
Classification of nerve injury by degree of involvement of various neural layers

**Nerve conduction studies**
- Stimulating electrode
- Stimulation at elbow
- Motor (recording electrodes)
- Stimulation at wrist
- Sensory (recording electrodes)

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**Classification of nerve injury by degree of involvement of various neural layers**

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<td>Nerve conduction</td>
<td>- Resting potential: a polar difference is maintained between intracellular &amp; extracellular environments</td>
</tr>
<tr>
<td>Nerve conduction</td>
<td>- Action potential: change in Na⁺ permeability depolarizes cells, produces signal conduction</td>
</tr>
<tr>
<td>Nerve conduction study (NCS)</td>
<td>- Measures nerve conduction velocity by using a combination of stimulating &amp; recording electrodes</td>
</tr>
<tr>
<td>Nerve conduction study (NCS)</td>
<td>- Velocity can be decreased by compression or demyelination (injury or disease)</td>
</tr>
<tr>
<td>Receptors</td>
<td>- Multiple types: pain, pressure, thermal, mechanical, etc</td>
</tr>
<tr>
<td>Receptors</td>
<td>- Pacinian corpuscle: pressure; Meissner: dynamic 2pt (rapid); Merkel: static 2pt (static)</td>
</tr>
<tr>
<td>Disorders</td>
<td>- <strong>Guillain-Barré:</strong> ascending motor weakness/paralysis. Caused by demyelination of peripheral nerves. Typically follows a viral syndrome. Most cases are self-limiting. May need IV Ig.</td>
</tr>
<tr>
<td>Disorders</td>
<td>- <strong>Charcot-Marie-Tooth:</strong> Autosomal dominant disorder. Demyelinating disorder affecting motor &gt; sensory nerves. Peroneals, hand &amp; foot intrinsics commonly affected: cavus feet, claw toes.</td>
</tr>
</tbody>
</table>

**Nerve Injury**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurapraxia</td>
<td>- Local myelin damage (often from compression), axon is intact; no distal degeneration</td>
</tr>
<tr>
<td>Axonotmesis</td>
<td>- Disruption of axon &amp; myelin, epineurium is intact; Wallerian degeneration occurs</td>
</tr>
<tr>
<td>Neurotmesis</td>
<td>- Complete disruption of the nerve; poor prognosis; nerve repair typically needed</td>
</tr>
</tbody>
</table>
Physiology of Neuromuscular Junction

Acetylcholine (ACh) formed in nerve terminal from acetyl CoA of mitochondria plus choline, catalyzed by choline acetyltransferase. ACh enters synaptic vesicles.

Acetylcholine (ACh) attaches to receptors of postsynaptic membrane at apex of junctional folds, causing channels to open for inflow of Na+ and outflow of K+, which results in depolarization and initiation of electric impulse (action potential).

Acetylcholinesterase (AChE) promptly degrades ACh into acetate and choline, thus terminating its activity.

Choline reenters nerve terminal to be recycled.

Electric impulse traverses sarcolemma to transverse tubules where it causes release of Ca++ from sarcoplasmic reticulum, thus initiating muscle contraction.

Electric impulse causes channels to open in presynaptic membrane, permitting Ca++ to enter nerve terminal.

Postsynaptic membrane

Ca++ binds to sites at active zone of presynaptic membrane, causing release of ACh from vesicles.

Junctional fold

ACh receptors

ACh attaches to receptors of postsynaptic membrane at apex of junctional folds, causing channels to open for inflow of Na+ and outflow of K+, which results in depolarization and initiation of electric impulse (action potential).

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Neuromuscular junction

Motor unit

Electromyography (EMG)

Disorders

Axon of motor neuron synapses with the muscle (motor end plate).

Acetylcholine (the neurotransmitter) stored in axon crosses the synaptic cleft and binds to receptors on the sarcoplasmic reticulum and depolarizes it.

All the muscles fibers innervated by a single motor neuron.

Evaluates motor units to determine if muscle dysfunction is from the nerve, neuromuscular junction, or the muscle itself. Fibrillation is abnormal.

Myasthenia gravis: relative shortage of acetylcholine receptors due to competitive binding to them by thymus-derived antibodies. Treatment involves thymectomy or anti-acetylcholinesterase agents.

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<td>Disorders</td>
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**MUSCLE ANATOMY**

### Types of muscle
- Smooth (e.g., bowel), cardiac, and skeletal
- Skeletal muscle: under voluntary control; has an origin and insertion
- Types: type 1 “slow twitch” are aerobic; type 2 “fast twitch” are anaerobic

### Muscle
- Composed of multiple fascicles (bundles) surrounded by epimysium

### Fascicle (bundle)
- Composed of multiple muscle fibers (cells) surrounded by perimysium

### Fiber (cell)
- Elongated muscle cell composed of multiple myofibrils surrounded by endomysium

### Myofibril
- Composed of multiple myofilaments arranged end to end without a surrounding tissue

### Sarcomere
- Composed of interdigitated thick (myosin) and thin (actin) filaments organized into bands
- Z line to Z line defines the length of the sarcomere
- A band: length of the thick filament, does not change with contraction
- I band (actin only), H band (myosin only), and sarcomere length all change with contraction

### Myosin
- Thick filament; has “head” that binds ATP and attaches to thin filaments (actin)

### Actin
- Thin filament; fixed to Z bands, associated with troponin and tropomyosin

### Troponin
- Associated with actin and tropomyosin, binds Ca^{++} ions

### Tropomyosin
- Long molecule lies in helical groove of actin and blocks myosin from binding to the actin

### Sarcoplasmic reticulum
- Stores intracellular calcium ions (in T tubules), which are stimulated to be released during contraction

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**STRUCTURE**

**COMMENT**

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<td>Fascicle (bundle)</td>
<td>Composed of multiple muscle fibers (cells) surrounded by perimysium</td>
</tr>
<tr>
<td>Fiber (cell)</td>
<td>Elongated muscle cell composed of multiple myofibrils surrounded by endomysium</td>
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<tr>
<td>Actin</td>
<td>Thin filament; fixed to Z bands, associated with troponin and tropomyosin</td>
</tr>
<tr>
<td>Troponin</td>
<td>Associated with actin and tropomyosin, binds Ca^{++} ions</td>
</tr>
<tr>
<td>Tropomyosin</td>
<td>Long molecule lies in helical groove of actin and blocks myosin from binding to the actin</td>
</tr>
<tr>
<td>Sarcoplasmic reticulum</td>
<td>Stores intracellular calcium ions (in T tubules), which are stimulated to be released during contraction</td>
</tr>
</tbody>
</table>
ATP binds to myosin head groups protruding from thick filaments, forming charged myosin-ATP intermediates, not yet attached to thin filaments. Note: reactions shown occurring at only one cross bridge, but same process takes place at all or most cross bridges.

Ca++ released from sarcoplasmic reticulum in response to electric impulse binds to troponin, which then permits charged intermediates to form active complexes with actin of thin filaments.

ATP cleaved into ADP and Pi by ATPase of active complexes, and its chemical energy thus converted to mechanical energy. Cross bridges (myosin head groups) flex into rigor position and thus slide thin filaments along thick filaments. This “rowing” process is repeated over and over, producing muscle contraction.

COMMENT

MUSCLE CONTRACTION

**Steps**
- Contraction initiated when acetylcholine binds to receptors on the sarcoplasmic reticulum, depolarizing it
- Depolarization causes release of Ca++, which binds to troponin molecules. This binding causes the tropomyosin to move, allowing the “charged” myosin head (ATP bound) to bind to actin.
- Breakdown of the ATP causes contraction of the filament (shortening of the sarcomere) and the release of the filaments (actin and myosin) in preparation to repeat the process.

**Types**
- **Isotonic**
  - Muscle tension/resistance is the same throughout the contraction
- **Eccentric**
  - Muscle elongates as it contracts. Common injury mechanism (e.g., biceps, quadriceps rupture)
- **Concentric**
  - Muscle shortens as it contracts
- **Isometric**
  - Muscle length is constant (resistance changes)
- **Isokinetic**
  - Muscle contracts at constant velocity; best for muscle strengthening
**Types of tendons**

- **Avascular tendon**
  - Vinculum breve
  - Vincula longa
  - Flexor digitorum profundus tendon
  - Flexor digitorum superficialis tendon

- **Rotator cuff tendon**
  - Supraspinatus tendon
  - Infraspinatus muscle/tendon
  - Teres minor tendon
  - Teres minor muscle

- **Achilles tendon**
  - Gastrocnemius muscle
  - Soleus muscle
  - Musculotendinous junction
  - Achilles tendon

- **Extensor tendons**
  - EDQ tendon
  - EPL tendon
  - EDC tendon

---

### Tendon anatomy

- Longitudinal bundles of collagen and/or elastic fibers
- Transverse fibers of loose connective tissue
- Fibroblast nuclei

---

### Structure

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>Connects muscles to bones so the muscle can exert its effect</td>
</tr>
<tr>
<td>Anatomy</td>
<td>Various shapes and sizes (long, broad, short, flat, etc)</td>
</tr>
<tr>
<td></td>
<td>Type 1 collagen grouped into microfibrils, then subfibrils, then fibrils, surrounded by endotenon</td>
</tr>
<tr>
<td>Fibril</td>
<td>Fibroblasts and fibrils surrounded by a peritenon</td>
</tr>
<tr>
<td>Fascicle</td>
<td>Groups of fascicles surrounded by an epitenon</td>
</tr>
<tr>
<td>Tendon</td>
<td>Tendinous tissue (primarily type 1 collagen) attaches to fibrocartilage</td>
</tr>
<tr>
<td></td>
<td>Fibrocartilage attaches to calcified fibrocartilage (Sharpey’s fibers)</td>
</tr>
<tr>
<td></td>
<td>Calcified fibrocartilage (Sharpey’s fibers) attaches to bone/periosteum</td>
</tr>
<tr>
<td>Insertion</td>
<td>Vascular tendons have a paratenon (no sheath) that surrounds them and supplies blood</td>
</tr>
<tr>
<td></td>
<td>Avascular tendons (in a sheath) have a vinculum to supply blood</td>
</tr>
<tr>
<td>Blood supply</td>
<td>Transition from muscle to tendon; weakest portion of the myotendinous complex and site of most injuries</td>
</tr>
</tbody>
</table>
**COMMENT**

**MUSCLE COMPARTMENTS**

Muscles are contained within fibro(fascia)-osseous(bone) spaces known as compartments.

- Results from increased pressure within fibroosseous compartment
- Multiple etiologies (fracture/hematoma, edema, burns, compression, etc)
- The increased pressure occludes the vascular supply to the compartment muscles
- Symptoms: the “5 P’s”: pain (on passive stretch, most sensitive), paresthesias, pallor, paralysis, pulselessness (a late finding)
- Physical exam: firm/tense compartments +/- some or all of the 5 P’s; it is a clinical diagnosis
- Two methods for intracompartmental pressure tests: 1. absolute value, 2. ΔP from diastolic BP
- Compartment release/fasciotomy is a **surgical emergency** to prevent muscle necrosis/contracture
Spine • TOPOGRAPHIC ANATOMY

### Structure

<table>
<thead>
<tr>
<th>Structure</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brachial plexus</td>
<td>Interscalene nerve block commonly used for upper extremity procedures</td>
</tr>
<tr>
<td>Sternocleidomastoid</td>
<td>Contracted in torticollis</td>
</tr>
<tr>
<td>Trapezius</td>
<td>Large muscle, muscle spasm common cause of neck and upper back pain</td>
</tr>
<tr>
<td>Rhomboid muscles</td>
<td>Overuse and spasm common cause of upper back pain</td>
</tr>
<tr>
<td>C7 spinous process</td>
<td>“Vertebral prominens” is an easily palpable landmark</td>
</tr>
<tr>
<td>Iliac crest</td>
<td>Site for “hip pointers” (contusion of iliac crest)</td>
</tr>
<tr>
<td>Erector spinae muscles</td>
<td>Common site for autologous bone graft harvest</td>
</tr>
<tr>
<td>Posterior superior iliac spine</td>
<td>Site of bone graft harvest in posterior spinal procedures</td>
</tr>
<tr>
<td>Sacroiliac joint</td>
<td>Degeneration or injury to joint can cause lower back pain</td>
</tr>
<tr>
<td>Coccyx</td>
<td>Distal end of vertebral column (tailbone), can be fractured in a fall (LBP)</td>
</tr>
</tbody>
</table>

---

**Image Notes:**
- **Brachial plexus Interscalene nerve block** commonly used for upper extremity procedures.
- **Sternocleidomastoid** Contracted in torticollis.
- **Trapezius** Large muscle, muscle spasm common cause of neck and upper back pain.
- **Rhomboid muscles** Overuse and spasm common cause of upper back pain.
- **C7 spinous process** “Vertebral prominens” is an easily palpable landmark.
- **Iliac crest** Site for “hip pointers” (contusion of iliac crest)
- **Erector spinae muscles** Common site for autologous bone graft harvest.
- **Posterior superior iliac spine** Site of bone graft harvest in posterior spinal procedures.
- **Sacroiliac joint** Degeneration or injury to joint can cause lower back pain.
- **Coccyx** Distal end of vertebral column (tailbone), can be fractured in a fall (LBP).
### GENERAL INFORMATION

- **33 Vertebrae**: 7 cervical, 12 thoracic, 5 lumbar, 5 sacral (fused), 4 coccygeal (fused)
- **Vertebrae form a functional column**
- **3 column theory (Denis)**: spine is divided into 3 columns
  - Anterior: ALL & anterior ⅓ of vertebral body/annulus
  - Middle: PLL & posterior ⅓ of vertebral body/annulus
  - Posterior: Pedicles, lamina, spinous process, and ligaments
- **Spinal curves**: normal curves
  - Cervical lordosis
  - Thoracic kyphosis
  - Lumbar lordosis
  - Sacral kyphosis

### Spinal Regions

<table>
<thead>
<tr>
<th>Region</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>C1-C2</td>
<td>Unique bones allow stabilization of occiput to spine and rotation of head. Motion: rotation and flexion/extension.</td>
</tr>
<tr>
<td>Thoracic</td>
<td></td>
<td>Relatively stiff due to costal articulations. Motion: rotation. Minimal flexion/extension.</td>
</tr>
<tr>
<td>Thoraco-lumbar</td>
<td></td>
<td>Facet orientation transitions from semicoronal to sagittal. Segments are mobile. Most common site of lower spine injuries.</td>
</tr>
<tr>
<td>Sacrum</td>
<td></td>
<td>No motion. Is center of pelvis.</td>
</tr>
</tbody>
</table>

### Vertebrae

- Uniquely shaped bones that support the axial musculature and protect the spinal cord and nerve roots

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body (centrum)</td>
<td>Has articular cartilage on both superior &amp; inferior surfaces. Articulates with intervertebral discs &amp; gets larger distally.</td>
</tr>
<tr>
<td>Arch</td>
<td>Made up of pedicles and lamina. Develops from 2 ossification centers that fuse. Failure to fuse occurs in spina bifida. It forms the vertebral canal for the spinal cord.</td>
</tr>
<tr>
<td>Processes</td>
<td>Spinous: ligament attachment site. Transverse: rib (T-spine) and ligament attachment site.</td>
</tr>
</tbody>
</table>

### LEVEL CORRESPONDING STRUCTURE

<table>
<thead>
<tr>
<th>Level</th>
<th>Corresponding Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2-3</td>
<td>Mandible</td>
</tr>
<tr>
<td>C3</td>
<td>Hyoid cartilage</td>
</tr>
<tr>
<td>C4-5</td>
<td>Thyroid cartilage</td>
</tr>
<tr>
<td>C6</td>
<td>Cricoid cartilage</td>
</tr>
<tr>
<td>C7</td>
<td>Vertebral prominens</td>
</tr>
<tr>
<td>T3</td>
<td>Spine of scapula</td>
</tr>
<tr>
<td>T7</td>
<td>Xyphoid, tip of scapula</td>
</tr>
<tr>
<td>T10</td>
<td>Umbilicus</td>
</tr>
<tr>
<td>L1</td>
<td>Conus medullaris (end of cord)</td>
</tr>
<tr>
<td>L3</td>
<td>Aorta bifurcation</td>
</tr>
<tr>
<td>L4</td>
<td>Iliac crest</td>
</tr>
</tbody>
</table>
### CERVICOCRANUM

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>OSSIFY</th>
<th>FUSE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlas (C1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Ring shaped</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 2 lateral masses with facets; facets are concave</td>
<td>Lateral masses/posterior arch</td>
<td>7mo fetal to birth</td>
<td>3-4yr</td>
</tr>
<tr>
<td>• 2 arches connect lateral masses:</td>
<td>Body/anterior arch</td>
<td>6-12mo</td>
<td>7yr</td>
</tr>
<tr>
<td>◦ anterior tubercle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>◦ posterior tubercle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Transverse process has a foramen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Superior articular facets articulate with occiput; inferior facets articulate with C2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Posterior arch has groove for vertebral artery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Attachment site of ALL and longus colli</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Attachment site of ligamentum nuchae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Vertebral artery through foramen transversarium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Axis (C2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Body</td>
<td>Primary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Odontoid process (dens)</td>
<td>Body</td>
<td>4mo fetal</td>
<td>3-7yr</td>
</tr>
<tr>
<td>• Lateral masses with facets and two small transverse processes</td>
<td>Lateral mass/neural arch [2]</td>
<td>7mo fetal</td>
<td>2-yr</td>
</tr>
<tr>
<td>• Pedicles (between facets)</td>
<td>Odontoid—Body</td>
<td>6mo fetal</td>
<td>3-6yr</td>
</tr>
<tr>
<td>• Spinous process</td>
<td>Tip</td>
<td>2-3 yr</td>
<td>12yr</td>
</tr>
<tr>
<td>• Odontoid projects superiorly &amp; allows C1-C2 rotation; primary horizontal stabilizer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Concave superior facets allow for rotation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Vertebral artery through foramen transversarium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Pedicles (isthmus) susceptible to fracture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Bifid, relatively large and palpable</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There are two secondary ossification centers in the axis: ossiculum terminale and inferior ring apophysis.
Inferior aspect of C3 and superior aspect of C4 showing the sites of the facet and uncovertebral articulations

**C3**
- Inferior aspect
- Bifid spinous process
- Lamina
- Vertebral foramen
- Pedicle
- Posterior tubercle
- Anterior tubercle
- Transverse process
- Vertebral body
- Articular surface of right uncinate process
- Inferior articular process
- Area for articulation of left uncinate process of C4
- Left uncinate process
- Superior articular process and facet

**C4**
- Superior aspect

4th cervical vertebra: anterior view
- Superior articular process
- Lamina
- Uncinate process
- Articular surface
- Body
- Foramen transversarium
- Pedicle
- Lamina
- Spinous process
- Uncinate process
- Costal lamella
- Articular surface
- Bony spicule dividing foramen transversarium
- Posterior tubercle
- Anterior tubercle
- Transverse process
- Inferior articular facet for T1
- Body
- Uncinate process
- Costal lamella
- Foramen transversarium
- Pedicle
- Lamina
- Articular surface of uncinate process
- Foramen transversarium (reduplicated)
- Groove for C7 spinal nerve
- Transverse process (posterior tubercle)
- Superior articular process and facet
- Inferior articular process
- Spinous process

7th cervical vertebra: anterior view
- Superior articular process
- Uncinate process
- Articular surface
- Body
- Costal lamella
- Bony spicule dividing foramen transversarium
- Posterior tubercle
- Anterior tubercle
- Transverse process
- Inferior articular process
- Spinous process

**CERVICAL (C3-7)**

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>OSSIFY</th>
<th>FUSE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Primary</td>
<td>7-8wk</td>
<td>Concave superiorly, convex inferiorly</td>
</tr>
<tr>
<td>Uncinate processes</td>
<td>Body/centrum</td>
<td>fetal</td>
<td>Articulates with adjacent vertebral body</td>
</tr>
<tr>
<td>Small pedicles</td>
<td>Neural arch</td>
<td>5-8yr</td>
<td>Angled medial &amp; superior, too small for screws</td>
</tr>
<tr>
<td>Transverse processes</td>
<td>Secondary</td>
<td>12-15yr</td>
<td>Have foramen for vertebral artery except C7</td>
</tr>
<tr>
<td>Lateral masses—2 facets</td>
<td>Spinous process</td>
<td>25yr</td>
<td>Can accept screws if angled laterally (artery at risk in foramen)</td>
</tr>
<tr>
<td>Facets (superior &amp; inferior)</td>
<td>Transverse process</td>
<td></td>
<td><em>Semi-coronal</em> orientation allows for flexion/extension</td>
</tr>
<tr>
<td>Lamina</td>
<td>Annular (ring) epiphysis</td>
<td></td>
<td>Connects lateral masses to spinous process</td>
</tr>
<tr>
<td>Spinous process</td>
<td></td>
<td></td>
<td>Usually bifid (C3-5), C7 is the largest</td>
</tr>
</tbody>
</table>

*The foramina transversaria of C7 transmit vertebral veins, but not the vertebral artery, and are asymmetrical in this specimen*
**Characteristics**

**Ossify**

**Fuse**

**Comments**

<table>
<thead>
<tr>
<th>Thoracic</th>
<th>Primary</th>
<th>Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body: costal facets (articulate w/ ribs)</td>
<td>Body/centrum</td>
<td>Spinal process</td>
</tr>
<tr>
<td>Articular processes/facets</td>
<td>Transverse process</td>
<td>Annular (ring) epiphysis [2]</td>
</tr>
<tr>
<td>Transverse process</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamina</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinal process</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Upper thoracic have superior & inferior facets; lower thoracic have a single facet.
- Can accept screws for spinal fixation, have anteromedial orientation.
- Facets are semicoronal, allow for rotation but minimal flexion/extension.
- Have costal facet in upper T-spine.
- Broad & overlapping (like shingles).
- Long with steep posterior slope.

Landmark for pedicle screw: junction of lines through upper 1/2 transverse process and just lateral to vertical line through facet.
### Characteristics

**Ossify** | **Fuse** | **Comments**
--- | --- | ---
**LUMBAR**
- Body: large
- Pedicles: large, short, but strong
- Articular processes/facets: has a mammillary process
- Pars interarticularis
- Transverse process
- Lamina
- Spinous process

**Primary**
- Body/centrum
- Neural arch [2]

**Secondary**
- Mammillary proc.
- Ring epiphysis [2]
- Transverse process [2]
- Spinous process

- 7-8wk | 6yr | Broad, oval, cylindrical shaped bone
- Fetal | 5-8yr | Orientation changes through L-spine; this portion of bone accepts screw fixation
- 12-15yr | 25yr | Sagittal orientation allows flexion/extension
- Superior facets are lateral to inferior facets/articular processes
- Area b/w facets, site of spondyloysis/fx
- Avulsion fracture can occur here.
- Do not overlap adjacent levels
- Long, palpable posteriorly

Landmark for pedicle screw: junction lines through middle of transverse process and lateral border of facet joint.
Failure of fusion of two neural arch (pedicle/lamina) ossification centers results in spina bifida.

---

**OSTEOLOGY • Spine**

- **Vertebral body**
- **Vertebral foramen**
- **Pedicle**
- **Transverse process**
- **Superior articular process**
- **Mammillary process**
- **Lamina**
- **Spinous process**
- **Intervertebral disc**
- **Vertebral canal**
- **Pars interarticularis**
- **Accessory process**
- **Superior articular process**
- **Inferior vertebral notch**
- **Intervertebral (neural) foramen**
- **Articular facet**
- **Inferior articular process**
- **Lumbar vertebrae, assembled:**
  - **Left lateral view**
- **L3 and L4 vertebrae:**
  - **Posterior view**
- **L2 vertebra:**
  - **Superior view**
### SACRUM
- 5 vertebrae are fused
- 4 pairs of foramina (left and right)
- Ala (wing) expands laterally
- Kyphotic (approx 25°), apex at S3
- Sacral canal opens to hiatus distally

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
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<th>FUSE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
<td>Body</td>
<td>7-8wk</td>
<td>2-8yr</td>
</tr>
<tr>
<td>Arches</td>
<td>fetal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
<td>11-14yr</td>
<td>12-18yr</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### COCCYX
- 4 vertebrae are fused
- Lack features of typical vertebrae
- Bones become smaller distally

<table>
<thead>
<tr>
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<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
<td>Body</td>
<td>7-8wk</td>
<td>1-2yr</td>
</tr>
<tr>
<td>Arches</td>
<td>fetal</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**RADIOLOGY • Spine**

**Odontoid**
- Vertebrae body
- Spinous process

**C-spine x-ray, AP**
- C1 body (atlas)
- Body of C2 (axis)
- Pedicle

**C-spine x-ray, lateral**
- Atlantodens interval (ADI)
- Odontoid process (dens)
- Spinous process of C7 (vertebral prominens)

**C-spine x-ray, odontoid**
- Odontoid (dens) process
- C2 body (axis)

**C-spine x-ray, oblique**
- Posterior arch of C1
- Pedicle
- Neural foramen

### RADIOGRAPH

<table>
<thead>
<tr>
<th>TECHNIQUE</th>
<th>FINDINGS</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AP (anteroposterior)</strong></td>
<td>Erect/supine, beam w/slight cephalad tilt at mid C-spine</td>
<td>Vertebral bodies (esp. C3-7), intervertebral disc spaces</td>
</tr>
<tr>
<td><strong>Lateral (crosstable)</strong></td>
<td>Supine, horizontal beam to mid C-spine (must see C7)</td>
<td>Bodies, disc space, facets 4 lines: 1. Ant. vert. (ALL); 2. Post. vert. (PLL); 3. Spino-laminar (ligamentum flavum); 4. Post. spinous</td>
</tr>
<tr>
<td><strong>Odontoid (open mouth)</strong></td>
<td>Beam into open mouth</td>
<td>Odontoid, lateral masses</td>
</tr>
<tr>
<td><strong>Swimmer’s view</strong></td>
<td>Prone, one arm above head, beam into axilla</td>
<td>C7, T1, and T2</td>
</tr>
<tr>
<td><strong>Obliques</strong></td>
<td>AP, turn body 45°</td>
<td>Neural foramina &amp; facet joints</td>
</tr>
<tr>
<td><strong>Flexion/extension views</strong></td>
<td>Lateral with flexion/extension</td>
<td>Same as lateral</td>
</tr>
</tbody>
</table>

Multiple measurements can be made from the lateral C-spine radiograph
1. ADI (atlantodens interval): Posterior aspect of C1 anterior arch to anterior border of odontoid. Normal is ≤3mm
2. SAC (space available for cord): Posterior odontoid to anterior aspect of posterior arch: Normal = 17mm
3. Power ratio: Basion (B) to C1 post. arch (O), opisthion (O) to C1 ant. arch (A). Ratio BC/OA >1 = occipitoatlantal dx
4. Chamberlain’s line: Opisthion to hard palate. Odontoid tip ≤5mm above line, >5mm is basilar invagination
### Thoracic Spine

<table>
<thead>
<tr>
<th>Radiograph</th>
<th>Technique</th>
<th>Findings</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP (anteroposterior)</td>
<td>Supine, beam to mid T-spine</td>
<td>Vertebral bodies</td>
<td>Alignment, scoliosis (Cobb angle)</td>
</tr>
<tr>
<td>Lateral</td>
<td>Lateral, beam to T-spine</td>
<td>Bodies &amp; posterior elements</td>
<td>Alignment, kyphosis, scoliosis, fx</td>
</tr>
<tr>
<td>Bending films</td>
<td>AP or lateral w/ bending</td>
<td>Thoracic vertebrae</td>
<td>Access flexibility of scoliosis curves</td>
</tr>
</tbody>
</table>

### Lumbar Spine

<table>
<thead>
<tr>
<th>Radiograph</th>
<th>Technique</th>
<th>Findings</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP (anteroposterior)</td>
<td>Supine, flex hips, beam @L3</td>
<td>Bodies, disc spaces, pedicle position, transverse process</td>
<td>Fracture (body-pedicle widening, transverse process), dislocation</td>
</tr>
<tr>
<td>Lateral</td>
<td>Lateral, flex hips, beam @L3</td>
<td>Bodies, pars, disc spaces</td>
<td>Fractures, spondylolisthesis</td>
</tr>
<tr>
<td>Obliques</td>
<td>AP, turn body 45°</td>
<td>Neural foramina, pars interarticularis, facet joints</td>
<td>Foraminal stenosis, spondylosis, facet hypertrophy (DJD)</td>
</tr>
<tr>
<td>Flexion/extension views</td>
<td>Lateral with flexion/extension</td>
<td>Same as lateral</td>
<td>Instability/spondylolisthesis</td>
</tr>
</tbody>
</table>
Jefferson fracture of atlas (C1)
Each arch may be broken in one or more places

Fracture of odontoid process

Traumatic spondylolisthesis

**DESCRIPTION**

- Injuries to this region can be both subtle and devastating
- ATLS protocols warranted
- Occipital/cervical dx: high mortality, increased incidence in pediatric patients
- Atlantoaxial instability: disruption of transverse ligament [TAL] +/- alar & apical ligaments determine degree of instability
- Type 2 odontoid fractures have high nonunion rate
- Traumatic spondylolisthesis is bilateral pars fracture (similar to hangman’s fx, but different mechanism)

**EVALUATION**

- Hx: High-energy trauma, (e.g., MVA, fall, diving), +/- pain, numbness, tingling, weakness
- PE: Stabilize head & neck
- Inspect & palpate neck
- Neuro exam: CN’s, UE & LE motor/sensory/reflexes
- XR: Lateral, odontoid, AP basion to dens ≤5mm
  - Power’s ratio ≤1 is normal; ADI ≤3mm is normal; flexion/extension views: to evaluate dynamic instability
- CT: Best for all fractures
- MR: Ligaments, cord, roots

**CLASSIFICATION**

- Occipitocervical dissociation
  - Atlantoaxial instability:
    - 1. midsubstance, 2. avulsion C1 (atlantis) (7 types): burst (3-4 fx, Jefferson)[1], post. arch [2], comminuted [3], ant. arch [4], lat. mass [5], trans. proc.[6], inf. tubercle [7]
    - C2 (axis):
      - Odontoid fx: type 1: tip, type 2: base (xn dens/body), type 3: C2 body
      - Traumatic spondylolisthesis: 1. nondisplaced, 2. displaced & angulated, 2a. angulated, 3. fx w/ C2-3 facet dx

**TREATMENT**

- 0-C dx: halo vs fusion
- C1-C2: ADI ≤5mm: collar
- ADI >5mm: C1-2 fusion
- C1 fracture:
  - Unstable/wide: C1-2 fusion
  - Stable: halo vs collar immobilization 3mo
- Avulsion: soft collar 6wk
- C2 fracture:
  - Odontoid:
    - Collar
    - ORIF(displaced) vs halo (nondisplaced)
  - Halo vest
- Traumatic spondylolisthesis
  - Collar immobilization
  - CR/halo vs ORIF
  - ORIF (C2 screws)

**COMPLICATIONS:** Nonunion (esp. odontoid type 2); neurologic (cord trauma); persistent pain, instability, or stiffness
Subluxation with angulation greater than 11° and/or anterior displacement greater than 3.5 mm generally indicative of instability

Facet dislocation

Anterior facet dislocation of C5 on C6 with tear of interspinous ligament, facet capsules, and posterior fibers of intervertebral disc

X-ray (lateral view) shows bilateral facet dislocation at C5–C6

**DESCRIPTION**

- Compression fx: involve ant. half of vertebral body
- Burst fx: involve whole vertebral body & have retropulsion into spinal canal
- Instability (White & Panjabi)
  - >3.5mm of translation
  - >11° kyphotic angulation
  - + stretch test
  - Neuro (cord or root) injury
  - Ant. elements destroyed
  - Post. elements destroyed
  - Narrow spinal canal
  - Disc space narrowing
- Heavy loads anticipated

**EVALUATION**

- Hx: High-energy trauma, (e.g., MVA, fall, diving), +/- pain, numbness, tingling or weakness
- PE: Stabilize head & neck
- Palpate neck for “step off.”
- Neuro exam: CN’s, UE & LE motor/sensory/reflexes
- XR: Lateral, odontoid, AP
  - Evaluate for stability criteria
  - Flexion/extension views: to evaluate dynamic instability
- CT: Best study for all fractures
- MR: Assess posterior ligaments & for disc herniation on cord

**CLASSIFICATION**

- By mechanism (each class is subclassified by severity)
  1. Flexion-compression [#1]
  2. Vertical compression
  3. Flexion-distraction [#2]
  4. Extension-compression
  5. Extension-distraction
  6. Lateral flexion
- Descriptive
  - Compression
  - Burst
  - Facet dislocation
  - Unilateral
  - Bilateral

**TREATMENT**

- Compression fx: collar
- Burst fx: ACDF (anterior corpectomy, diskec-tomy, and fusion [ant. plate]) vs decompression/post. fusion
- Flexion-compression:
  - Stable: collar or halo;
  - Unstable: ant. or post. fusion
- Flexion-distraction/ facet dx: Closed (acute, awake pt) vs open (unconscious or late presentation) reduction with anterior (ACDF) or posterior spinal fusion

**Three-Column Concept of Spinal Stability**

- **Posterior column**
- **Middle column**
- **Anterior column**

Lateral view: Note that lateral facet (zygapophyseal) joints in posterior column, with intervertebral foramina in middle column.

Burst fracture of unstable vertebral body involving both anterior and middle columns resulted in instability and spinal cord compression.

**Chance fracture**

Flexion distraction results in complete transverse fracture through entire vertebra. Note hinge effect of anterior longitudinal ligament.

**Thoracolumbar Fractures**

- **Mechanism:** MVA or fall (lap belt can be fulcrum to cause flexion-distraction fx)
- **Thoracolumbar junction is most common site of fracture/injury**
- **Determining stability is key to treatment**
- **3-column theory (Denis):** ≥1 column injured = unstable
- **Burst fx:** caused by 1. flexion and 2. axial compression
- **Chance fx:** flexion-distraction fx, all 3 columns fail in tension

**Evaluation**

- **Hx:** High-energy trauma, pain +/- numbness or weakness
- **PE:** Palpate for "step off" Neuro exam: LE motor/sensory/reflexes (including anal wink & bulbocavernosus)
- **XR:** Lateral (body ht, kyphosis) AP (pedicle widening) Flexion/extension views: to evaluate dynamic instability
- **CT:** Best study for all fractures Evaluate for retropulsion
- **MR:** Discs & post. ligaments

**Classification**

- **Compression:** 1 (anterior) column only, stable fx
  - **Stable burst:** 2 columns
    - 1. <25° kyphosis
    - 2. <50% body ht loss
    - 3. <50% canal retropulsion

- **Unstable burst:** 2-3 columns fail above criteria or have neurologic compromise

- **Flexion-distraction:** 2-3 columns; columns fail posterior to anterior
  - **Translation (fx/dx):** All 3 columns fail; unstable

**Treatment**

- **Compression:** observation or orthosis 12wk
- **Stable burst:** TLSO or hyperextension brace for 12wk (f/u x-rays to confirm stability)
- **Unstable burst:** decompression & posterior spinal fusion
- **Flexion-distraction:** most require posterior fusion
- **Translation:** needs reduction & stabilization/fusion

**Complications:** Neurologic: Spinal cord/cauda equina injury. Immobilization: DVT, PE. Surgical: Infection, dural tears.
Central cord syndrome
Central cord hemorrhage and edema. Parts of 3 main tracts involved on both sides. Upper limbs more affected than lower limbs.

Anterior spinal artery syndrome
Artery damaged by bone or cartilage spicules (shaded area affected). Bilateral loss of motor function and pain sensation below injured segment; position sense preserved.

Brown-Sequard syndrome
One side of cord affected. Loss of motor function and position sense on same side and of pain sensation on opposite side.

Posterior column syndrome (uncommon)
Position sense lost below lesion; motor function and pain sensation preserved.

---

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spinal Cord Trauma</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Young males most common</td>
<td>Hx: High-energy trauma (MVA, fall), +/- numbness or weakness</td>
<td><strong>Complete</strong>: no function below the injured level (spinal shock must be resolved to diagnose)</td>
<td>• Methylprednisolone IV given within 8 hr of injury may improve functional level</td>
</tr>
<tr>
<td>• High association w/C-spine fractures (easily missed)</td>
<td>PE: Find lowest functional neurologic level Central: UE&gt;LE motor loss Anterior: LE&gt;UE motor and sensory, proprioception intact B-S: Ipsilateral motor loss, contralateral pain/temp loss</td>
<td><strong>Incomplete</strong>: partial sparing of distal function</td>
<td>• Most patients recover 1 (or 2) levels of function in complete injuries</td>
</tr>
<tr>
<td>• Central: #1, hyperextension mechanism, seen in elderly, with cervical spondylosis</td>
<td>X: r/o or evaluate C-spine fx</td>
<td><strong>Central</strong>: central gray matter</td>
<td>• Decompression of cord (reduce dislocations or remove bone fragments) with internal or external (e.g., collar or halo) immobilization</td>
</tr>
<tr>
<td>• Anterior: #2, worst prognosis</td>
<td>CT: r/o or evaluate C-spine fx</td>
<td><strong>Anterior</strong>: Spinothalamic &amp; corticospinal tracts out, posterior columns spared</td>
<td></td>
</tr>
<tr>
<td>• Brown-Sequard: usually penetrating trauma, rare injury, best prognosis</td>
<td>MR: Shows cord, disc herniation (on cord), posterior ligaments</td>
<td><strong>Brown-Sequard</strong>: lateral half of spinal cord (&quot;hemisection&quot;)</td>
<td></td>
</tr>
<tr>
<td>• Posterior: very rare; this pattern may not exist</td>
<td></td>
<td><strong>Posterior</strong>: posterior columns</td>
<td></td>
</tr>
</tbody>
</table>

**Complications**: Neurologic; autonomic dysreflexia (treat with urinary catheter/rectal disimpaction); spinal instability.

- Spinal shock: Paralysis/areflexia from physiologic cord injury. Return of bulbocavernous reflex is end of spinal shock.
### JOINTS • Spine

#### Ligament Attachments

<table>
<thead>
<tr>
<th>Ligament</th>
<th>Attachments</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Occipitoatlantal Joint</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Articulation between convex occipital condyles and concave superior facets of atlas (C1). This articulation is horizontal (especially in pediatrics) allowing for rotation, but is inherently horizontally unstable. ROM: flexion/extension 25°; lateral bending 5° (each side); rotation 5° (each side).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capsule</td>
<td>Surrounds joints (condyle &amp; facet)</td>
<td>Loose tissue provides minimal stability</td>
</tr>
<tr>
<td>Ant. atlantooccipital</td>
<td>Ant. atlas arch to ant. foramen mag.</td>
<td>Continuation of ALL</td>
</tr>
<tr>
<td>Tectorial membrane</td>
<td>Post. axis to ant. foramen magnum</td>
<td>Primary stabilizer. Continuation of PLL, limits extension</td>
</tr>
<tr>
<td>Post. atlantooccipital</td>
<td>Post. arch to post. foramen magnum</td>
<td>Homologous to ligamentum flavum</td>
</tr>
</tbody>
</table>

| Atlantoaxial Joint (C1-2) |
| Made up of 3 articulations: Central (median) atlantoaxial joint (pivot type): between the odontoid and anterior arch. Lateral atlantoaxial joints [2] (plane type): between the articulating facets of atlas and axis, allow for rotation. ROM: flex/extend 20°; lateral bending 5° (each side); rotation 40° (each side). Supplies 50% of cervical rotation. |
| Capsule | Surrounds lateral facet joints | Loose capsule allows for rotation |
| Cruciate | Surrounded by transverse atlantal ligament (TAL) | Has 3 components, is anterior to tectorial membrane |
| Transverse atlantal (TAL) | Posterior odontoid to anterior arch | Strongest ligament, holds odontoid to atlas. ADI <3mm. Injury results in C1-2 instability. |
| Superior longitudinal | Odontoid to ant. foramen magnum | Posterior to apical ligament, secondary stabilizer. |
| Inferior longitudinal | Odontoid to body of axis | Secondary stabilizer |
| Alar | Odontoid to occipital condyles | Strong, stabilizing ligaments, limit rotation & lateral bending. Injury results in C1-2 instability. |
| Apical | Odontoid to ant. foramen magnum | Thin ligament provides minimal stability |
| Accessory | Axis body to occipital condyles | Secondary stabilizers |
## LIGAMENT ATTACHMENTS COMMENTS

### INTERVERTEBRAL ARTICULATION

Adjacent vertebrae are joined by a complex of smaller joints/articulations, ligaments, muscles, & connecting structures.

- An intervertebral disc lies between the vertebral bodies (except b/w C1-2 and b/w the fused sacral segments).
- Paired facet (apophyseal) joints connect the posterior elements. Their orientation dictates that intervertebral motion.
- Uncovertbral joints (of Luschka) add stability between vertebral bodies in the cervical spine.

<table>
<thead>
<tr>
<th>LIGAMENT</th>
<th>ATTACHMENTS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervertebral disc</td>
<td>To adjacent vertebral bodies</td>
<td>Annulus gives strong connection b/w adjacent bodies</td>
</tr>
<tr>
<td>Anterior longitudinal ligament (ALL)</td>
<td>Adjacent anterior vertebral bodies and discs</td>
<td>Strong, thick ligament. Resists hyperextension.</td>
</tr>
<tr>
<td>Posterior longitudinal ligament (PLL)</td>
<td>Adjacent posterior vertebral bodies &amp; discs (full length of spine)</td>
<td>Weak, limits hyperflexion. Disc herniates around ligament. Tectorial membrane is the superior continuation.</td>
</tr>
<tr>
<td>Ligamentum flavum</td>
<td>Anterior lamina (superior vert.) to posterior lamina (inferior vert.)</td>
<td>Strong, yellow, not a long continuous structure. Hypertrophy may contribute to nerve root impingement.</td>
</tr>
<tr>
<td>Ligamentum nuchae</td>
<td>Occipital protuberance to C1 post. arch &amp; C2-C6 spinous processes</td>
<td>Continuation of supraspinous ligament</td>
</tr>
<tr>
<td>Supraspinous</td>
<td>Dorsal spinous processes to C7</td>
<td>Strong. Ligamentum nuchae is its superior continuation.</td>
</tr>
<tr>
<td>Interspinous</td>
<td>Between spinous processes</td>
<td>Weak. Torn in ligamentous flexion-distraction injuries.</td>
</tr>
<tr>
<td>Intertransverse</td>
<td>Between transverse processes</td>
<td>Weak ligament, adds little support.</td>
</tr>
<tr>
<td>Iliolumbar</td>
<td>L5 transverse process to ilium</td>
<td>May avulse in pelvic fracture (e.g., vertical shear fx).</td>
</tr>
</tbody>
</table>
Left lateral view (partially sectioned in median plane)

- Inferior articular process
- Capsule of zygapophyseal (facet) joint (partially opened)
- Superior articular process
- Transverse process
- Spinous process
- Ligamentum flavum
- Interspinous ligament
- Supraspinous ligament
- Intervertebral foramen
- Anterior longitudinal ligament
- Lumbar vertebral body
- Intervertebral disc
- Anterior longitudinal ligament
- Posterior longitudinal ligament

Lumbar MRI, sagittal view

- Conus medullaris
- Cauda equina
- Intervertebral disc
- L1
- L5
- S1

Posterior view

- Pedicle
- Intervertebral disc
- Posterior longitudinal ligament
- Superior articular processes; facet tropism (difference in facet axis) on right side
- Spinous process
- Lamina
- Transverse process
- Superior articular process
- Ligamentum flavum
- Iliolumbar ligament
- Iliac crest
**Spine • JOINTS**

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**LIGAMENT ATTACHMENTS COMMENTS**

### FACET (IZYG)APOPHYSEAL JOINT

- Paired (L & R) articulations between the inferior & superior articular processes of adjacent vertebrae.
  - Orientation changes from semi-coronal (cervical) to sagittal (lumbar) and allows/dictates motion of that segment.
  - Inferior articular process is anterior & inferior (C-spine) and anterior & lateral (L-spine) to the superior articular process.
  - Joint innervation is from dorsal rami of two adjacent nerve root levels.
  - Hypertrophic changes in degenerative disease can cause/contribute to nerve root impingement.

<table>
<thead>
<tr>
<th>Capsule</th>
<th>Surrounded the articular processes</th>
<th>Weak structure, adds little support. May hypertrophy in degenerative joints and narrow neural foramen.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meniscus/disc</td>
<td>Within joint b/w processes</td>
<td>Can be injured or degenerate and be source of pain</td>
</tr>
</tbody>
</table>

**INTERVERTEBRAL DISCS**

- The discs make up 25% of the spine height. Disc degeneration with age results in loss of spinal column height.

<table>
<thead>
<tr>
<th>Anulus fibrosus</th>
<th>Strong attachments to end plates of adjacent vertebral bodies (via “outer annulus”)</th>
<th>Two layers: 1. outer annulus: dense fibers (type 1 collagen); 2. inner annulus: fibrocartilage, looser type 2 collagen fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucleus pulposus</td>
<td>Contained within the annulus</td>
<td>Gelatinous mass of water, proteoglycans, &amp; type 2 collagen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resists compressive loads (highest when sitting forward)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water &amp; proteoglycan content decrease with advancing age</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can herniate out of annulus &amp; compress nerve root (L4-5 #1)</td>
</tr>
</tbody>
</table>
**JOINTS • Spine**

**Ligament Attachments**

### Uncovertebral Joints

- **“Joints of Luschka”:** articulation in cervical spine b/w the uncinate process on the concave superior end plates of the inferior vertebral body & the articulating portion of the convex inferior end plate of the superior adjacent vertebral body.
- **Articular cartilage at this joint can degenerate and contribute to cervical spondylosis.**

### Costovertebral Joints

- Articulation between the head of the rib and the thoracic vertebra (body and transverse process)
  - **Capsule:** Surround head of rib/joint, Weak support of joint
  - **Intraarticular:** Head of rib to body/disc, Deep to radiate
  - **Radiate:** Head of rib to bodies & disc, Fan shaped, reinforces joint anteriorly
  - **Costotransverse:** Transverse process to rib, Superior costotransverse attaches to TP of superior vertebrae

### Other

- Neural foramen: Boundaries: superior & inferior pedicles; anterior: body & disc (uncinate process in C-spine); posterior: facet joint & capsule. Osteophytes, discs, facet hypertrophy, and ligamentum flavum can all narrow foramen.

---

**Left lateral view**

- Anterior longitudinal ligament
- Inferior costal facet (for head of rib of same number higher)
- Interarticular ligament of head of rib
- Superior costal facet (for head of rib one number higher)
- Radiate ligament of head of rib

**Transverse section: superior view**

- Superior articular facet of rib head
- Intraarticular ligament
- Synovial cavities
- Superior costotransverse ligament (cut)
- Superior costotransverse ligament
- Costotransverse ligament
- Lateral costotransverse ligament

**LIGAMENT ATTACHMENTS COMMENTS**

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<td><strong>UNCOVERTEBRAL JOINTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>“Joints of Luschka”:</em> articulation in cervical spine b/w the uncinate process on the concave superior end plates of the inferior vertebral body &amp; the articulating portion of the convex inferior end plate of the superior adjacent vertebral body.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Articular cartilage at this joint can degenerate and contribute to cervical spondylosis.</em></td>
<td></td>
</tr>
<tr>
<td><strong>COSTOVERTEBRAL JOINTS</strong></td>
<td>Articulation between the head of the rib and the thoracic vertebra (body and transverse process)</td>
<td></td>
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<tr>
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<tr>
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<td>Fan shaped, reinforces joint anteriorly</td>
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<tr>
<td>Costotransverse</td>
<td>Transverse process to rib</td>
<td>Superior costotransverse attaches to TP of superior vertebrae</td>
</tr>
<tr>
<td><strong>OTHER</strong></td>
<td>Neural foramen: Boundaries: superior &amp; inferior pedicles; anterior: body &amp; disc (uncinate process in C-spine); posterior: facet joint &amp; capsule. Osteophytes, discs, facet hypertrophy, and ligamentum flavum can all narrow foramen.</td>
<td></td>
</tr>
</tbody>
</table>
Head-on collision with stationary object or oncoming vehicle may, if seat belts not used, drive forehead against windshield. This sharply hyperextends neck, resulting in dislocation with or without fracture of cervical vertebrae.

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>Young</td>
<td>Disc injuries, spondylolisthesis</td>
</tr>
<tr>
<td></td>
<td>Middle age</td>
<td>Sprain/strain, nucleus pulposis/disc (HNP), degenerative disc disease (DDD)</td>
</tr>
<tr>
<td></td>
<td>Elderly</td>
<td>Spinal stenosis, herniated disc, DDD, spondylosis</td>
</tr>
<tr>
<td>2. Pain</td>
<td>a. Character Radiating (shooting)</td>
<td>Radiculopathy (herniated nucleus pulposis [HNP])</td>
</tr>
<tr>
<td></td>
<td>b. Location Unilateral vs bilateral</td>
<td>Unilateral: herniated nucleus pulposis; Bilateral: systemic or metabolic disease, space-occupying lesion</td>
</tr>
<tr>
<td></td>
<td>c. Occurrence Neck</td>
<td>Cervical spondylosis, neck sprain or muscle strain</td>
</tr>
<tr>
<td></td>
<td>d. Alleviating Arms (+/- radiating)</td>
<td>Cervical spondylosis (+/- myelopathy), HNP</td>
</tr>
<tr>
<td></td>
<td>e. Exacerbating Lower back</td>
<td>DDD, back sprain/muscle strain, spondylolisthesis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Legs (+/- radiating)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night pain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arms elevated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sit down</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Back extension</td>
</tr>
<tr>
<td>3. Trauma</td>
<td>MVA (seatbelt?)</td>
<td>Cervical strain (whiplash), cervical fractures, ligamentous injury</td>
</tr>
<tr>
<td>4. Activity</td>
<td>Sports (stretching injury)</td>
<td>“Burners/stingers” (esp. in football), fractures</td>
</tr>
<tr>
<td>5. Neurologic symptoms</td>
<td>Pain, numbness, tingling</td>
<td>Radiculopathy, neuropathy, cauda equina syndrome</td>
</tr>
<tr>
<td></td>
<td>Spasticity, clumsiness</td>
<td>Myelopathy</td>
</tr>
<tr>
<td></td>
<td>Bowel/bladder symptoms</td>
<td>Cauda equina syndrome</td>
</tr>
<tr>
<td>6. Systemic complaints</td>
<td>Fever, weight loss, night sweats</td>
<td>Infection, tumor</td>
</tr>
</tbody>
</table>
**PHYSICAL EXAMINATION • Spine**

### EXAM TECHNIQUE CLINICAL APPLICATION

#### INSPECTION

<table>
<thead>
<tr>
<th>EXAM</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait</td>
<td>Leaning forward</td>
<td>Spinal stenosis, Myelopathy</td>
</tr>
<tr>
<td></td>
<td>Wide-based</td>
<td></td>
</tr>
<tr>
<td>Alignment</td>
<td>Malalignment</td>
<td>Dislocation, scoliosis, lordosis, kyphosis</td>
</tr>
<tr>
<td>Posture</td>
<td>Head tilted</td>
<td>Dislocation, spasm, spondylosis, torticollis</td>
</tr>
<tr>
<td></td>
<td>Pelvis tilted</td>
<td>Loss of lordosis: spasm</td>
</tr>
<tr>
<td>Skin</td>
<td>Disrobe patient</td>
<td>Cafe-au-lait spots, growths: possibly neurofibromatosis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Port wine spots, soft masses: possibly spina bifida</td>
</tr>
</tbody>
</table>

#### PALPATION

<table>
<thead>
<tr>
<th>EXAM</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bony structures</td>
<td>Spinal processes</td>
<td>Focal/point tenderness: fracture; step-off: dislocation/spondylothesis</td>
</tr>
<tr>
<td>Soft tissues</td>
<td>Cervical facet joints</td>
<td>Tenderness: osteoarthritis, dislocation</td>
</tr>
<tr>
<td></td>
<td>Coccyx, via rectal exam</td>
<td>Tenderness: fracture or contusion</td>
</tr>
<tr>
<td></td>
<td>Paraspinal muscles</td>
<td>Diffuse tenderness: sprain/muscle strain; trigger point: spasm</td>
</tr>
</tbody>
</table>

#### RANGE OF MOTION

<table>
<thead>
<tr>
<th>EXAM</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion/extension: cervical</td>
<td>Chin to chest/occiput back</td>
<td>Normal: Flexion: chin within 3-4cm of chest; ext. 70° Normal: 45-60° in flexion, 20-30° in extension</td>
</tr>
<tr>
<td>Flexion/extension: lumbar</td>
<td>Touch toes with legs straight</td>
<td></td>
</tr>
<tr>
<td>Lateral flexion: cervical</td>
<td>Ear to shoulder</td>
<td>Normal: 30-40° in each direction</td>
</tr>
<tr>
<td>Lateral flexion: lumbar</td>
<td>Bend to each side</td>
<td>Normal: 10-20° in each direction</td>
</tr>
<tr>
<td>Rotation: cervical</td>
<td>Stabilize shoulders: rotate</td>
<td>Normal: 75° in each direction</td>
</tr>
<tr>
<td>Rotation: lumbar</td>
<td>Stabilize hip: rotate</td>
<td>Normal: 5-15° in each direction</td>
</tr>
</tbody>
</table>
## Physical Examination

### Neurovascular

<table>
<thead>
<tr>
<th>Level</th>
<th>Motor</th>
<th>Reflex</th>
<th>Sensory</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>Deltoi: resisted abduction</td>
<td>Biceps brachii</td>
<td>Deficit indicates a corresponding cervical root compression/lesion</td>
</tr>
<tr>
<td>C6</td>
<td>Biceps: resisted elbow flexion</td>
<td>Brachioradialis</td>
<td>Deficit indicates a corresponding cervical root compression/lesion</td>
</tr>
<tr>
<td>C7</td>
<td>Triceps: resisted elbow ext.</td>
<td>Triceps brachii</td>
<td>Deficit indicates a corresponding cervical root compression/lesion</td>
</tr>
<tr>
<td>C8</td>
<td>Intrinsics: resisted finger abduction</td>
<td>None</td>
<td>Deficit indicates a corresponding cervical root compression/lesion</td>
</tr>
</tbody>
</table>

### Technique

<table>
<thead>
<tr>
<th>Exam</th>
<th>Technique</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>Lateral shoulder</td>
<td>Deficit indicates a corresponding cervical root compression/lesion</td>
</tr>
<tr>
<td>C6</td>
<td>Thumb</td>
<td>Deficit indicates a corresponding cervical root compression/lesion</td>
</tr>
<tr>
<td>C7</td>
<td>Middle finger</td>
<td>Deficit indicates a corresponding cervical root compression/lesion</td>
</tr>
<tr>
<td>C8</td>
<td>Ring &amp; small fingers</td>
<td>Deficit indicates a corresponding cervical root compression/lesion</td>
</tr>
<tr>
<td>T1</td>
<td>Ulnar forearm &amp; hand</td>
<td>Deficit indicates a corresponding cervical root compression/lesion</td>
</tr>
</tbody>
</table>

### Motor

- C5: Deltoid: resisted abduction  
- C6: Biceps: resisted elbow flexion  
- C7: Triceps: resisted elbow ext.  
- C8: Intrinsics: resisted finger abduction  

### Reflexes

- C5: Biceps  
- C6: Brachioradialis (BR)  
- C7: Triceps  
- Inverted radial: Tap BR tendon in distal forearm  
- Hoffman’s: Flick MF DIPJ into flexion

### Pathology

- Hypoactive/absent indicates C5 radiculopathy
- Hypoactive/absent indicates C6 radiculopathy
- Hypoactive/absent indicates C7 radiculopathy
- Pathologic if thumb IPJ flexes: myelopathy

### Vascular

- Brachial, radial, ulnar  
- Diminished/absent = vascular injury or compromise
<table>
<thead>
<tr>
<th>Level</th>
<th>Motor</th>
<th>Reflex</th>
<th>Sensory</th>
</tr>
</thead>
<tbody>
<tr>
<td>L4</td>
<td>Quadriceps</td>
<td>Patella tendon (&quot;knee jerk&quot;)</td>
<td>Medial calf/ankle</td>
</tr>
<tr>
<td></td>
<td>Tibialis anterior</td>
<td>L4</td>
<td></td>
</tr>
<tr>
<td>L5</td>
<td>Extensor hallucis longus</td>
<td>None</td>
<td>Dorsal foot and 1st web space</td>
</tr>
<tr>
<td>S1</td>
<td>Gastrocnemius</td>
<td>Achilles tendon (&quot;ankle jerk&quot;)</td>
<td>Plantar and lateral foot</td>
</tr>
</tbody>
</table>

**EXAM TECHNIQUE CLINICAL APPLICATION**

<table>
<thead>
<tr>
<th>Neurovascular</th>
<th>L3</th>
<th>Anterior &amp; medial thigh</th>
<th>Deficit indicates corresponding lumbar root compression/lesion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory</td>
<td>L4</td>
<td>Medial leg &amp; ankle</td>
<td>Deficit indicates corresponding lumbar root compression/lesion</td>
</tr>
<tr>
<td>L5</td>
<td>Dorsal foot &amp; 1st web space</td>
<td>Deficit indicates corresponding lumbar root compression/lesion</td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>Lateral &amp; plantar foot</td>
<td>Deficit indicates corresponding lumbar root compression/lesion</td>
<td></td>
</tr>
<tr>
<td>S2-4</td>
<td>Perianal sensation</td>
<td>Deficit indicates corresponding lumbar root compression/lesion</td>
<td></td>
</tr>
</tbody>
</table>

| Motor | L3-4 | Quadriceps: knee extension | Weakness indicates corresponding lumbar root compression/lesion |
|       | L4   | Tibialis anterior: ankle DF | Weakness indicates corresponding lumbar root compression/lesion |
|       | L5   | Extensor hallucis longus: toe DF | Weakness indicates corresponding lumbar root compression/lesion |
|       | S1   | Gastrocnemius: ankle PF | Weakness indicates corresponding lumbar root compression/lesion |
|       | S2-4 | Anal sphincter: anal squeeze | Weakness indicates corresponding lumbar root compression/lesion |

| Reflexes | L4 | Patellar tendon ("knee jerk") | Hypoactive/absent indicates L4 radiculopathy |
|          | S1 | Achilles tendon ("ankle jerk") | Hypoactive/absent indicates S1 radiculopathy |
|          | S2-3 | Bulbo cavernous | Hypoactive/absent indicates S2-3 radiculopathy or spinal shock |
|          | Babinski | Run stick along plantar foot | Upgoing great toe: upper motor neuron/myelopathy |
|          | Ankle clonus | Rapidly flex & extend ankle | Multiple beats of clonus: upper motor neuron/myelopathy |

| Pulses | Posterior tibial, dorsalis pedis | Diminished/absent = vascular injury or compromise |
### PHYSICAL EXAMINATION

#### FORWARD BENDING TEST

![Image](image.png)

Estimation of rib hump and evaluation of curve unwinding as patient turns trunk from side to side.

#### SPURLING MANEUVER

![Image](image.png)

Hyperextension and flexion of neck ipsilateral to the side of lesion cause radicular pain in neck and down the affected arm.

#### STRAIGHT LEG TEST

Passively flex hip. Stop when pain occurs. Lower leg until pain resolves, then dorsiflex foot.

![Image](image.png)

Extend knee, hip relaxed.

---

<table>
<thead>
<tr>
<th>EXAM</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SPECIAL TESTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cervical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spurling</td>
<td>Axial load, then laterally flex &amp; rotate neck</td>
<td>Radiating pain indicates nerve root compression</td>
</tr>
<tr>
<td>Distraction</td>
<td>Upward distracting force</td>
<td>Relief of symptoms indicates foraminal compression of nerve root</td>
</tr>
<tr>
<td>Kernig</td>
<td>Supine: flex neck</td>
<td>Pain in or radiating to legs indicates meningeal irritation/infection</td>
</tr>
<tr>
<td>Brudzinski</td>
<td>Supine: flex neck, hip flex</td>
<td>Pain reduction with knee flexion indicates meningeal irritation</td>
</tr>
<tr>
<td><strong>Lumbar</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight leg</td>
<td>Flex hip to pain, dorsiflex foot</td>
<td>Symptoms reproduced (pain radiating below knee) indicative of radiculopathy</td>
</tr>
<tr>
<td>Straight leg 90/90</td>
<td>Supine: flex hip &amp; knee 90°, extend knee</td>
<td>&gt;20° of flexion = tight hamstrings: source of pain</td>
</tr>
<tr>
<td>Bowstring</td>
<td>Raise leg, flex knee, popliteal press</td>
<td>Radicular pain with popliteal pressure indicates sciatic nerve cause</td>
</tr>
<tr>
<td>Sitting root (flip sign)</td>
<td>Seated: distract patient, passively extend knee</td>
<td>Patient with sciatic pain will arch/flip backward when knee extended</td>
</tr>
<tr>
<td>Forward bending</td>
<td>Standing, bend at waist</td>
<td>Asymmetry of back (scapula/ribs) is indicative of scoliosis</td>
</tr>
<tr>
<td>Hoover</td>
<td>Supine: hands under heels, patient then raises one leg</td>
<td>Pressure should be felt under opposite heel. No pressure indicates lack of effort, not true weakness</td>
</tr>
<tr>
<td>LAYER</td>
<td>CONTENTS</td>
<td>COMMENT</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td>Platysma</td>
<td>Thin superficial muscle</td>
<td>Highly vascular, must be split to access cervical spine</td>
</tr>
<tr>
<td>Deep cervical fascia</td>
<td>Invests sternocleidomastoid</td>
<td>Incised in anterior cervical approach</td>
</tr>
<tr>
<td>Pretracheal fascia</td>
<td>Invests thyroid, trachea</td>
<td>Incised off of carotid sheath to access cervical spine</td>
</tr>
<tr>
<td>Carotid sheath</td>
<td>Carotid artery, internal jugular vein, vagus nerve (CN 10)</td>
<td>Left intact and used to retract structures laterally unless access to contents of sheath is needed</td>
</tr>
<tr>
<td>Prevertebral fascia</td>
<td>Covers A.L.L. &amp; longus colli</td>
<td>Deepest fascial layer, incised to access vertebral body and disc</td>
</tr>
<tr>
<td>MUSCLE</td>
<td>ORIGIN</td>
<td>INSERTION</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td><strong>ANTERIOR NECK</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platysma</td>
<td>Fascia: deltoid/pectoralis major</td>
<td>Mandible; skin</td>
</tr>
<tr>
<td>Sternoceleidomastoid</td>
<td>Manubrium &amp; clavicle</td>
<td>Mastoid process</td>
</tr>
<tr>
<td><strong>ANTERIOR CERVICAL TRIANGLE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Suprahyoid Muscles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digastric</td>
<td>Anterior: mandible</td>
<td>Hyoid body</td>
</tr>
<tr>
<td></td>
<td>Posterior: mastoid notch</td>
<td></td>
</tr>
<tr>
<td>Mylohyoid</td>
<td>Mandible</td>
<td>Raphe on hyoid</td>
</tr>
<tr>
<td>Stylohyoid</td>
<td>Styloid process</td>
<td>Body of hyoid</td>
</tr>
<tr>
<td>Geniohyoid</td>
<td>Genial tubercle of mandible</td>
<td>Body of hyoid</td>
</tr>
<tr>
<td><strong>Infrahyoid Muscles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Superficial</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sternohyoid</td>
<td>Manubrium &amp; clavicle</td>
<td>Body of hyoid</td>
</tr>
<tr>
<td>Omohyoid</td>
<td>Suprascapular notch</td>
<td>Body of hyoid</td>
</tr>
<tr>
<td><strong>Deep</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thyrohyoid</td>
<td>Thyroid cartilage</td>
<td>Greater horn of hyoid</td>
</tr>
<tr>
<td>Sternothyoid</td>
<td>Manubrium</td>
<td>Thyroid cartilage</td>
</tr>
</tbody>
</table>
Epicranial aponeurosis (galea aponeurotica)
Occipital belly (occipitalis) of occipitofrontalis muscle
Greater occipital nerve (dorsal ramus of C2 spinal nerve)
Occipital artery
3rd (least) occipital nerve (dorsal ramus of C3 spinal nerve)
Semispinalis capitis and splenius capitis muscles in posterior triangle of neck
Posterior auricular artery
Great auricular nerve (cervical plexus C2, 3)
Lesser occipital nerve (cervical plexus C2, 3)
Sternocleidomastoid muscle
Trapezius muscle
Posterior cutaneous branches of dorsal rami of C4, 5, 6 spinal nerves

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>ACTION</th>
<th>NERVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior neck</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scalene muscles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>C3-6 transverse process</td>
<td>1st rib</td>
<td>Laterally flexes neck and elevates 1st or 2nd rib</td>
<td>C5-C8 nerve roots</td>
</tr>
<tr>
<td>Middle</td>
<td>C2-7 transverse process</td>
<td>2nd rib</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>C4-6 transverse process</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rectus capitis posterior major</td>
<td>Spine of axis</td>
<td>Inferior nuchal line</td>
<td>Extend, rotate, laterally flex head</td>
<td>Suboccipital nerve</td>
</tr>
<tr>
<td>Rectus capitis posterior minor</td>
<td>Posterior tubercle of atlas</td>
<td>Occipital bone</td>
<td>Extend, laterally flex</td>
<td>Suboccipital nerve</td>
</tr>
<tr>
<td>Obliquus capitis superior</td>
<td>Atlas transverse process</td>
<td>Occipital bone</td>
<td>Extend, rotate, laterally flex</td>
<td>Suboccipital nerve</td>
</tr>
<tr>
<td>Obliquus capitis inferior</td>
<td>Spine of axis</td>
<td>Atlas transverse process</td>
<td>Extend, laterally rotate</td>
<td>Suboccipital nerve</td>
</tr>
<tr>
<td>Suboccipital Triangle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Semispinalis, see page 58; Splenius, see page 57.
<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>ACTION</th>
<th>NERVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezius</td>
<td>Spinous process C7-T12</td>
<td>Clavicle; scapula (spine, acromion)</td>
<td>Rotate scapula</td>
<td>CN 11</td>
</tr>
<tr>
<td>Latissimus dorsi</td>
<td>Spinous process T6-S5</td>
<td>Humerus</td>
<td>Extend, adduct, IR arm</td>
<td>Thoracodorsal</td>
</tr>
<tr>
<td>Levator scapulae</td>
<td>Transverse process C1-4</td>
<td>Scapula (medial)</td>
<td>Elevate scapula</td>
<td>Dorsal scapular, C3, C4 (dorsal rami)</td>
</tr>
<tr>
<td>Rhomboid minor</td>
<td>Spinous process C7-T1</td>
<td>Scapula (spine)</td>
<td>Adduct scapula</td>
<td>Dorsal scapular</td>
</tr>
<tr>
<td>Rhomboid major</td>
<td>Spinous process T2-T5</td>
<td>Scapula (medial border)</td>
<td>Adduct scapula</td>
<td>Dorsal scapular</td>
</tr>
<tr>
<td>Serratus posterior superior</td>
<td>Spinous process C7-T3</td>
<td>Ribs 2-5 (upper border)</td>
<td>Elevate ribs</td>
<td>Intercostal n, (T1-4)</td>
</tr>
<tr>
<td>Serratus posterior inferior</td>
<td>Spinous process T11-L3</td>
<td>Ribs 9-12 (lower border)</td>
<td>Depress ribs</td>
<td>Intercostal n, (T9-12)</td>
</tr>
<tr>
<td>MUSCLE</td>
<td>ORIGIN</td>
<td>INSERTION</td>
<td>ACTION</td>
<td>NERVE</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------------</td>
<td>------------------------------------------------</td>
<td>----------------------------------------------------------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td><strong>DEEP (INTRINSIC)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Splenius capitis</td>
<td>Ligamentum nuchae</td>
<td>Mastoid &amp; nuchal line</td>
<td>Both: laterally flex &amp; rotate neck to same side</td>
<td>Dorsal rami of inferior cervical nerves</td>
</tr>
<tr>
<td>Splenius cervicis</td>
<td>Spinous process T1-6</td>
<td>Transverse process C1-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intermediate Layer: Sacrospinalis Group (Erector Spinae)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iliocostalis</td>
<td>Common origin: sacrum, iliac crest, and</td>
<td>Ribs</td>
<td>Laterally flex, extend, and rotate head (to same side)</td>
<td>Dorsal rami of spinal nerves</td>
</tr>
<tr>
<td>Longissimus</td>
<td>lumbar spinous process</td>
<td>T &amp; C spinous process, mastoid process</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinalis</td>
<td></td>
<td>T-spine: spinous process</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All have three parts: thoracis, cervicis, and capitus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MUSCLE</td>
<td>ORIGIN</td>
<td>INSERTION</td>
<td>ACTION</td>
<td>NERVE</td>
</tr>
<tr>
<td>------------------------------</td>
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<td>---------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td><strong>Deep (INTRINSIC)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semispinalis capitus</td>
<td>Transverse process</td>
<td>Nuchal ridge</td>
<td>Extend head</td>
<td>Dorsal primary rami</td>
</tr>
<tr>
<td>(T1-6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semispinalis (C&amp;T)</td>
<td>Transverse process</td>
<td>Spinous process</td>
<td>Extend, rotate opposite side</td>
<td>Dorsal primary rami</td>
</tr>
<tr>
<td>Multifidi (C2-S4)</td>
<td>Transverse process</td>
<td>Spinous process</td>
<td>Flex laterally, rotate opposite</td>
<td>Dorsal primary rami</td>
</tr>
<tr>
<td>Rotatores</td>
<td>Transverse process</td>
<td>Spinous process +1</td>
<td>Rotate superior vertebrae opposite</td>
<td>Dorsal primary rami</td>
</tr>
<tr>
<td>Levator costarum</td>
<td>Transverse process</td>
<td>Brevis: rib – 1</td>
<td>Elevate rib during inspiration</td>
<td>Dorsal primary rami</td>
</tr>
<tr>
<td>Interspinales</td>
<td>Spinous process</td>
<td>Spinous process +1</td>
<td>Extend column</td>
<td>Dorsal primary rami</td>
</tr>
<tr>
<td>Intertransversarii</td>
<td>Transverse process</td>
<td>Transverse process +1</td>
<td>Laterally flex column</td>
<td>Dorsal primary rami</td>
</tr>
</tbody>
</table>
**Cervical Spine Injury: Incomplete Spinal Syndromes**

**Spinal cord orientation**
- Posterior columns (position sense)
- Lower limb
  - Trunk
  - Upper limb
- Lateral corticospinal tract (motor)
- Lower limb
  - Trunk
  - Upper limb
- Lateral spinothalamic tract (pain and temperature); fibers decussate before ascending
- Anterior spinal artery

**Nerves**
- Spine

**TRACT** | **FUNCTION** | **COMMENT**
--- | --- | ---
**Spinal cord**
- Runs from brain stem to conus medullaris (termination at L1) within the spinal canal where it is protected.
- Terminale filum and cauda equina (lumbar and sacral nerve roots) continue in the spinal canal.
- It has a layered covering (membranes): dura mater, arachnoid mater, pia mater.
- It is wider in the cervical and lumbar spines, where the roots form plexus to innervate the upper and lower extremities.
- Paired (R & L) nerve roots emerge from each level. Nerve roots made up of ventral (motor) and dorsal (sensory) roots.
- Injury can be either complete or incomplete (see page 42 for spinal cord injuries).

**Descending (Motor)**
- Anterior corticospinal
  - Innervates motor neurons—voluntary motor
  - Minor motor pathway, injured in anterior cord syndrome
- Lateral corticospinal
  - Innervates motor neurons—voluntary motor
  - Major motor pathway, injured in Brown-Sequard syndrome

**Ascending (Sensory)**
- Anterior spinothalamic
  - Light touch sensation
  - Injured in anterior cord syndrome
- Lateral spinothalamic
  - Pain and temperature sensation
  - Injured in Brown-Sequard syndrome
- Dorsal columns
  - Proprioception and vibratory sensation
  - Usually preserved, injured in posterior cord syndrome
**SPINAL NERVES**

- Spinal nerves are made up of a ventral (motor) root and a dorsal (sensory) root. There are 31 pairs (L & R).
- Cell bodies for sensory nerves are in dorsal root ganglia. Motor nerve cell bodies are in ventral horn of spinal cord.
- Roots exit spinal column via the intervertebral (neural) foramen (under pedicle); (C1-7 exit above their vertebrae, C8-L5 exit below their vertebrae (C7 exits above and C8 exits below C7 vertebra)).
- They can be compressed by herniated discs, osteophytes, and hypertrophied soft tissues (ligamentum flavum, facet capsule). In lumbar spine the traversing nerve is usually affected, and exiting root is not (except in far lateral compression).
- The lumbar and sacral nerves form the cauda equina (“horse’s tail”) in the spinal canal before exiting.
- Spinal nerve divides into dorsal and ventral rami. Dorsal rami innervate local structures (neck and back musculature, overlying skin, facet capsules, etc). Ventral rami contribute to plexus (e.g., cervical, brachial, lumbosacral) and become peripheral nerves to the extremities.
- Ventral rami of spinal nerve commonly referred to as a spinal “roots.” The roots combine to form the various plexus.
Levels of principal dermatomes

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>Clavicles</td>
</tr>
<tr>
<td>C5, 6, 7</td>
<td>Lateral parts of upper limbs</td>
</tr>
<tr>
<td>C8, T1</td>
<td>Medial sides of upper limbs</td>
</tr>
<tr>
<td>C6</td>
<td>Thumb</td>
</tr>
<tr>
<td>C6, 7, 8</td>
<td>Hand</td>
</tr>
<tr>
<td>C8</td>
<td>Ring and little fingers</td>
</tr>
<tr>
<td>T4</td>
<td>Level of nipples</td>
</tr>
<tr>
<td>T10</td>
<td>Level of umbilicus</td>
</tr>
<tr>
<td>L1</td>
<td>Inguinal or groin regions</td>
</tr>
<tr>
<td>L1, 2, 3, 4</td>
<td>Anterior and inner surfaces of lower limbs</td>
</tr>
<tr>
<td>L4, 5, S1</td>
<td>Foot</td>
</tr>
<tr>
<td>L4</td>
<td>Medial side of great toe</td>
</tr>
<tr>
<td>S1, 2, L5</td>
<td>Posterior and outer surfaces of lower limbs</td>
</tr>
<tr>
<td>S1</td>
<td>Lateral margin of foot and little toe</td>
</tr>
<tr>
<td>S2, 3, 4</td>
<td>Perineum</td>
</tr>
</tbody>
</table>

Schematic demarcation of dermatomes (according to Keegan and Garrett) shown as distinct segments. There is actually considerable overlap between any two adjacent dermatomes.
<table>
<thead>
<tr>
<th>LEVEL</th>
<th>MOTOR</th>
<th>SENSORY</th>
<th>REFLEX</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Geniohyoid&lt;br&gt;Thyrohyoid&lt;br&gt;Rectus capitus</td>
<td>None</td>
<td>None</td>
<td>Part of cervical plexus, contributes to ansa cervicalis</td>
</tr>
<tr>
<td>C2</td>
<td>Longus colli/capitis</td>
<td>Parietal scalp</td>
<td>None</td>
<td>Muscle innervation via the dorsal rami</td>
</tr>
<tr>
<td>C3</td>
<td>Diaphragm</td>
<td>Occipital scalp</td>
<td>None</td>
<td>Contributes to phrenic &amp; dorsal scapular nerves</td>
</tr>
<tr>
<td>C4</td>
<td>Diaphragm</td>
<td>Base of neck</td>
<td>None</td>
<td>Branches to phrenic and dorsal scapular nerves &amp; levator scapula muscle</td>
</tr>
<tr>
<td>C5</td>
<td>Deltoid</td>
<td>Lateral shoulder and arm</td>
<td>Biceps</td>
<td>Dorsal scapular n. branches from C5 root</td>
</tr>
<tr>
<td>C6</td>
<td>Biceps brachii&lt;br&gt;ECRL, ECRB</td>
<td>Lateral forearm and thumb</td>
<td>Brachioradialis</td>
<td>Most commonly compressed cervical nerve root</td>
</tr>
<tr>
<td>C7</td>
<td>Triceps brachii&lt;br&gt;FCR, FCU</td>
<td>Posterior forearm, central hand, and middle finger</td>
<td>Triceps</td>
<td>Exits above C7 vertebra</td>
</tr>
<tr>
<td>C8</td>
<td>FDS, FDP</td>
<td>Medial forearm, ulnar fingers</td>
<td>None</td>
<td>Exits below C7 vertebra</td>
</tr>
<tr>
<td>T1</td>
<td>Interosseous</td>
<td>Medial arm</td>
<td>None</td>
<td>Only thoracic root in brachial plexus</td>
</tr>
</tbody>
</table>
Segmental innervation of lower limb movements

**Anterior view**

- **Hip**
  - Extension
  - Flexion

- **Knee**
  - Dorsiflexion
  - Flexion

- **Ankle**
  - Inversion
  - Eversion

**Posterior view**

- **Foot**
  - Plantar flexion
  - Dorsiflexion

**NERVES**

- **Spine**

**LEVEL** | **MOTOR** | **SENSORY** | **REFLEX** | **COMMENT**
--- | --- | --- | --- | ---

**LUMBOSACRAL ROOTS**

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>MOTOR</th>
<th>SENSORY</th>
<th>REFLEX</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>Transversus abdominis</td>
<td>Inguinal region</td>
<td>None</td>
<td>Rarely injured nerve root</td>
</tr>
<tr>
<td>L2</td>
<td>Psoas</td>
<td>Upper thigh</td>
<td>None</td>
<td>Test with hip flexion</td>
</tr>
<tr>
<td>L3</td>
<td>Quadriceps</td>
<td>Anterior and medial thigh</td>
<td>None</td>
<td>L3 &amp; L4 tested with quadriceps</td>
</tr>
<tr>
<td>L4</td>
<td>Tibialis anterior</td>
<td>Medial leg, ankle, foot</td>
<td>Patellar</td>
<td>Test with ankle dorsiflexion</td>
</tr>
<tr>
<td>L5</td>
<td>Extensor hallucis longus</td>
<td>Dorsal/plantar foot, 1st web space, lateral leg</td>
<td>Hamstring</td>
<td>Most commonly compressed lumbar root; test with hallux dorsiflexion</td>
</tr>
<tr>
<td>S1</td>
<td>Gastrocnemius</td>
<td>Lateral foot, posterior leg</td>
<td>Achilles</td>
<td>Test with ankle plantar flexion/Toe walking</td>
</tr>
<tr>
<td>S2-4</td>
<td>Sphincter</td>
<td>Perianal sensation</td>
<td>Anal wink</td>
<td>Test tone to evaluate for cauda equina syndrome</td>
</tr>
</tbody>
</table>
CERVICAL PLEXUS

**C1-C4 ventral rami (behind IJ and SCM)**

<table>
<thead>
<tr>
<th><strong>Lesser Occipital Nerve (C2-3):</strong> arises from posterior border of sternocleidomastoid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensory:</strong> Superior region behind auricle</td>
</tr>
<tr>
<td><strong>Motor:</strong> None</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Great Auricular Nerve (C2-3):</strong> exits inferior to lesser occipital nerve, ascends on SCM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensory:</strong> Over parotid gland and behind ear</td>
</tr>
<tr>
<td><strong>Motor:</strong> None</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Transverse Cervical Nerve (C2-3):</strong> exits inferior to greater auricular nerve, then to anterior neck</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensory:</strong> Anterior triangle of the neck</td>
</tr>
<tr>
<td><strong>Motor:</strong> None</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Supraclavicular</strong> (C2-3): splits into 3 branches: anterior, middle, posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensory:</strong> Over clavicle, outer trapezius and deltoid</td>
</tr>
<tr>
<td><strong>Motor:</strong> None</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Ansa Cervicalis</strong> (C1-3): superior (C1-2) &amp; inferior (C2-3) roots form loop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensory:</strong> None</td>
</tr>
<tr>
<td><strong>Motor:</strong> Omothyroid</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Phrenic Nerve</strong> (C3-5): On anterior scalene, into thorax between subclavian artery and vein</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensory:</strong> Pericardium and mediastinal pleura</td>
</tr>
<tr>
<td><strong>Motor:</strong> Diaphragm</td>
</tr>
</tbody>
</table>
**Right anterior dissection**

- Internal jugular vein
- Common carotid artery
- Phrenic nerve
- Anterior scalene muscle
- Inferior thyroid artery
- Ascending cervical artery
- Dorsal scapular artery
- Suprascapular artery
- Costocervical trunk
- Thyrocervical trunk
- Subclavian artery and vein

- Thyroid gland (reflected)
- Middle cervical sympathetic ganglion
- Vagus nerve (X)
- Vertebral artery
- Common carotid artery
- Recurrent laryngeal nerve
- Brachiocephalic trunk
- Internal jugular vein (cut)

**Right oblique schematic view**

- Vertebral artery
- Deep cervical artery (ascending to, anastomose with descending branch of occipital artery)
- Suprascapular artery
- Thyrocervical trunk
- Common carotid artery
- Thyroid gland (reflected)
- Middle cervical sympathetic ganglion
- Vagus nerve (X)
- Vertebral artery
- Common carotid artery
- Recurrent laryngeal nerve
- Brachiocephalic trunk
- Internal jugular vein (cut)

---

**SUBCLAVIAN ARTERY**

- Branches off aorta (L) or brachiocephalic trunk (R) b/w anterior and middle scalene muscles
- Vertebral arteries (R & L)
  - Main arterial supply to the cervical spine and cord
  - Has 4 primary branches
  - Runs with phrenic nerve on anterior scalene muscles
  - Crosses posterior triangle of neck (scalenes, etc)
  - Off costocervical trunk, anastomoses w/ occipital artery

**VERTEBRAL ARTERY**

- Enters foramen transversarium from C6 through C1 then runs in a groove on the atlas, then to brain stem to form basilar artery
- Anterior spinal artery
  - Single midline artery supplies anterior 2/3 of spinal cord
  - 2 paired arteries supply posterior 1/3 of spinal cord
  - Give primary supply to odontoid
  - Contribute to anterior spinal artery
  - Contribute to posterior spinal arteries

Injury or infarct of the anterior or posterior spinal arteries can result in an anterior/central or posterior cord syndrome.
### COURSE BRANCHES COMMENT/SUPPLY

#### INTERCOSTAL (THORACIC)/LUMBAR ARTERY

- Paired arteries (R & L) branch off aorta, run posterior along vertebral bodies (between ribs in thoracic region)

- **Ventral branch**
  - Dorsal branch
  - Spinal branch
  - Major anterior segmental medullary (radicular)
  
  - To vertebral bodies
  - To posterior elements and cord
  - Supplies cord, nerve roots, and body
  
  *“Artery of Adamkiewicz”—single medullary artery (usually left T10-T12) to ant. spinal artery is primary supply to thoracolumbar cord. Injury can cause cord ischemia/paralysis.*

#### SPINAL BRANCH

- Branches off dorsal branch and enters intervertebral foramen

  - **Anterior radicular**
    - Runs on ventral root, anastomoses with anterior spinal artery
  
  - **Posterior radicular**
    - Runs on dorsal root, anastomoses with posterior spinal artery
  
  - Postcentral branch
    - Prelaminar branch
    - Supplies vertebral body and dura
    - Supplies lamina/posterior elements

#### ANTERIOR SPINAL

- Single midline artery supplies anterior ⅔ of spinal cord

  - Central (sulcal) branches
    - Pial arterial plexus
    - Supplies central cord region
    - Supplies peripheral ⅔ of spinal cord

#### POSTERIOR SPINAL

- Paired (R & L) arteries supply posterior ⅓ of spinal cord

  - Supplied by posterior medullary/radicular arteries
Note: All spinal nerve roots have associated radicular or segmental medullary arteries. Most roots have radicular arteries. Both types of arteries run along roots, but radicular arteries end before reaching anterior or posterior spinal arteries; larger segmental medullary arteries continue on to supply a segment of these arteries.
**Spinal stenosis: Laminectomy**

**DESCRIPTION**
- Narrowing of spinal canal results in cord/root compression
- Causes: hypertrophy of facet capsule or ligamentum flavum, bulging disc, DDD/osteoophytes

**Hx:** Pain, paresthesias relieved by sitting/forward leaning (neurogenic claudication)

**PE:** Pain with back extension, do good neurologic exam

**XR:** L-spine series: DDD, facet DJD
**CT:** Canal narrowing
**MR:** Evaluate cord/root compression

**TREATMENT**
- Activity modification, NSAIDs
- PT—flexion exercises
- Nerve root blocks/epidural injection
- Decompression (laminectomy +/- partial facetectomy)
**HERNIATED NUCLEUS PULPOSUS (HNP)**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protrusion of nucleus pulposus through torn annulus fibers</strong></td>
<td>Neck/back pain, +/- extremity (radiating) pain, paresthesias, and weakness</td>
<td>Often normal +/- disc space narrowing or spondylosis</td>
<td>Rest, activity modification</td>
</tr>
<tr>
<td><strong>Lumbar: L4-5 #1, traversing root</strong></td>
<td>Variable: decreased ROM, spinal tenderness</td>
<td>MR: Best study to show protruding disc and nerve or cord compression</td>
<td>NSAIDs (limit narcotic use)</td>
</tr>
<tr>
<td><strong>Thoracic: rare</strong></td>
<td>Cervical: +/- Spurling's straight leg raise</td>
<td>Epidural steroid injections</td>
<td>Physical therapy</td>
</tr>
<tr>
<td><strong>Cervical: associated with spondylosis</strong></td>
<td>Neuro: Radicular findings</td>
<td>Diskectomy +/- fusion:</td>
<td>Epidural steroid injections</td>
</tr>
<tr>
<td><strong>Can compress cord or roots</strong></td>
<td></td>
<td></td>
<td>Failed conservative treatment</td>
</tr>
</tbody>
</table>

**CAUDA EQUINA SYNDROME**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx/PE</th>
<th>WORKUP</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compression of cauda equina</strong></td>
<td>“Saddle” (perianal) anesthesia, lower extremity numbness/ weakness, decreased rectal tone</td>
<td>Normal or disc space narrowing</td>
<td>Emergency surgical decompression-laminectomy/diskectomy</td>
</tr>
<tr>
<td><strong>Usually from large midline disc herniation or extrusion</strong></td>
<td></td>
<td>MR: Study of choice: compression of cauda equina</td>
<td>(Prognosis is still guarded even with prompt diagnosis and treatment.)</td>
</tr>
<tr>
<td><strong>Bowel &amp; bladder dysfunction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Surgical emergency</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Spine Involvement in Osteoarthritis**

Extensive thinning of cervical discs and hyperextension deformity with narrowing of intervertebral foramina. Lateral radiograph reveals similar changes.

**Degenerative Disc Disease**

Radiograph of thoracic spine shows narrowing of intervertebral spaces and spur formation. Degeneration of lumbar intervertebral discs and hypertrophic changes at vertebral margins with spur formation. Osteophytic encroachment on intervertebral foramina compresses spinal nerves.

### Table: Cervical Spondylosis

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degenerative changes in discs, facets, and unco-vertebral joints</td>
<td>Hx: Neck pain, +/- UE pain, paresthesias, and/or weakness</td>
<td>XR: Loss of lordosis/cervical straightening, loss of disc space</td>
<td>NSAIDs, activity modification, physical therapy, +/- traction</td>
</tr>
<tr>
<td>C5-6 #1, C6-7 #2; men &gt; women</td>
<td>PE: Decreased ROM, +/- Spurling's test, +/- neurologic symptoms</td>
<td>MR: Shows disc degeneration or herniation</td>
<td>Epidural or facet injections, surgical: Anterior diskectomy and fusion (ACDF), posterior decompression/fusion</td>
</tr>
<tr>
<td>Causes axial/neck pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can result in cord or root compression: myelo/ radiculopathy</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table: Degenerative Disc Disease

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disc properties change (decr. H₂O, proteins altered, etc) leads to decr. mechanical properties</td>
<td>Hx: Back pain without radiculopathy</td>
<td>XR: Can be normal or disc height loss</td>
<td>Rest, activity modification, NSAIDs, +/- muscle relaxers</td>
</tr>
<tr>
<td>Ligaments/facets assume greater load, can be source of pain</td>
<td>PE: +/- decreased ROM or painful ROM, normal tension signs (straight leg/bowstring tests)</td>
<td>MR: Low signal (black disc), decreased height</td>
<td>Physical therapy: stretching, strengthening, weight control</td>
</tr>
<tr>
<td>Natural process: unclear why only some have pain</td>
<td>Discography: confirms disc as pain source (used for preop. eval.)</td>
<td></td>
<td>Surgical: lumbar fusion as options</td>
</tr>
</tbody>
</table>

70 NETTER’S CONCISE ORTHOPAEDIC ANATOMY
**Spondylolysis and Spondylolisthesis**

- **Superior articular process (ear of Scottie dog)**
- **Pedicle (eye)**
- **Transverse process (head)**
- **Lamina and spinous process (body)**
- **Isthmus (neck)**
- **Inferior articular process (foreleg)**
- **Opposite inferior articular process (hind leg)**

**Spondylolysis without spondylolisthesis.** Posterolateral view demonstrates formation of radiographic Scottie dog. On lateral radiograph, dog appears to be wearing a collar

**Isthmic type spondylolisthesis.** Anterior subluxation of L5 on sacrum due to fracture of isthmus. Note that gap is wider and dog appears decapitated

### SPONDYLOLISTHESIS

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slippage of one vertebra on adjacent vertebrae</td>
<td>Insidious onset of low back pain, worse with activities</td>
<td>Lateral view used to determine grade (% of vertebral body slipped)</td>
<td>• Rest, activity modification</td>
</tr>
<tr>
<td>Six types:</td>
<td></td>
<td></td>
<td>• Physical therapy; esp. stretching, flexion exercises</td>
</tr>
<tr>
<td>Dysplastic (congenital)</td>
<td></td>
<td></td>
<td>• Lumbar brace</td>
</tr>
<tr>
<td>Isthmic (#1, L5-S1, hyperextension)</td>
<td></td>
<td></td>
<td>• Surgery uncommon without advanced spondylolisthesis</td>
</tr>
<tr>
<td>Degenerative (elderly)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traumatic (acute pars fx)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pathologic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-surgical</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### SPONDYLOLISTHESIS

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defect or fracture of pars interarticularis (without slip)</td>
<td>Insidious onset of low back pain, worse with activities</td>
<td>L-spine obliques “Scottie dog has a collar/neck”</td>
<td>• Rest, activity modification</td>
</tr>
<tr>
<td>Assoc. w/ hyperextension sports (gymnasts, linemen)</td>
<td></td>
<td></td>
<td>• Physical therapy; esp. stretching, flexion exercises</td>
</tr>
<tr>
<td>Common in pediatrics</td>
<td></td>
<td></td>
<td>• Lumbar brace</td>
</tr>
<tr>
<td>L5 most common site</td>
<td></td>
<td></td>
<td>• Surgery uncommon without advanced spondylolisthesis</td>
</tr>
</tbody>
</table>

**DESCRIPTION** Hx & PE WORKUP TREATMENT

**SPONDYLOLISTHESIS**

**Low grade (1-2):**
- • Rest, activity modification
- • Physical therapy
- • Lumbar bracing

**High grade (3-4):**
- Peds: prophylactic posterior lateral (PL) fusion
- Adults: decompression and PL fusion
**DESCRIPTION** | **EVALUATION** | **TREATMENT**
---|---|---
**MYELODYSPLASIA**
- Incomplete spinal cord development (neural tube closure defect)
- 4 types depending on severity
- Associated w/elevated maternal AFP
- Prenatal folic acid decreases incidence
- Associated with multiple deformities (spine, hips, knees, and feet)
- Often associated with latex allergy

Hx: Can be diagnosed intrauterine
PE/XR: Based on type of defect:
  1. Spina bifida
  2. Meningocele
  3. Myelomeningocele
  4. Rachischisis
Symptoms/exam based on lowest functional level (intact L4 allows for ambulation)

- Must individualize for each patient
- Most need ambulation aids and/or orthoses
- Muscle balancing (releases)
- Individual deformities
  - Scoliosis: most need fusion
  - Hips: keep them contained
  - Feet: release or arthrodesis

**SCOLIOSIS**
- Lateral bending & rotation of the spine
- Types:
  - I. Congenital (abnormal vertebrae)
  - II. Idiopathic: #1, often + fam hx;
  - Infantile: <3y.o., M>F;
  - Juvenile: 3-10y.o.;
  - Adolescent: #1, F>M, R>L;
  - III. Neuromuscular: associated with neuromuscular disease
- Curve progression evaluated by:
  - Curve magnitude: x-ray/Cobb angle
  - Skeletal maturity: use Risser stage
  - Classifications: King & Moe, Lenke

Hx: Patient or parents may notice asymmetry of back; found on school screening; +/- pain; neuro sx rare
PE: Gross or subtle spinal deformity, + forward bending test; neurologic findings rare (increased with left-sided curves)
XR: Full length spinal films: use Cobb technique to determine angle
Bending films used to determine flexibility of the curve/deformity

- School screening is effective
- Congenital: progression & need for surgery depend on severity/type
- Idiopathic: depends on curve & age
  - <25°: observation
  - 25-40°: bracing
  - >40°: spinal fusion
- Juvenile type often needs fusion
- Neuromuscular: often require longer fusions, both anterior & posterior

**TORTICOLLIS**
- Head tilted, chin rotated opposite side
- Sternocleidomastoid (SCM) contracture
- Etiology unknown
- Associated with intrauterine position
- Associated with other disorders

Hx: Parents notice deformity, +/- lump in the neck (on sternocleido-mastoid)
PE: Head tilted/rotated, +/- SCM lump. +/- cranial and/or facial asymmetry
XR: Spine/hips: t/o other deformities

- Rule out any associated disorders
- Physical therapy/stretching (SCM)
- Helmet may be needed for cranium
- Surgical release if persistent
- Poor eye development is concern
**Anterior Approach to Cervical Spine**

Transverse incisions at desired level (left side preferred)

Prevertebral fascia (opened)
Intervertebral disc
Vertebral body
Longus colli (retracted)
Esophagus (retracted)
Trachea (retracted)

**USES**
- Anterior cervical disectomy & fusion (ACDF) for cervical spondylosis and/or HNP
- Tumor or biopsy

**SUPERFICIAL**
- Deep cervical fascia: SCM goes lateral
- Pretracheal fascia: carotid sheath goes lateral

**DEPTH**
- Prevertebral fascia between longus colli muscles (right & left)

**DANGERS**
- Recurrent laryngeal n.
- Sympathetic n.
- Carotid artery
- Internal jugular
- Vagus nerve
- Inferior thyroid artery

**COMMENT**
- Access C3 to T1
- Right recurrent laryngeal nerve more susceptible to injury; many surgeons approach on left side
- Thyroid arteries limit extension of the approach
**Surgical Approaches**

### Cervical Spine

- **Uses**: Posterior fusion/spondylosis, Facet dislocation.
- **Internervous Plane**: Left and right paracervical muscles (posterior cervical rami).
- **Dangers**: Spinal cord, Nerve roots, Posterior rami, Vertebral artery, Segmental vessels.
- **Comment**: Most common C-spine approach. Mark level of pathology with radiopaque marker preop to assist finding the appropriate level intraoperatively.

### Lumbar Spine

- **Uses**: Herniated disc (HNP)/nerve compression & diskectomy, Lumbar fusion.
- **Internervous Plane**: Left and right paraspinal muscles (dorsal rami).
- **Dangers**: Segmental vessels to paraspinals.
- **Comment**: Incision is along the spinous processes.
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### STRUCTURE

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<th>Structure</th>
<th>Clinical Application</th>
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<tr>
<td>Sternoclavicular (SC) joint</td>
<td>Uncommon site of infection or dislocation</td>
</tr>
<tr>
<td>Clavicle</td>
<td>Subcutaneous bone: most common bone to fracture</td>
</tr>
<tr>
<td>Acromioclavicular (AC) joint</td>
<td>Common site of “shoulder separation” or degenerative joint disease/pain</td>
</tr>
<tr>
<td>Acromion</td>
<td>Landmark of shoulder (especially for injections, e.g., subacromial)</td>
</tr>
<tr>
<td>Deltoid muscle</td>
<td>Can test muscle function for axillary nerve motor function</td>
</tr>
<tr>
<td>Trapezius</td>
<td>Common site of pain; weakness results in lateral scapular winging</td>
</tr>
<tr>
<td>Serratus anterior</td>
<td>Weakness/palsy results in medial scapular winging</td>
</tr>
<tr>
<td>Pectoralis major</td>
<td>Can rupture off humeral insertion, results in a defect in the axillary fold</td>
</tr>
<tr>
<td>Cephalic vein</td>
<td>Lies in the deltopectoral interval</td>
</tr>
<tr>
<td>Spine of scapula</td>
<td>More prominent with supra/infraspinatus muscle wasting (suprascapular nerve palsy)</td>
</tr>
<tr>
<td>Inferior angle of scapula</td>
<td>May “wing” medially or laterally if muscles are weak (nerve palsies)</td>
</tr>
</tbody>
</table>

**Sternocleidomastoid muscle**

**Acromioclavicular joint**

**Sternoclavicular joint**

**Deltoid muscle**

**Cephalic vein**

**Serratus anterior muscle**

**Trapezius muscle**

**Spine of scapula**

**Infraspinatus muscle**

**Teres major muscle**

**Latissimus dorsi muscle**

**Triceps brachii muscle**

**Biceps brachii muscle**

**Anterior axillary fold**

**Posterior axillary fold (pectoralis major)**

**Pectoralis major muscle**

**Clavicular head**

**Sternal head**

**Axilla**

**Inferior angle of scapula**

**Medial border of scapula**

**Triangle of auscultation**

**Clavicle**

**Trapezius**

**Serratus anterior**

**Pectoralis major**

**Cephalic vein**

**Spine of scapula**

**Inferior angle of scapula**

**Triangle of auscultation**
OSTEOLOGY • Shoulder

**SCAPULA**

- Flat, triangular bone
- Spine posteriorly separates two fossae (supra/infraspinatus)
- Two notches
- Coracoid process anteriorly
- Glenoid: pear shaped
- Acromion: hook-shaped lateral prominence

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<tr>
<th>CHARACTERISTICS</th>
<th>OSSIFY</th>
<th>FUSE</th>
<th>COMMENTS</th>
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</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
<td>Body</td>
<td>8wk fetal</td>
<td>15-20yr</td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
<td>Coracoid</td>
<td>1yr</td>
<td>All fuse between</td>
</tr>
<tr>
<td></td>
<td>Glenoid</td>
<td>15-18yr</td>
<td>15-20yr</td>
</tr>
<tr>
<td></td>
<td>Acromion</td>
<td>15-18yr</td>
<td>15-20yr</td>
</tr>
<tr>
<td></td>
<td>Inferior angle</td>
<td>15-18yr</td>
<td>15-20yr</td>
</tr>
</tbody>
</table>

- Suprascapular nerve can be compressed in suprascapular notch (dener-vates SS & IS) or in the spinoglenoid notch (dener-vates IS only)
- Coracoid is the “lighthouse” to the shoulder
- Glenoid: 5–7° retroverted, 5° superior tilt
- Unfused acromion results in os acromiale
- Body of scapula is very thin, angle is thicker

**PROXIMAL HUMERUS**

- Head is retroverted: 35°
- Anatomic and surgical necks
- Head/neck angle: 130°
- Two tuberosities: Greater is lateral, Lesser is anterior
- Bicipital groove between gtr and lsr tuberosities: bicep tendon

<table>
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<tr>
<th>CHARACTERISTICS</th>
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<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
<td>Shaft</td>
<td>8-9wk fetal</td>
<td>Birth</td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
<td>Proximal (3): Head</td>
<td>Birth</td>
<td>17-20yr</td>
</tr>
<tr>
<td></td>
<td>Gtr tuberosity</td>
<td>1-2yr</td>
<td>17-20yr</td>
</tr>
<tr>
<td></td>
<td>Lsr tuberosity</td>
<td>3-4yr</td>
<td>17-20yr</td>
</tr>
</tbody>
</table>

- Anatomic neck fx site: risk for osteonecrosis
- Surgical neck: common fx site (especially in the elderly)
- 80% of bone growth from proximal physis; proximal fx in children have great remodeling potential
- Greater tuberosity: insertion site of supraspinatus, infraspinatus, teres minor
- Lesser tuberosity: insertion site of subscapularis
**CHARACTERISTICS**  
**OSSIFY**  
**FUSE**  
**COMMENTS**

<table>
<thead>
<tr>
<th>CLAVICLE</th>
</tr>
</thead>
</table>
| • S-shaped cylindrical bone | Primary (2)  
| • Middle ⅓ is narrowest, no muscle insertions | Medial & lateral  
| • Clavicle widens laterally | 7wk fetal  
| • No true medullary canal | 9wk fetal |  
| | Secondary  
| | Sternal  
| | 18-20yr  
| | Acromial  
| | 18-20yr  
| | 19-22yr |  
| | Only link from upper extremity to axial skeleton  
| | Most commonly fractured bone in body; middle ⅓ is most common location of fracture (80%)  
| | First bone to ossify, last to fuse  
| | Starts as intramembranous, then finishes as membranous ossification |
### Radiography Techniques and Findings in Shoulder Imaging

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<tr>
<th><strong>Radiograph</strong></th>
<th><strong>Technique</strong></th>
<th><strong>Findings</strong></th>
<th><strong>Clinical Application</strong></th>
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<tr>
<td><strong>Clavicle</strong></td>
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<td></td>
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<tr>
<td>Clavicle (2 view)</td>
<td>AP w/caudal &amp; cephalic tilt</td>
<td>Clavicle</td>
<td>Fracture, DJD of ACJ</td>
</tr>
<tr>
<td>Zanca</td>
<td>AP (of ACJ) w/10° cephalic tilt</td>
<td>Acromioclavicular joint</td>
<td>ACJ pathology (DJD, fx)</td>
</tr>
<tr>
<td>Stress views</td>
<td>Both ACJs w/out weights</td>
<td>Acromioclavicular joints</td>
<td>ACJ separation/instability</td>
</tr>
<tr>
<td>Serendipity</td>
<td>40° cephalic tilt manubrium</td>
<td>Sternoclavicular joint</td>
<td>Sternoclavicular pathology</td>
</tr>
<tr>
<td><strong>Shoulder</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>Plate perpendicular to scapula</td>
<td>Glenohumeral joint space</td>
<td>Trauma (fx/dx), arthritis</td>
</tr>
<tr>
<td>Axillary lateral</td>
<td>Abduct arm, beam into axilla</td>
<td>Glenoid/humeral head position</td>
<td>Dislocations, Hill-Sachs lesion</td>
</tr>
<tr>
<td>Scapular Y</td>
<td>Beam parallel to scapula</td>
<td>Humeral head position</td>
<td>Trauma, acromion type</td>
</tr>
<tr>
<td>Supraspinatus outlet</td>
<td>Scapular Y w/10° caudal tilt</td>
<td>Acromion morphology</td>
<td>Hooked acromion (type 3) is assoc. w/ impingement synd.</td>
</tr>
<tr>
<td>Stryker notch</td>
<td>Hand on head, 10° cephalic tilt</td>
<td>Humeral head</td>
<td>Hill-Sachs lesion</td>
</tr>
<tr>
<td>West point</td>
<td>Prone, beam into axilla</td>
<td>Anterior inferior glenoid</td>
<td>Bony Bankart lesion</td>
</tr>
<tr>
<td><strong>Other Studies</strong></td>
<td></td>
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</tr>
<tr>
<td>CT</td>
<td>Axial, coronal, sagittal</td>
<td>Articular congruity, fx fragment position</td>
<td>Fractures (esp. proximal humerus, glenoid/intraarticular)</td>
</tr>
<tr>
<td>MRI</td>
<td>Sequence protocols vary</td>
<td>Soft tissues (tendons, labrum)</td>
<td>Rotator cuff or labral tears</td>
</tr>
</tbody>
</table>
**Shoulder • TRAUMA**

---

**Fractures of lateral third of clavicle**

**Type I.** Fracture with no disruption of ligaments and therefore no displacement. Treated with simple sling for few weeks.

**Type IIA.** Fracture is medial to ligaments. Both ligaments are intact.

**Type IIB.** Fracture is between ligaments; coroid is disrupted, trapezoid is intact. Medial fragment may elevate.

**Type III.** Fracture through acromioclavicular joint; no displacement. Often missed and may later cause painful osteoarthritis requiring resection arthroplasty.

---

**DESCRIPTION** | **EVALUATION** | **CLASSIFICATION** | **TREATMENT**
---|---|---|---

**CLAVICLE FRACTURE**

- **Most common fx**
- **60% in middle third** (group 1)
- **15% group 2, 5% group 3**
- **Mechanism:** fall onto shoulder (e.g., football, hockey)
- **Clavicle is unfused until early 20’s, periosteal sleeve avulsion fx can result distally**

- **Hx:** Trauma/fall, pain
- **PE:** Swelling, tenderness. +/- tenting of skin/clinical deformity; do thorough neurovascular exam
- **XR:** 2 views of clavicle (evaluate for shortening)
- **CT:** Rarely needed

- **Group 1: middle 1/3**
- **Group 2: distal 1/3**
  - **Type 1:** lateral to CC ligaments
  - **Type 2a:** medial to CC ligaments
  - **Type 2b:** between CC ligaments (conoid torn, trapezoid intact)
  - **Type 3:** fx into ACJ
  - **Group 3: proximal 1/3**

- **Closed treatment/sling for most groups 1 & 3 fxs**
- **ORIF for fxs severely shortened, tented, open, associated with vascular injuries**
- **ORIF for most group 2/type 2 distal fxs**

**COMPLICATIONS:** Nonunion (esp. distal/group 2 fx); vascular or nerve injury

---

**SCAPULA FRACTURE**

- **Mechanism:** high-energy trauma
- **Uncommon injury**
- **Young males most common**
- **>85% have associated injuries:** pulmonary contusion, pneumothorax
- **Good healing potential provided by surrounding muscles**

- **Hx:** Trauma (e.g., MVA), pain in back and/or shoulder
- **PE:** Swelling, tenderness to palpation, decreased ROM
- **XR:** AP/axillary lateral/scapular Y; CXR
- **CT:** Intraarticular/glenoid fractures, displaced body fractures

- **Anatomic classification:** A-G
  - **Type I:** anterior avulsion fx
  - **Type II:** transverse/oblique fx through glenoid; exits inferiorly
  - **Type III:** oblique fx through glenoid, exits superiorly
  - **Type IV:** transverse fx exits through the scapula body
  - **Type V:** types II + IV

- **Closed treatment with sling for 2wk for most fxs, then early ROM**
- **ORIF for displaced, unstable, or large (>25%) intraarticular or angulated neck fxs**

**COMPLICATIONS:** Associated injuries: Rib fracture #1, pulmonary contusion, pneumothorax, vascular or brachial plexus
ACROMIOCLAVICULAR SEPARATION

**DESCRIPTION**
- Mechanism: fall onto shoulder (e.g., football, bicycles, etc)
- Progression from isolated AC ligament injury to combined AC and CC (coracoclavicular) ligament disruption with varying clavicle displacement
- Aka “shoulder separation”

**EVALUATION**
- Hx: Fall/direct blow, pain, swelling, +/- popping
- PE: AC tenderness, +/- instability & deformity
- XR: AC joint (+/- stress views, esp. grade I) (measure CC distance)
- MR: Evaluate CC ligaments

**CLASSIFICATION**
- Rockwood grade:
  - I: AC ligament sprain
  - II: AC tear, CC intact
  - III: AC & CC ligament tears ≤ 100% superior displacement
  - IV: Grade III w/posterior displacement
  - V: Grade III ≤ 300% superior displacement
  - VI: Grade III w/ inferior displacement

**TREATMENT**
- Grades I & II: sling, rest, physical therapy
- Grade III: controversial. Nonoperative for most, CC reconstruction for high-level athletes & laborers
- Grades IV-VI: CC ligament reconstruction

**COMPLICATIONS:** AC arthrosis/DJD; stiffness; associated injuries (pneumothorax, fracture, neurapraxia)
Anterior Dislocation

Anteroposterior radiograph
Anterior dislocation
(most common)

Posterior Dislocation

Anteroposterior radiograph.
Difficult to determine if humeral head within, anterior, or posterior to glenoid cavity.

Lateral radiograph (parallel to plane of body of scapula). Humeral head clearly seen to be posterior to glenoid cavity.

True axillary view. Also shows humeral head posterior to glenoid cavity.

**DESCRIPTION**

- Most common dislocation
- Common in young/athletic patients (recurrence >90% if <25y.o.)
- Associated w/ labral tears (<40y.o.) and rotator cuff tears (>40y.o.)
- Associated w/ fxs: tuberosity or glenoid rim ("bony Bankart")
- Posterior dislocations associated w/ seizures
- Humeral head impression fracture (Hill-Sachs lesion) can occur

**EVALUATION**

Hx: Trauma/fall, pain, inability to move arm
PE: “Flattened” shoulder, no ROM, test axillary nerve function
XR: 3-view shoulder; must have axillary lateral for posterior dislocation
CT: To evaluate fxs: tuberosity or glenoid

**CLASSIFICATION**

Anatomic (based on location of humeral head):
- Anterior (>90%)
- Posterior (often missed)
- Inferior (luxatio erecta: abducted arm cannot be lowered [rare])
- Superior (extremely rare)

**TREATMENT**

- Acute: reduce dislocation
- Methods (with sedation):
  - Hippocratic/traction
  - Stimson
  - Milch
- Scapular retraction
- Immobilize: sling for 2wk
- Physical therapy
- ORIF of displaced fxs
- Consider early labral repair in young patients

**COMPLICATIONS:** Recurrent dislocation/instability (esp. in young/<25y.o.); nerve injury (axillary, musculocutaneous)
Reduction of Anterior Dislocation of Glenohumeral Joint

**Stimson maneuver**
Patient prone on table with affected limb hanging freely over edge; 10–15-lb weight suspended from wrist. Gradual traction overcomes muscle spasm and in most cases achieves reduction in 20–25 minutes.

**Milch maneuver**
Patient supine; steady downward traction applied at elbow, combined with slow, gradual external rotation and abduction of limb.

**Hippocratic maneuver**
Patient supine on table. Examiner places sole of foot (shoe removed) against patient’s axillary fold for countertraction, grasps patient’s wrist with both hands, and applies steady longitudinal traction. Ancient but occasionally useful method.
Neer four-part classification of fractures of proximal humerus:
1. Articular fragment (humeral head).
2. Lesser tuberosity.
3. Greater tuberosity.
4. Shaft. If no fragments displaced, fracture considered stable (most common) and treated with minimal external immobilization and early range-of-motion exercise.

### Neer Classification of Proximal Humerus Fractures

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<tr>
<th>2 Part</th>
<th>3 Part</th>
<th>4 Part</th>
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<td>Anatomical neck</td>
<td>Surgical neck</td>
<td>Greater tuberosity</td>
</tr>
<tr>
<td>Greater tuberosity</td>
<td>Greater tuberosity</td>
<td>Greater and lesser tuberosities</td>
</tr>
<tr>
<td>Lesser tuberosity</td>
<td>Lesser tuberosity</td>
<td></td>
</tr>
</tbody>
</table>

**DESCRIPTION**
- Common fx, esp. in elderly/osteoporotic patients
- Proximal humeral cancellous bone is susceptible to fx
- Muscular attachments determine displacement pattern
- Most are minimally displaced/1-part fx
- Associated with rotator cuff tears

**EVALUATION**
- Hx: Trauma/fall, pain, difficult to move arm
- PE: Humeral tenderness, decreased ROM, +/- deformity
- XR: 3-view shoulder
- CT: Identify fragments and displacement

**CLASSIFICATION**
- Neer: based on number of parts (fragments)
  - Parts (4): head, GT, LT, shaft
  - Fragment must be >1cm displaced or 45° angulation to be considered a “part”
  - Multiple combinations of fragments/parts possible

**TREATMENT**
- 1 part: sling, early motion
- 2 part: closed reduction & coaptation splint, then PT
- 3 part: operative: PCP vs ORIF (locking plate)
- 4 part: ORIF vs hemi-arthroplasty

**COMPLICATIONS:** Shoulder stiffness, AVN (anatomic neck fractures), nerve injury (axillary, brachial plexus), nonunion
The shoulder is made up of 4 separate articulations. Shoulder motion is a combined movement from all 4 articulations: 1. Sternoclavicular joint, 2. Glenohumeral joint, 3. Acromioclavicular joint, 4. Scapulothoracic articulation. The shoulder joint has the most range of motion in the body.

- **Forward flexion:** 0-170°
- **Extension:** 0-60°
- **Abduction:** 0-170°/180°
- **Internal rotation:** to thoracic spine
- **External rotation:** up to 70°

A 2:1 ratio of glenohumeral joint to scapulothoracic articulation motion during shoulder abduction.

Inherently unstable joint with huge ROM potential. Static and dynamic stabilizers give joint stability.

- Static: glenoid, labrum, articular congruity, glenohumeral ligaments & capsule, negative intraarticular pressure
- Dynamic: rotator cuff muscles/tendons, biceps tendon, scapular stabilizers (periscapular muscles), proprioception

Shallow glenoid "socket" gives minimal bony stability, but is deepened/stabilized by the fibrocartilaginous labrum. Labrum serves as a "bumper"/stop to humeral subluxation, as well attachment site for capsuloligamentous structures. Joint instability can result from labral tear/detachment with loss of "bumper" and resultant ligamentous laxity.

Rotator cuff: confluent "horseshoe-" shaped insertion of 4 stabilizing muscle tendons inserting on the proximal humerus (greater & lesser tuberosities). RC muscles actively keep humeral head seated into glenoid during all motions.

### Sternoclavicular Joint

Diarthrodial/double gliding joint. Only true attachment of upper extremity to axial skeleton. ROM: clavicle rotates in joint up to 50° on the fixed sternum.

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<th>LIGAMENT</th>
<th>ATTACHMENTS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SHOULDER JOINTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The shoulder is made up of 4 separate articulations. Shoulder motion is a combined movement from all 4 articulations: 1. Sternoclavicular joint, 2. Glenohumeral joint, 3. Acromioclavicular joint, 4. Scapulothoracic articulation. The shoulder joint has the most range of motion in the body.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Forward flexion: 0-170°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Extension: 0-60°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Abduction: 0-170°/180°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Internal rotation: to thoracic spine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• External rotation: up to 70°</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2:1 ratio</strong> of glenohumeral joint to scapulothoracic articulation motion during shoulder abduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inherently unstable joint with huge ROM potential. Static and dynamic stabilizers give joint stability.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Static: glenoid, labrum, articular congruity, glenohumeral ligaments &amp; capsule, negative intraarticular pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Dynamic: rotator cuff muscles/tendons, biceps tendon, scapular stabilizers (periscapular muscles), proprioception</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shallow glenoid &quot;socket&quot; gives minimal bony stability, but is deepened/stabilized by the fibrocartilaginous labrum. Labrum serves as a &quot;bumper&quot;/stop to humeral subluxation, as well attachment site for capsuloligamentous structures. Joint instability can result from labral tear/detachment with loss of &quot;bumper&quot; and resultant ligamentous laxity.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotator cuff: confluent &quot;horseshoe-&quot; shaped insertion of 4 stabilizing muscle tendons inserting on the proximal humerus (greater &amp; lesser tuberosities). RC muscles actively keep humeral head seated into glenoid during all motions.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Sternoclavicular Joint

Diarthrodial/double gliding joint. Only true attachment of upper extremity to axial skeleton. ROM: clavicle rotates in joint up to 50° on the fixed sternum.

<table>
<thead>
<tr>
<th>LIGAMENT</th>
<th>ATTACHMENTS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capsule</strong></td>
<td>Surrounds joint</td>
<td>Secondary stabilizer</td>
</tr>
<tr>
<td><strong>Sternoclavicular</strong></td>
<td>Medial clavicle to sternum</td>
<td>Primary stabilizer of sternoclavicular joint</td>
</tr>
<tr>
<td></td>
<td>Anterior and posterior ligaments</td>
<td>Posterior stronger, anterior dislocation more common</td>
</tr>
<tr>
<td><strong>Costoclavicular</strong></td>
<td>Inferior clavicle to costal cartilage</td>
<td>Strongest sternoclavicular ligament</td>
</tr>
<tr>
<td><strong>Interclavicular</strong></td>
<td>Between medial ends of clavicle</td>
<td>Secondary stabilizer</td>
</tr>
<tr>
<td><strong>Disc</strong></td>
<td>Intraarticular disc</td>
<td>Fibrocartilage disc within the joint</td>
</tr>
</tbody>
</table>

### Scapulothoracic Articulation

The articulation is not an actual joint. Scapula slides/rotates along posterior ribs (2-7). Multiple muscles (including serratus anterior and trapezius) are involved. 2:1 ratio of GHJ to scapulothoracic motion during flexion & abduction.
### Shoulder • Joints

**Coronal section through joint**

- Acromion
- Synovial membrane
- Glenohumeral ligament (SGHL)
- Subdeltoid bursa
- Supraspinatus tendon
- Deltoid muscle
- Glenoid cavity of scapula
- Axillary recess (pouch)

**Joint opened: lateral view**

- Supraspinatus tendon (fused to capsule)
- Subdeltoid bursa
- Infraspinatus tendon (fused to capsule)
- Glenoid cavity (cartilage)
- Teres minor tendon (fused to capsule)
- Synovial membrane
- Posterior band
- Openings of subtendinous bursa of subscapularis

**MRI axial, shoulder**

- **Key**
  - G Greater tuberosity
  - L Lesser tuberosity
  - h Humeral head
  - * Subscapularis tendon
  - # Subscapularis
  - s Subscapularis
  - g Glenoid
  - a Anterior labrum
  - + Anterior labrum
  - + Anterior labrum

**MRI coronal, shoulder**

- **Key**
  - D Deltoid
  - s Supraspinatus
  - + Supraspinatus tendon
  - a Acromion
  - G Greater tuberosity
  - + Superior labrum
  - g Glenoid

### Glenohumeral Joint

Spheroidal ("ball & socket") joint. Inherently unstable joint stabilized by dynamic and static restraints.

#### Glenohumeral Ligaments

<table>
<thead>
<tr>
<th>Ligament</th>
<th>Attachments</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior (SGHL)</td>
<td>Anterosuperior glenoid rim/labrum to proximal lesser tuberosity</td>
<td>Resists inferior translation &amp; ER in shoulder adduction; Resists posterior translation in 90° of forward flexion</td>
</tr>
<tr>
<td>Middle (MGHL)</td>
<td>Anterosuperior glenoid rim/labrum (inferior to SGHL) to just medial to lesser tuberosity</td>
<td>Resists anteroposterior translation in 45° of abduction; Secondary restraint to translation &amp; ER in adduction; Buford complex: thickened MGHL &amp; absent anterior/superior labrum</td>
</tr>
<tr>
<td>Inferior (IGHL)</td>
<td>Most important ligament, forms sling that tightens in abduction &amp; ER (ant. band)/IR (post. band)</td>
<td>Resists anterior &amp; inferior translation in abduction &amp; ER; Must be tightened/&quot;shifted&quot; in anterior instability or MDI</td>
</tr>
<tr>
<td>- Anterior band</td>
<td>Anterior glenoid/labrum (3 o'clock) to inferior humeral neck</td>
<td>Resists posterior translation in IR &amp; 90° flexion</td>
</tr>
<tr>
<td>- Posterior band</td>
<td>Posterior glenoid/labrum (9 o'clock) to inferior humeral neck</td>
<td></td>
</tr>
</tbody>
</table>

#### Other

- **Coracohumeral (CHL)**
  - Coracoid base to both LT and GT (either side of bicipital groove)
  - With SGHL, resists inferior translation in adduction; part of pulley to stabilize biceps tendon in joint and groove

- **Labrum**
  - Circumferentially attached to glenoid
  - Fibrocartilage: deepens glenoid, provides more contact area, adds stability; insertion site for some GH ligaments

- **Capsule**
  - Surrounds joint
  - Maintains intraarticular negative pressure, thin posteriorly

**Ligament Attachments Comments**

- **Glenohumeral Joints**
- Spheroidal (“ball & socket”) joint. Inherently unstable joint stabilized by dynamic and static restraints.
- **Glenohumeral Ligaments**
  - Superior (SGHL): Anterosuperior glenoid rim/labrum to proximal lesser tuberosity. Resists inferior translation & ER in shoulder adduction; Resists posterior translation in 90° of forward flexion.
  - Middle (MGHL): Anterosuperior glenoid rim/labrum (inferior to SGHL) to just medial to lesser tuberosity. Resists anteroposterior translation in 45° of abduction; Secondary restraint to translation & ER in adduction; Buford complex: thickened MGHL & absent anterior/superior labrum.
  - Inferior (IGHL): Most important ligament, forms sling that tightens in abduction & ER (ant. band)/IR (post. band). Resists anterior & inferior translation in abduction & ER; Must be tightened/"shifted" in anterior instability or MDI.
  - Anterior and Posterior bands: Resists posterior translation in IR & 90° flexion.

**Other**

- **Coracohumeral (CHL):** Coracoid base to both LT and GT (either side of bicipital groove). With SGHL, resists inferior translation in adduction; part of pulley to stabilize biceps tendon in joint and groove.

- **Labrum:** Circumferentially attached to glenoid. Fibrocartilage: deepens glenoid, provides more contact area, adds stability; insertion site for some GH ligaments.

- **Capsule:** Surrounds joint. Maintains intraarticular negative pressure, thin posteriorly.

- **Glenohumeral ligaments:** Discrete thickenings of anterior and inferior capsule that provide stability to the joint. There are no ligaments posteriorly or superiorly.
- **Rotator interval:** Triangular space between anterior border of supraspinatus and superior border of subscapularis.
  - Contents: SGHL, CHL, and biceps tendon, anterosuperior glenohumeral capsule.
  - Tightening of this interval can decrease the inferior translation in adduction/"sulcus sign" in the unstable shoulder.
- **Biceps pulley:** SGHL, CHL, subscapularis form an anterior pulley to keep biceps tendon located in joint/bicipital groove.
**ACROMIOCLAVICULAR JOINT**

- **Ligament Attachments**
  - **Coracoacromial ligament**
  - **Supraspinatus tendon (cut)**
  - **Coracoacromial ligament**
  - **Greater tubercle and Lesser tubercle of humerus**
  - **Intertubercular (bicipital) tendon sheath (communicates with synovial cavity)**
  - **Subscapularis tendon (cut)**
  - **Biceps brachii tendon (long head)**

- **Coracoclavicular ligament**
  - **Conoid**
  - **Trapezoid**

- **Disc**
  - In joint, between clavicle & acromion

- **Capsule**
  - Surrounds joints
  - Weak stabilizer, but sufficient under routine loads

- **Acromioclavicular**
  - Thickening of superior capsule
  - Provides anterior to posterior stability and axial stability
  - Injured (to some degree) in all AC separations

- **Coracoclavicular**
  - Coracoid base to inferior clavicle
  - Posteromedial insertion on clavicle
  - Anterolateral insertion on clavicle
  - Provides vertical stability to the clavicle at the AC joint
  - Stronger resistance to vertical load than trapezoid
  - Resists axial load to shoulder (more oblique fibers)

- **Disc**
  - In joint, between clavicle & acromion
  - Interposed to cushion partially incongruent joint

**OTHER STRUCTURES**

- **Coracoacromial**
  - Coracoid tip to anterior and inferior acromion
  - Key component of the coracoacromial arch; prevents humerus migration in rotator cuff–deficient shoulder

- **Superior transverse scapular**
  - Crosses suprascapular notch
  - Suprascapular nerve travels under ligament, suprascapular artery crosses over it

- **Transverse humeral**
  - Lesser tuberosity to greater tuberosity (crosses bicipital groove)
  - Stabilizes biceps tendon within the bicipital groove
  - Lateral aspect of rotator interval
MINOR PROCEDURES

INJECTION OF ACROMIOCLAVICULAR JOINT

1. Ask patient about allergies
2. Palpate clavicle distally to AC joint (sulcus)
3. Prep skin (iodine/antiseptic soap) over AC joint
4. Anesthetize skin with local (quarter size spot)
5. Use 25g needle, insert needle into sulcus vertically (or with slight lateral to medial tilt) and into joint. You should feel a “pop/give” as the needle enters the joint. Inject 2ml of 1:1 local/corticosteroid preparation (the joint may hold 2ml of fluid). A subcutaneous wheal indicates that the needle tip is superficial to the AC capsule.
6. Dress injection site

INJECTION OF THE SUBACROMIAL SPACE

1. Ask patient about allergies
2. Palpate the acromion: define its borders (esp. lateral border & posterolateral corner)
3. Prep skin (iodine/antiseptic soap) over acromial edge
4. Anesthetize skin with local (quarter size spot)
5. Hold finger (sterile glove) on acromion, insert needle under acromion (lateral or posterior) w/ slight cephalad tilt. Aspirate to ensure not in a vessel, then inject 5ml of preparation; will flow easily if in joint. Use: a. diagnostic injection: local only; b. therapeutic injection: local/corticosteroid
6. Dress injection site

GLENOHUMERAL INJECTION

1. Ask patient about allergies
2. Palpate the posterior shoulder for the “soft spot” (usually 2cm down, 1cm medial to posterolateral corner of the acromion). Also palpate the coracoid process on the anterior aspect of the shoulder.
3. Prepare skin (iodine/antiseptic soap) over the “soft spot” on posterior shoulder
4. Anesthetize the skin overlying the “soft spot” (quarter size spot)
5. With sterile gloves, palpate the “soft spot” and the coracoid process. Then insert the needle into the soft spot and aim it toward the coracoid process. If the needle hits bone it should be redirected (glenoid: move lateral; humerus: move medial). Aspirate to ensure not in a vessel. Inject preparation (local +/- corticosteroid) into joint (should flow easily if in the joint space)
6. Dress injection site
### Receiver athletes can develop rotator cuff tears, internal impingement, and motion abnormalities.

Shoulder instability is common in swimmers.

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>Old</td>
<td>Rotator cuff tear, impingement, arthritis (OA), adhesive capsulitis (frozen shoulder), humerus fracture (after fall) Instability, labral tear, AC injury, distal clavicle osteolysis, impingement in athletes</td>
</tr>
<tr>
<td></td>
<td>Young</td>
<td></td>
</tr>
<tr>
<td>2. Pain</td>
<td>Acute</td>
<td>Fracture, dislocation, rotator cuff tear, acromioclavicular injury</td>
</tr>
<tr>
<td>a. Onset</td>
<td>Chronic</td>
<td>Impingement, arthritis/DJD, rotator cuff tear</td>
</tr>
<tr>
<td>b. Location</td>
<td>On top/AC joint</td>
<td>AC joint arthrosis/separation</td>
</tr>
<tr>
<td>c. Occurrence</td>
<td>Night pain</td>
<td>Classic for RC tear, tumor (rare)</td>
</tr>
<tr>
<td>d. Exacerbating/relieving</td>
<td>Overhead worse</td>
<td>Rotator cuff tear, impingement</td>
</tr>
<tr>
<td></td>
<td>Overhead better</td>
<td>Cervical radiculopathy</td>
</tr>
<tr>
<td>3. Stiffness</td>
<td>Yes</td>
<td>Osteoarthritis (OA), adhesive capsulitis</td>
</tr>
<tr>
<td>4. Instability</td>
<td>“Slips in and out”</td>
<td>Dislocation (&gt;90% anterior, esp. in abduction &amp; ER (e.g., throwing), subluxation, labral tear</td>
</tr>
<tr>
<td>5. Trauma</td>
<td>Direct blow</td>
<td>Acromioclavicular (AC) injury</td>
</tr>
<tr>
<td></td>
<td>Fall on outstretched hand</td>
<td>Glenohumeral dislocation (subluxation; fracture)</td>
</tr>
<tr>
<td>6. Work/activity</td>
<td>Overhead usage</td>
<td>Rotator cuff tear</td>
</tr>
<tr>
<td></td>
<td>Weight lifting</td>
<td>Osteolysis (distal clavicle)</td>
</tr>
<tr>
<td></td>
<td>Athlete: throwing type</td>
<td>RC tear/impingement (internal), instability (swimmer’s)</td>
</tr>
<tr>
<td></td>
<td>Long-term manual labor</td>
<td>Arthritis (OA)</td>
</tr>
<tr>
<td>7. Neurologic sx</td>
<td>Numbness/tingling/“heavy”</td>
<td>Thoracic outlet syndrome, brachial plexus injury</td>
</tr>
<tr>
<td>8. PMHx</td>
<td>Cardiopulmonary/GI</td>
<td>Referred pain to shoulder</td>
</tr>
</tbody>
</table>
Clinical appearance: glenohumeral dislocation

- Acromion prominent
- Shoulder flattened
- Humeral head prominent
- Arm in slight abduction
- Elbow flexed
- Forearm internally rotated, supported by other hand

Both shoulders must be undressed to examine the shoulder.

Rupture of tendon of long head of right biceps brachii muscle indicated by active flexion of elbow

- AC joint
- Supraspinatus
- Bicipital groove

Careful palpation helps isolate the location of the patient’s pain.

**EXAM/OBSERVATION** | **TECHNIQUE** | **CLINICAL APPLICATION**
--- | --- | ---
**INSPECTION**
Both shoulders must be undressed for proper inspection and examination of the shoulder.
Symmetry | Compare both sides | Acromioclavicular separation, dislocation, muscle atrophy
Wasting | Loss of contour/muscle mass | RC tear, nerve compression (e.g., suprascapular)
Gross deformity | Superior displacement | Acromioclavicular injury (separation)
Gross deformity | Anterior displacement | Anterior dislocation (glenohumeral joint)
Gross deformity | “Popeye” arm | Biceps tendon rupture (usually proximal end of long head)

**PALPATION**
AC joint | Feel for end of clavicle | Pain indicates acromioclavicular pathology, instability of distal clavicle, AC separation
Supraspinatus tendon | Feel acromion, down to acromio-humeral sulcus | Pain indicates bursitis and/or supraspinatus tendon (rotator cuff) tear
Greater tuberosity | Prominence on lateral humeral head | Pain indicates rotator cuff tendinitis, tear, or fx
Biceps tendon/bicipital groove | Feel tendon in groove on humerus | Pain indicates biceps tendinitis
**PHYSICAL EXAM • Shoulder**

### RANGE OF MOTION

<table>
<thead>
<tr>
<th>EXAM/OBSERVATION</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward flexion</td>
<td>Arms from sides forward</td>
<td>0-160°/180° normal</td>
</tr>
<tr>
<td>Extension</td>
<td>Arms from sides backward</td>
<td>0-60° normal</td>
</tr>
<tr>
<td>Abduction</td>
<td>Arms from sides outward</td>
<td>0-160°/180° normal</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>Reach thumb up back, note level</td>
<td>Mid thoracic (T7) normal, compare sides</td>
</tr>
<tr>
<td>External rotation</td>
<td>1. Elbow at side, rotate forearms laterally</td>
<td>30-60° normal, ER decreased in adhesive capsulitis</td>
</tr>
<tr>
<td></td>
<td>2. Abduct arm to 90°, externally rotate up</td>
<td></td>
</tr>
</tbody>
</table>

- Rotator cuff tear: AROM decreased, PROM ok. Adhesive capsulitis: AROM and PROM are both decreased.
- Increased ER may indicate a subscapularis tear.
## Shoulder • PHYSICAL EXAM

<table>
<thead>
<tr>
<th>EXAM/OBSERVATION</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NEUROVASCULAR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sensory</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supraventricular nerve (C4)</td>
<td>Superior shoulder/clavicular area</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Axillary nerve (C5)</td>
<td>Lateral shoulder</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td>T2 segmental nerve</td>
<td>Axilla</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td><strong>Motor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinal accessory (CN11)</td>
<td>Resisted shoulder shrug</td>
<td>Weakness = Trapezius or corresponding nerve lesion</td>
</tr>
<tr>
<td>Suprascapular (C5-6)</td>
<td>Resisted abduction</td>
<td>Weakness = Supraspinatus or nerve/root lesion</td>
</tr>
<tr>
<td></td>
<td>Resisted external rotation</td>
<td>Weakness = Infraspinatus or nerve/root lesion</td>
</tr>
<tr>
<td>Axillary (C5)</td>
<td>Resisted abduction</td>
<td>Weakness = Deltoid or corresponding nerve/root lesion</td>
</tr>
<tr>
<td></td>
<td>Resisted external rotation</td>
<td>Weakness = Teres minor or nerve/root lesion</td>
</tr>
<tr>
<td>Dorsal scapular nerve (C5)</td>
<td>Shoulder shrug</td>
<td>Weakness = Levator scapulae/rhomboid or corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Thoracodorsal nerve (C7-8)</td>
<td>Resisted adduction</td>
<td>Weakness = Latissimus dorsi or nerve/root lesion</td>
</tr>
<tr>
<td>Lateral pectoral nerve (C5-7)</td>
<td>Resisted adduction</td>
<td>Weakness = Pect. major or nerve/root lesion</td>
</tr>
<tr>
<td>U/L subscapular nerve (C5-6)</td>
<td>Resisted internal rotation</td>
<td>Weakness = Subscapularis or nerve/root lesion</td>
</tr>
<tr>
<td>Long thoracic nerve (C5-7)</td>
<td>Scapular protraction/reach</td>
<td>Weakness = Serratus anterior or nerve/root lesion</td>
</tr>
</tbody>
</table>
### PHYSICAL EXAM • Shoulder

#### Test for rotator cuff tear
- **Technique:** Resisted flexion in the scapular plane.

#### Special Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Technique</th>
<th>Clinical Application/DDX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Impingement/Rotator Cuff</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impingement sign</td>
<td>Forward flexion $&gt;90^\circ$</td>
<td>Pain indicates impingement syndrome</td>
</tr>
<tr>
<td>Hawkins test</td>
<td>FF $90^\circ$, then IR</td>
<td>Pain indicates impingement syndrome</td>
</tr>
<tr>
<td>Supraspinatus/Jobe empty can</td>
<td>Pronate arm, resisted FF in scapular plane</td>
<td>Pain or weakness indicates rotator cuff (supraspinatus) tear (partial or full thickness)</td>
</tr>
<tr>
<td>Drop arm</td>
<td>FF $&gt;90^\circ$, try to maintain it</td>
<td>Inability to hold flexion (arm drops) indicates supraspinatus tear</td>
</tr>
<tr>
<td>ER lag sign</td>
<td>ER shoulder, patient holds it</td>
<td>Inability to maintain ER indicates infraspinatus tear</td>
</tr>
<tr>
<td>Horn blower’s</td>
<td>Resisted ER in slight abduction</td>
<td>Weakness indicates rotator cuff tear involving infraspinatus</td>
</tr>
<tr>
<td>Lift off</td>
<td>Hand behind back, push backward</td>
<td>Weakness indicates subscapularis tear</td>
</tr>
<tr>
<td>Lift off lag sign</td>
<td>Lift hand off back, patient holds it</td>
<td>Inability to hold hand off of low back indicates subscapularis tear</td>
</tr>
<tr>
<td>Belly press</td>
<td>Hand on belly, push toward belly</td>
<td>Weakness indicates subscapularis tear</td>
</tr>
<tr>
<td><strong>Biceps/Superior Labrum</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active compression (O’Brien’s)</td>
<td>FF $90^\circ$, adduct $10^\circ$, resisted flexion; in pronation, then supination</td>
<td>Pain with resisted flexion, greater in pronation indicates SLAP tear; may also suggest AC joint pathology</td>
</tr>
<tr>
<td>Crank</td>
<td>Abduct $90^\circ$, axial load, rotate</td>
<td>Pain indicates a SLAP tear</td>
</tr>
<tr>
<td>Speed’s test</td>
<td>Resisted flexion in scapular plane</td>
<td>Pain indicates biceps lesion or tendinitis</td>
</tr>
<tr>
<td>Yergason’s test</td>
<td>Elbow $90^\circ$, resisted supination</td>
<td>Pain indicates biceps tendinitis</td>
</tr>
<tr>
<td><strong>Instability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apprehension test</td>
<td>Abduct, externally rotate</td>
<td>Pain or apprehension of indicates anterior instability</td>
</tr>
<tr>
<td>Relocation</td>
<td>Abduct, ER, posterior force to arm</td>
<td>Relief of pain/apprehension indicates anterior instability</td>
</tr>
<tr>
<td>Load &amp; shift</td>
<td>Axial load, ant/post translation</td>
<td>Increased translation indicates anterior OR posterior instability</td>
</tr>
<tr>
<td>Jerk test</td>
<td>Supine, adduct, FF $90^\circ$, push posterior</td>
<td>Pain/apprehension/translation indicates posterior instability</td>
</tr>
<tr>
<td>Sulcus</td>
<td>Pull down on adducted arm</td>
<td>Sulcus under lateral acromion indicates inferior instability</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-body adduction</td>
<td>Adduct arm across body</td>
<td>Pain at AC joint indicates AC joint pathology (e.g., arthrosis)</td>
</tr>
<tr>
<td>Scapular winging</td>
<td>Push against a wall</td>
<td>Winging of scapula indicates nerve palsy or muscle weakness</td>
</tr>
<tr>
<td>Adson’s test</td>
<td>Palpate pulse, rotate neck</td>
<td>Numbness or tingling suggestive of thoracic outlet syndrome</td>
</tr>
<tr>
<td>Wright’s test</td>
<td>Extend arm, rotate neck away</td>
<td>Numbness or tingling suggestive of thoracic outlet syndrome</td>
</tr>
<tr>
<td>Spurling’s test</td>
<td>Lateral flex/axially compress neck</td>
<td>Reproduction of symptoms indicates cervical neck pathology</td>
</tr>
</tbody>
</table>
The scapula has 17 muscles that either originate or insert on it.

Mnemonic for proximal humerus insertions (from lateral to medial): “PLT sandwich” (Pect., Lat., Teres major)

---

**Muscles: Origins and Insertions**

<table>
<thead>
<tr>
<th>CORACOID PROCESS</th>
<th>GREATER TUBerosity</th>
<th>PROXIMAL Humerus</th>
<th>SCAPULA (ANTERIOR)</th>
<th>SCAPULA (POSTERIOR)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ORIGINS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biceps (SH)</td>
<td></td>
<td></td>
<td>Subscapularis</td>
<td>Supraspinatus</td>
</tr>
<tr>
<td>Coracobrachialis</td>
<td></td>
<td></td>
<td>Triceps brachii</td>
<td>Infraspinatus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(long head)</td>
<td>Deltoid (spine/acromion)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Infraspinatus</td>
<td>Teres major &amp; minor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Latissimus dorsi</td>
<td>Latissimus dorsi</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Teres major</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deltoid muscle</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>INSERTIONS</strong></td>
<td></td>
<td></td>
<td>Pectoralis minor</td>
<td>Trapezius (spine/acromion)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Supraspinatus</td>
<td>Levator scapulae</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Infraspinatus</td>
<td>Rhomboid major &amp; minor</td>
</tr>
<tr>
<td>Pectoralis minor</td>
<td></td>
<td></td>
<td>Serratus anterior</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Infra spinatus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Latissimus dorsi</td>
<td>Teres minor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teres major</td>
<td>Teres major</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deltoid muscle</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MUSCLES: PERISCAPULAR • Shoulder

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezius</td>
<td>C7-T12 spinous process</td>
<td>Clavicle, acromion spine of scapula</td>
<td>Cranial nerve XI</td>
<td>Elevate &amp; rotate scapula</td>
<td>Weakness results in lateral winging</td>
</tr>
<tr>
<td>Latissimus dorsi</td>
<td>T7-T12, iliac crest</td>
<td>Humerus (intertubercular groove)</td>
<td>Thoracodorsal</td>
<td>Adduct, extend arm, IR humerus</td>
<td>Used for large free flap</td>
</tr>
<tr>
<td>Levator scapulae</td>
<td>C1-C4 transverse process</td>
<td>Superior medial scapula</td>
<td>Dorsal scapular, C3-4</td>
<td>Elevate scapula</td>
<td>Connects UE to spine</td>
</tr>
<tr>
<td>Rhomboid minor</td>
<td>C7-T1 spinous process</td>
<td>Medial scapula (at the spine)</td>
<td>Dorsal scapular</td>
<td>Adduct scapula</td>
<td>Connects UE to spine</td>
</tr>
<tr>
<td>Rhomboid major</td>
<td>T2-T5 spinous process</td>
<td>Medial scapula</td>
<td>Dorsal scapular</td>
<td>Adduct scapula</td>
<td>Connects UE to spine</td>
</tr>
</tbody>
</table>
**MUSCLES: ROTATOR CUFF**

<table>
<thead>
<tr>
<th>SPACE/INTERVAL</th>
<th>BORDERS</th>
<th>STRUCTURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triangular space</td>
<td>Teres minor</td>
<td>Circumflex scapular artery</td>
</tr>
<tr>
<td></td>
<td>Teres major</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Triceps (long head)</td>
<td></td>
</tr>
<tr>
<td>Quadrangular space</td>
<td>Teres minor</td>
<td>Axillary nerve</td>
</tr>
<tr>
<td></td>
<td>Teres major</td>
<td>Posterior circumflex artery</td>
</tr>
<tr>
<td></td>
<td>Triceps (long head)</td>
<td>Humeral artery</td>
</tr>
<tr>
<td></td>
<td>Humerus (medial border)</td>
<td></td>
</tr>
<tr>
<td>Triangular interval</td>
<td>Teres major</td>
<td>Radial nerve</td>
</tr>
<tr>
<td></td>
<td>Triceps (long head)</td>
<td>Deep artery of arm</td>
</tr>
<tr>
<td></td>
<td>Triceps (lateral head)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ROTATOR CUFF</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supraspinatus</td>
<td>Supraspinatus fossa (scapula)</td>
<td>Greater tuberosity (superior)</td>
<td>Suprascapular</td>
<td>Abduct FF arm</td>
<td>Trapped in impingement, #1 torn rotator cuff tendon</td>
</tr>
<tr>
<td>Infraspinatus</td>
<td>Infraspinatus fossa (scapula)</td>
<td>Greater tuberosity (middle)</td>
<td>Suprascapular</td>
<td>ER arm, stability</td>
<td>Weak ER: cuff tear or ss nerve lesion in notch</td>
</tr>
<tr>
<td>Teres minor</td>
<td>Lateral scapula</td>
<td>Greater tuberosity (inferior)</td>
<td>Axillary</td>
<td>ER arm, stability</td>
<td>Rarely torn rotator cuff tendon</td>
</tr>
<tr>
<td>Subscapularis</td>
<td>Subscapular fossa (scapula)</td>
<td>Lesser tuberosity</td>
<td>Upper and lower subscapular</td>
<td>IR, adduct arm, stability</td>
<td>At risk from anterior approach</td>
</tr>
</tbody>
</table>

| OTHER               |                              |                                              |                  |                       |                                              |
| Deltoid             | Clavicle, acromion spine of scapula | Humerus (deltoid tuberosity)          | Axillary        | Abduct arm            | Atrophy: axillary nerve damage               |
| Teres major         | Inferior angle of the scapula | Humerus (inter-tubercular groove)         | Low subscapular  | IR, adduct arm        | Protects radial nerve in posterior approach  |
## MUSCLES: DELTOPECTORAL • Shoulder

### Oblique parasagittal section of axilla

- **Trapezius muscle**
  - **Origin**: Clavicle, acromion spine of scapula
  - **Nerve**: Axillary
  - **Action**: Abducts arm
  - **Comment**: Atrophy: axillary nerve damage

- **Pectoralis major**
  - **Origin**: 1. Clavicle, 2. Sternal
  - **Insertion**: Humerus (intertubercular groove)
  - **Nerve**: Lateral pectoral, medial pectoral
  - **Action**: Addsucts arm, IR humerus
  - **Comment**: Can rupture during weight lifting

- **Pectoralis minor**
  - **Origin**: Ribs 3-5
  - **Insertion**: Coracoid process (scapula)
  - **Nerve**: Medial pectoral
  - **Action**: Stabilizes scapula
  - **Comment**: Divides axillary artery into 3 parts

- **Serratus anterior**
  - **Origin**: Ribs 1-8 (lateral)
  - **Insertion**: Scapula (antero-medial border)
  - **Nerve**: Long thoracic
  - **Action**: Holds scapula to chest wall
  - **Comment**: Paralysis results in medial winging

- **Subclavius**
  - **Origin**: Rib 1 (and costal cartilage)
  - **Insertion**: Clavicle (inferior border/mid 3rd)
  - **Nerve**: Nerve to subclavius
  - **Action**: Depresses clavicle
  - **Comment**: Cushions subclavian vessels

---

### Anterior view

- **Trapezius muscle**
- **Omoohyoid muscle**
- **Clavicle**
- **Subclavius muscle and fascia**
- **Costocoracoid ligament**
- **Thoracoacromial artery and cephalic vein**
- **Costocoroid membrane**
- **Lateral pectoral nerve**
- **Axillary artery and vein**
- **Pectoralis major muscle and fascia**
- **Pectoralis minor muscle and fascia**
- **Medial pectoral nerve**
- **Suspensory ligament of axilla**
- **Axillary fascia (fenestrated)**

**Muscles and Nerves**

- **Supraspinatus muscle**
- **Scapula**
- **Infraspinatus muscle**
- **Subscapularis muscle**
- **Teres minor muscle**
- **Teres major muscle**
- **Latissimus dorsi muscle**
- **Axillary lymph nodes**

**Comments**

- **Brachial plexus**
  - **Lateral cord**
  - **Posterior cord**
  - **Medial cord**

**Nerves**

- **Trapezius**
- **Sternocleidomastoid**
- **Clavicular head**
- **Sternocostal head**
- **Abdominal part**

**Organs**

- **Scapula**
- **Sternum**
- **Clavicle**
- **6th costal cartilage**
- **Anterior layer of rectus sheath**

---

**Muscle Origin, Insertion, Nerve, Action, Comment**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve</th>
<th>Action</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deltoid</td>
<td>Clavicle, acromion spine of scapula</td>
<td>Humerus (deltoid tuberosity)</td>
<td>Axillary</td>
<td>Abducts arm</td>
<td>Atrophy: axillary nerve damage</td>
</tr>
<tr>
<td>Pectoralis major</td>
<td>1. Clavicle, 2. Sternal</td>
<td>Humerus (intertubercular groove)</td>
<td>Lateral pectoral, Medial pectoral</td>
<td>Addsucts arm, IR humerus</td>
<td>Can rupture during weight lifting</td>
</tr>
<tr>
<td>Pectoralis minor</td>
<td>Ribs 3-5</td>
<td>Coracoid process (scapula)</td>
<td>Medial pectoral</td>
<td>Stabilizes scapula</td>
<td>Divides axillary artery into 3 parts</td>
</tr>
<tr>
<td>Serratus anterior</td>
<td>Ribs 1-8 (lateral)</td>
<td>Scapula (antero-medial border)</td>
<td>Long thoracic</td>
<td>Holds scapula to chest wall</td>
<td>Paralysis results in medial winging</td>
</tr>
<tr>
<td>Subclavius</td>
<td>Rib 1 (and costal cartilage)</td>
<td>Clavicle (inferior border/mid 3rd)</td>
<td>Nerve to subclavius</td>
<td>Depresses clavicle</td>
<td>Cushions subclavian vessels</td>
</tr>
</tbody>
</table>
Note: Usual composition shown. Prefixed plexus has large C4 contribution but lacks T1. Postfixed plexus lacks C5 but has T2 contribution.

CRANIAL NERVES

Spinal Accessory (CN 11): Runs on levator scapulae
  Sensory: None
  Motor: Trapezius, Sternocleidomastoid

CERVICAL PLEXUS

Supraclavicular (C2-3): 3 parts: anterior, middle, posterior
  Sensory: Over trapezius, clavicle, deltoid (superior shoulder)
  Motor: None

BRACHIAL PLEXUS

Roots

Dorsal Scapular (C3-5): Pierces middle scalene, is deep to levator scapulae.
  Sensory: None
  Motor: Levator scapulae, Rhomboid major & minor

Long Thoracic (C5-7): Runs on anterior surface of serratus anterior with the lateral thoracic artery.
  Sensory: None
  Motor: Serratus anterior

Upper Trunk

Suprascapular (C5-6): Under the ligament in suprascapular notch, innervates supraspinatus, then through the spinalglenoid notch (where it can be compressed) to infraspinatus fossa (innervates infraspinatus)
  Sensory: Shoulder joint capsule
  Motor: Supraspinatus, Infraspinatus

Nerve to Subclavius (C5-6): Descends posterior to clavicle
  Sensory: None
  Motor: Subclavius

Shoulder • NERVES
NERVES • Shoulder

### BRACHIAL PLEXUS

#### Lateral Cord

**Lateral Pectoral** (C5-7): Named for the cord, runs medial to the medial pectoral nerve with the pectoral artery.

- **Sensory:** None
- **Motor:**
  - Pectoralis major (clavicular portion)
  - Pectoralis minor (via a branch to the medial pectoral n.)

| Lateral root to median nerve |

#### Medial Cord

**Medial Pectoral** (C5-7): Named for the cord, is lateral to the lateral pectoral nerve

- **Sensory:** None
- **Motor:**
  - Pectoralis minor
  - Pectoralis major (sternal portion)

| Medial root to median nerve |

#### Posterior Cord

**Upper Subscapular** (C5-6)

- **Sensory:** None
- **Motor:** Upper subscapularis

**Thoracodorsal** (C7-8): Runs with thoracodorsal artery deep to latissimus dorsi muscle

- **Sensory:** None
- **Motor:** Latissimus dorsi

**Lower Subscapular** (C5-6)

- **Sensory:** None
- **Motor:**
  - Lower subscapularis
  - Teres major

**Axillary** (C5-6): Directly inferior to joint capsule, it travels posteriorly with post. circumflex humeral art. thru quadrangular space, then bends anteriorly approx. 5cm distal to acromion. It can be injured in glenohumeral dislocations and lateral approaches.

- **Sensory:** Lateral proximal arm: via superior lateral cutaneous n.
- **Motor:**
  - Deltoid: via deep branch
  - Teres minor: via superficial branch
**NEUROVASCULAR STRUCTURES**

**BRACHIAL PLEXUS**

- Brachial ("arm") plexus ("network") is a complex of intertwined nerves that innervate the shoulder and upper extremity.
- It is derived from the ventral rami from C5-T1 (variations: C4 [prefixed], T2 [post-fixed]).
- Subdivisions: rami (roots), trunks, divisions, cords, branches (mnemonic: **Rob Taylor Drinks Cold Beer**)
- Rami exit between the anterior and **medial** scalene muscles & travel with the subclavian artery in the axillary sheath.
- The rami and trunks are supraclavicular. There are 2 nerves from the rami, and 2 nerves from the trunks (upper)
- The divisions are under (posterior to) the clavicle. Anterior divisions innervate flexors. Posteriors innervate extensors.
- The cords and branches are infraclavicular. The cords are named for their relationship with the axillary artery.
- Terminal branches of the cords are peripheral nerves to the shoulder region and upper extremity.
- Injury to the plexus can be partial or complete. Injuries affect all nerves distal to the injury (e.g., Erb’s palsy: C5-6).
Anterior view

Dorsal scapular artery
Anterior circumflex humeral artery
Suprascapular artery
Ascending branch
Posterior circumflex humeral artery
Subscapular artery
Circumflex scapular artery
Brachial artery
Thoracodorsal artery
Lateral thoracic artery

Dorsal scapular artery
Supraspinatus muscle (cut)
Superior transverse scapular ligament and suprascapular notch
Infraspinatus muscle (cut)
Teres minor muscle (cut)

Suprascapular artery
Acromial branch of thoracoacromial artery
Infraspinous branch of suprascapular artery
Posterior circumflex humeral artery (in quadrangular space) and ascending and descending branches
Circumflex scapular artery

Posterior view

Transverse cervical artery
Thyroacromial artery
Clavicular branch
Acromial branch
Deltoid branch
Pectoral branch

Subclavian artery
Anterior scalene muscle
Superior thoracic artery
Thoracoacromial artery
Clavicular branch
Acromial branch

Subscapular artery
Circumflex scapular artery
Brachial artery
Thoracodorsal artery
Lateral thoracic artery

1, 2, 3 indicate 1st, 2nd and 3rd parts of axillary artery

---

**ARTERIES • Shoulder**

<table>
<thead>
<tr>
<th>COURSE</th>
<th>BRANCHES</th>
<th>COMMENT/SUPPLY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SUBCLAVIAN ARTERY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Branches off aorta (L) or brachiocephalic trunk (R), b/w anterior &amp; middle scalene muscles with the brachial plexus</td>
<td>Thyrocervical trunk</td>
<td>3 other branches into the neck</td>
</tr>
<tr>
<td></td>
<td>Suprascapular artery</td>
<td>Runs over the transverse scapular ligament to rotator cuff muscles</td>
</tr>
<tr>
<td></td>
<td>Infraspinatus branch</td>
<td>Runs around spinoglenoid notch with suprascapular n.</td>
</tr>
<tr>
<td></td>
<td>Dorsal scapular</td>
<td>Divides around the levator scapulae muscle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>AXILLARY ARTERY</strong></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuation of subclavian after the 1st rib. Runs through the axilla into the arm, becoming the brachial artery at the lower border of the teres major muscle</td>
<td>I. Superior thoracic</td>
<td>To serratus anterior and pectoralis muscles</td>
</tr>
<tr>
<td>II. Thoracoacromial</td>
<td>Clavicular branch</td>
<td>Has 4 branches</td>
</tr>
<tr>
<td></td>
<td>Acromial branch</td>
<td>Can be injured in clavicle fractures or surgery</td>
</tr>
<tr>
<td></td>
<td>Deltoid branch</td>
<td>With CA ligament, at risk in subacromial decompression</td>
</tr>
<tr>
<td></td>
<td>Pectoral branch</td>
<td>With cephalic vein, at risk in deltopectoral approach</td>
</tr>
<tr>
<td></td>
<td>Lateral thoracic</td>
<td>Runs with lateral pectoral nerve</td>
</tr>
<tr>
<td>III. Subscapular</td>
<td>Circumflex scapular</td>
<td>Runs with long thoracic nerve to serratus anterior</td>
</tr>
<tr>
<td></td>
<td>Thoracodorsal</td>
<td>Has 2 main branches</td>
</tr>
<tr>
<td></td>
<td>Anterior circumflex humeral</td>
<td>Seen posteriorly in triangular space</td>
</tr>
<tr>
<td></td>
<td>Ascending branch</td>
<td>Runs w/thoracodorsal nerve. Used for free flap</td>
</tr>
<tr>
<td></td>
<td>Arcuate artery</td>
<td>Primary supply of humeral head (via ascending br.)</td>
</tr>
<tr>
<td></td>
<td>Posterior circumflex humeral</td>
<td>Injury (e.g., anatomic neck fx) leads to osteonecrosis</td>
</tr>
</tbody>
</table>

The axillary artery is divided into 3 parts by the borders of the pectoralis minor muscle (1st prox., 2nd behind, 3rd distal). The first part (I) has 1 branch, 2nd part (II) has 2 branches, 3rd part (III) has 3 branches.

---

NETTER’S CONCISE ORTHOPAEDIC ANATOMY 101
Adhesions of peripheral capsule to distal articular cartilage

Adhesions obliterating axillary fold of capsule

Coronal section of shoulder shows adhesions between capsule and periphery of humeral head


AP radiograph of shoulder demonstrates typical changes of osteoarthritis of the shoulder with narrowing of the joints and prominent osteophyte formation at the interior aspect of the humeral head.

### Glenohumeral arthritis

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ADHESIVE CAPSULITIS (“FROZEN SHOULDER”)</strong></td>
<td>• Synovial inflammation leads to capsular fibrosis (thickening) &amp; loss of joint space (esp. pouch) • Three stages: pain, stiffness, resolving/thawing</td>
<td>• PMHx (DM, thyroid dz), trauma, immobilization PE: Decreased active AND passive ROM</td>
<td>• Physical therapy (gentle active and passive ROM) and pain management (6+ months) • Arthroscopic lysis of adhesions in refractory cases</td>
</tr>
<tr>
<td></td>
<td>Hx: Pain, stiffness, +/- PMHx, +/- trauma, +/- immobilization PE: Decreased active AND passive ROM</td>
<td>XR: Shoulder series: usually normal Arthrogram: shows decreased capsular volume</td>
<td></td>
</tr>
<tr>
<td><strong>ACROMIOCLAVICULAR ARTHROSIS</strong></td>
<td>• Degeneration of the AC joint • Associated with previous trauma, overuse, rotator cuff disease • Osteolysis in weight-lifters</td>
<td>Hx: Pain, +/- grinding PE: ACJ TTP, crossbody adduction pain, +/- subtle instability (on palpation)</td>
<td>• Rest, activity modification • Corticosteroid injection • Open vs arthroscopic distal clavicle resection (Mumford)</td>
</tr>
<tr>
<td></td>
<td>XR: AC narrowing/spurs MR: Oftentimes not needed; will show edema &amp; degeneration</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ARTHROITIS (GLENOHUMERAL)</strong></td>
<td>• Osteoarthritis #1, also RA • Can be posttraumatic (e.g., fx), 2° to RC tear, or 2° to surgery (e.g., Pudwill)</td>
<td>Hx: Usually elderly, pain, stiffness, +/- old trauma PE: Decreased ROM, +/- wasting, crepitus</td>
<td>• NSAIDs, physical therapy • Corticosteroid injections • Hemi vs total shoulder arthroplasty</td>
</tr>
<tr>
<td></td>
<td>XR: Joint narrowing, osteophytes MR: For rotator cuff evaluation if indicated</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BICEPS TENDINITIS</strong></td>
<td>• Assoc. w/impingement, RC tear (esp. subscapularis), &amp; tendon subluxation (biceps pulley injury)</td>
<td>Hx: Pain, +/- snapping PE: Biceps TTP, Speed &amp; Yergason tests</td>
<td>• Physical therapy • Corticosteroid injection • Tenodesis vs tenotomy</td>
</tr>
<tr>
<td></td>
<td>XR: Often normal MR: Evaluate for tear</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BICEPS TENDON RUPTURE (PROXIMAL)</strong></td>
<td>• Usually in older population • Often degenerative tear • Associated with impingement &amp; RC tears</td>
<td>Hx: Pain &amp; deformity PE: “Popeye” arm deformity, weak supination</td>
<td>• Physical therapy. Patient often has residual weakness in supination • Consider tenodesis (esp. in younger/active patients)</td>
</tr>
<tr>
<td></td>
<td>XR: Usually normal MR: Often not needed, but will show tear</td>
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</table>
Abduction of arm causes repeated impingement of greater tubercle of humerus on acromion, leading to degeneration and inflammation of supraspinatus tendon, secondary inflammation of bursa, and pain on abduction of arm. Calcific deposit in degenerated tendon produces elevation that further aggravates inflammation and pain.

**External impingement**

**Rotator cuff tear**

Communication between shoulder joint and subdeltoid bursa is pathognomonic of cuff tear

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORK-UP</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXTERNAL (OUTLET) IMPINGEMENT</strong></td>
<td></td>
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<tr>
<td>• Rotator cuff &amp; bursa trapped b/w acromion &amp; greater tuberosity</td>
<td>Hx: Pain w/ overhead activities, lifting, etc.</td>
<td>XR: Outlet view: look for hooked (type 2, 3) acromion or spur</td>
<td>• NSAIDs, activity modification</td>
</tr>
<tr>
<td>• Spectrum of disease from bursitis to tendinopathy to partial- to full-thickness RC tear</td>
<td>PE: +Neer sign/test, +Hawkins test. RC: strong +/- painful</td>
<td>MR: Best study to evaluate for possible RC tear</td>
<td>• Physical therapy (rotator cuff strengthening)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Subacromial steroid injection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Subacromial decompression</td>
</tr>
<tr>
<td><strong>ROTATOR CUFF TEAR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Chronic: associated w/impingement (usu. on bursal side)</td>
<td>Hx: Pain overhead &amp; at night, +/- weakness</td>
<td>XR: May show Ca++ of tendon, spurs, or humeral head elevation</td>
<td>• Activity modification, NSAIDs</td>
</tr>
<tr>
<td>• Acute: in throwers (articular side) or after dislocation (&gt; 40y.o.)</td>
<td>PE: SS: FF, + empty can</td>
<td>MR: Excellent for cuff tear imaging; contrast shows communication b/w joint &amp; subacromial space</td>
<td>• PT: ROM, RC strengthening, scapular stabilization</td>
</tr>
<tr>
<td>• Supraspinatus #1</td>
<td>IS: ER, + hornblower’s Subscap: IR, + lift off, + belly press, incr. ER</td>
<td></td>
<td>• Operative</td>
</tr>
<tr>
<td>• Graded by size: &lt;3cm, 3-5cm, &gt;5cm or # of tendons involved</td>
<td></td>
<td></td>
<td>• Partial tear: SA decompression and cuff debridement vs repair</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Full tear: RC repair</td>
</tr>
</tbody>
</table>
### Shoulder Disorders

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORK-UP</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Glenohumeral Instability</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>&quot;TUBS&quot;</td>
<td>• Result of a dislocation (Trauma)</td>
<td></td>
<td>• Physical therapy (rotator cuff strengthening) &amp; ROM</td>
</tr>
<tr>
<td></td>
<td>• Most often Unilateral</td>
<td></td>
<td>• Bankart (labral) repair with capsule imbrication (open or arthroscopically)</td>
</tr>
<tr>
<td></td>
<td>• Labral tear (Bankart lesion) results from the dislocation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Surgery is most often indicated (due to 90% recurrence rate)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hx: Dislocation, pain, &amp; recurrent instability</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PE: + apprehension &amp; relocation, + load &amp; shift (one direction), + jerk (posterior lesion)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>XR: West point view</td>
<td>CT: For glenoid lesions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MR Arthrogram: Sensitive for labral tear; may show increased capsular volume</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>&quot;AMBRI&quot;</td>
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<tr>
<td></td>
<td>• Atraumatic (no dislocation)</td>
<td></td>
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<tr>
<td></td>
<td>• Multidirectional (ant, inf, post)</td>
<td></td>
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<tr>
<td></td>
<td>• Bilateral (1 side often worse)</td>
<td></td>
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<tr>
<td></td>
<td>• Responds to Rehabilitation</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>• Inferior capsular shift may help</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hx: Pain (from increased joint mobility)</td>
<td></td>
<td>• Early repair indicated</td>
</tr>
<tr>
<td></td>
<td>PE: + load &amp; shift (usu. both ant. &amp; post.), + sulcus sign</td>
<td></td>
<td>• Late repair controversial</td>
</tr>
<tr>
<td></td>
<td>XR: Often normal</td>
<td>MR: Can evaluate for tendon retraction</td>
<td>• Nonoperative treatment yields adequate results</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EEH: Ambri sign</td>
<td></td>
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<tr>
<td><strong>Pectoralis Major Rupture</strong></td>
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<tr>
<td></td>
<td>• Rare injury, usu. young patients</td>
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<tr>
<td></td>
<td>• Most common in weight-lifters</td>
<td></td>
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<tr>
<td></td>
<td>• Maximal eccentric contraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hx: Acute pain</td>
<td></td>
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<tr>
<td></td>
<td>PE: Axilla deformity, accentuated with adduction</td>
<td></td>
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<tr>
<td></td>
<td>XR: Look for avulsion</td>
<td>EMG/NCS: Confirm neurovascular abnormality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MR: Can evaluate for tendon retraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Early repair indicated</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Late repair controversial</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Nonoperative treatment yields adequate results</td>
<td></td>
<td></td>
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<tr>
<td><strong>Scapular Winging</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>• Medial: serratus anterior weakness 2° long thoracic nerve palsy</td>
<td></td>
<td>• Observation (1-2 years)</td>
</tr>
<tr>
<td></td>
<td>• Lateral: trapezius weakness 2° spinal accessory (CN11) palsy</td>
<td></td>
<td>• Refractory cases: Medial: pect. major transfer</td>
</tr>
<tr>
<td></td>
<td>Hx: Weakness</td>
<td></td>
<td>Lateral: levator scapulae transfer</td>
</tr>
<tr>
<td></td>
<td>PE: Winging of scapula observed from back</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>XR: Usually normal</td>
<td>EMG/NCS: Confirm nerve palsy</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Superior Labral Tear (SLAP Lesion)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Tear of superior labrum (biceps anchor) from ant. to post.</td>
<td></td>
<td>• Rest, activity modification, physical therapy</td>
</tr>
<tr>
<td></td>
<td>• Chronic (with RCT) or acute (load on outstretched arm)</td>
<td></td>
<td>• Superior labral debridement, repair, or biceps tenodesis based on type of lesion (I-VII)</td>
</tr>
<tr>
<td></td>
<td>• 7 types based on extent of tear</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hx: Pain +/− popping, weakness, etc</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PE: + O’Brien’s test, + crank test, +/− painful arc of motion</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>XR: Usually normal</td>
<td>MR Arthrogram: Most sensitive for labral tears</td>
<td></td>
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<tr>
<td><strong>Thoracic Outlet Syndrome</strong></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>• Compression of neurovascular structure (artery, vein, brachial plexus) in the neck by 1st rib &amp; scalene muscles</td>
<td></td>
<td>• Activity modification</td>
</tr>
<tr>
<td></td>
<td>• Also assoc. w/cervical ribs</td>
<td></td>
<td>• PT &amp; posture training</td>
</tr>
<tr>
<td></td>
<td>Hx: Vague sx: pain &amp; numbness/coolness</td>
<td></td>
<td>• Rib (esp. cervical rib) or transverse process resection rarely indicated</td>
</tr>
<tr>
<td></td>
<td>PE: + Adson’s test, + Wright test, decr. pulses</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>XR: Shoulder: normal C-spine; look for cervical rib</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CXR: r/o lung mass</td>
<td>EMG: Brachial plexus</td>
<td></td>
</tr>
</tbody>
</table>
Sprengel’s Deformity

Radiograph shows omovertebral bone (arrows) connecting scapula to spinous processes of cervical vertebrae via osteochondral joint (J)

**Child with congenital elevation of left scapula. Note shortness of neck on that side and tendency to torticollis**

**PEDIATRIC DISORDERS • Shoulder**

**DESCRIPTION**
- Small (hypoplastic), undescended scapula. **Omovertebral** bone connects C-spine (spinous process) to scapula.
- Associated with Klippel-Feil syndrome, scoliosis, kidney disease

**EVALUATION**
- **Hx:** Parents notice abnormal neck/scapula
- **PE:** Neck appears short/full; often decreased ROM (esp. abduction)
- **XR:** Look for omovertebral bone

**TREATMENT**
- **Mild:** observation
- **Symptomatic:** omovertebral bone resection, scapula distalization with muscle transfer, +/- clavicle osteotomy to protect brachial plexus
**Deltopectoral Approach to Shoulder Joint**

**USES**
- Open rotator cuff (esp. subscapularis) or labral repairs
- Arthroplasty (hemi vs total)
- Proximal humerus fx

**INTERNERVOUS PLANE**
- Deltoid [axillary]
- Pectoralis major [lateral & medial pectoral nerves]

**DANGERS**
- Musculocutaneous n. (with vigorous retraction of conjoined tendon)
- Cephalic vein
- Axillary nerve

**COMMENT**
- Subscapularis must be opened and repaired in approach
- 3 vessels run along inf. border of subscap.; may need ligation
- Adduct/ER protects axillary n.

**COMPLICATIONS:** Subscapularis rupture; neurapraxia (musculocutaneous or axillary nerve)
**PORTAL** | **PLACEMENT** | **DANGERS** | **COMMENT**
--- | --- | --- | ---
**ARTHROSCOPY PORTALS**

<table>
<thead>
<tr>
<th>Portal</th>
<th>Placement</th>
<th>Dangers</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior</td>
<td>2cm down, 1cm medial to posterolateral corner of acromion</td>
<td>Posterior capsule/labrum</td>
<td>Primary viewing portal</td>
</tr>
<tr>
<td>Anterior superior</td>
<td>Both anterior portals are b/w the AC joint &amp; lateral coracoid</td>
<td>Coracoacromial ligament and/or artery</td>
<td>Often used for instruments</td>
</tr>
<tr>
<td>Anterior inferior</td>
<td>In the rotator interval</td>
<td>Musculocutaneous nerve</td>
<td>Enters just above subscapularis tendon</td>
</tr>
<tr>
<td>Lateral</td>
<td>2cm distal to acromial edge</td>
<td>Axillary nerve (5cm distal)</td>
<td>Visualize RC and acromion</td>
</tr>
<tr>
<td>Wilmington</td>
<td>1cm ant, 1cm distal to posterolateral acromion corner</td>
<td>Safe portal</td>
<td>Useful in repairs of RC and labrum</td>
</tr>
<tr>
<td>Neviser (supraspinatus)</td>
<td>Posterior to AC joint in sulcus</td>
<td>Rotator cuff</td>
<td>Anterior glenoid view</td>
</tr>
<tr>
<td>Topic</td>
<td>Page</td>
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<td>Topographic Anatomy</td>
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### Structure and Clinical Application

<table>
<thead>
<tr>
<th>Structure</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triceps</td>
<td>Can be palpated on the posterior aspect of the arm. A tendon avulsion/rupture can be palpated immediately proximal to the olecranon.</td>
</tr>
<tr>
<td>Biceps</td>
<td>Can be palpated on the anterior aspect of the arm.</td>
</tr>
<tr>
<td>Cubital fossa</td>
<td>Biceps tendon can be palpated here. If ruptured, the tendon cannot be palpated.</td>
</tr>
<tr>
<td>Lateral epicondyle</td>
<td>Site of common extensor origin. Tender in lateral epicondylitis (&quot;tennis elbow&quot;)</td>
</tr>
<tr>
<td>Medial epicondyle</td>
<td>Site of common flexor origin. Tender in medial epicondylitis (&quot;golfer's elbow&quot;)</td>
</tr>
<tr>
<td>Olecranon</td>
<td>Proximal tip of ulna. Tenderness can indicate fracture.</td>
</tr>
<tr>
<td>Radial head</td>
<td>Proximal end of radius. Tenderness can indicate fracture.</td>
</tr>
</tbody>
</table>
**OSTEOLOGY • Arm**

**HUMERUS**

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>OSSIFY</th>
<th>FUSE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylindrical long bone</td>
<td>Primary</td>
<td>Shaft</td>
<td>6-7wk (fetal)</td>
</tr>
<tr>
<td>Deltoid tuberosity</td>
<td>Secondary</td>
<td>Head</td>
<td>Birth</td>
</tr>
<tr>
<td>Spiral groove: radial nerve runs in groove</td>
<td>Proximal (3):</td>
<td>Tuberosities</td>
<td>1-4yr</td>
</tr>
<tr>
<td>Lateral condyle</td>
<td>Distal (4):</td>
<td>Capitellum</td>
<td>1yr</td>
</tr>
<tr>
<td>• Capitellum (articular)</td>
<td></td>
<td>Medial</td>
<td>5yr</td>
</tr>
<tr>
<td>• Lateral epicondyle</td>
<td></td>
<td>epicondyle</td>
<td>Trochlea</td>
</tr>
<tr>
<td>• Medial condyle</td>
<td></td>
<td>Medial</td>
<td>8yr</td>
</tr>
<tr>
<td>• Trochlea (articular)</td>
<td></td>
<td>epicondyle</td>
<td>Trochlea</td>
</tr>
<tr>
<td>• Olecranon and coronoid fossae</td>
<td></td>
<td>Lateral</td>
<td>14-18yr</td>
</tr>
<tr>
<td>• Deltoid tuberosity</td>
<td></td>
<td></td>
<td>12-17yr</td>
</tr>
<tr>
<td>• Radial groove</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Medial supracondylar ridge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Lateral supracondylar ridge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Olecranon fossa</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>• Lateral epicondyle</td>
<td></td>
<td></td>
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<tr>
<td>• Cubital tunnel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Medial epicondyle</td>
<td></td>
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</tbody>
</table>

- Primary ossification:
  - Capitellum (articular)
  - Medial epicondyle
  - Olecranon and coronoid fossae

- Secondary ossification:
  - Head
  - Tuberosities

- Distal ossification:
  - Capitellum

- Limited remodeling potential in distal fx
- Deltoid is a deforming force in shaft fractures
- Radial nerve can be entrapped in distal ⅔ humeral shaft fractures (Holstein-Lewis fx)
- Fx of lateral condyle common in pediatrics
- Capitellum aligns with radial head on x-ray
- Lat. epicondyle: origin of extensor mass & LCL
- Supracondylar process present 5%: ligament of Struthers may entrap median nerve
- Med. epicondyle: origin of flexor mass & MCL
- Ulnar nerve runs post. to medial epicondyle
- Fossae filled with fat; can be displaced in fx, resulting in “fat pad” on x-ray

### CHARACTERISTICS

<table>
<thead>
<tr>
<th>OSSIFY</th>
<th>FUSE</th>
<th>COMMENTS</th>
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</thead>
<tbody>
<tr>
<td><strong>PROXIMAL RADIUS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Radial head &amp; physis are intraarticular</td>
<td>Secondary</td>
<td>• Anterolateral portion of radial head has less subchondral bone &amp; is most susceptible to fracture</td>
</tr>
<tr>
<td>• Radial neck: 10-15° angled</td>
<td>Head</td>
<td>• Radial head should always align with the capitellum</td>
</tr>
<tr>
<td>• Tuberosity: biceps insertion</td>
<td>2-3yr 16-18yr</td>
<td>• Tuberosity points ulnarly in supination</td>
</tr>
<tr>
<td><strong>PROXIMAL ULNA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Olecranon</td>
<td>Secondary</td>
<td>• Articulates with trochlea, part of greater notch</td>
</tr>
<tr>
<td>• Coronoid process</td>
<td>Olecranon</td>
<td>• Coronoid provides anterior stability &amp; MCL insertion</td>
</tr>
<tr>
<td>• Supinator crest</td>
<td>9yr 16-20yr</td>
<td>• Lateral ulnar collateral ligament (LUCL) inserts on supinator crest</td>
</tr>
<tr>
<td>• Ulnar tuberosity</td>
<td></td>
<td>• Brachialis inserts on ulnar tuberosity</td>
</tr>
<tr>
<td>• Greater sigmoid notch</td>
<td></td>
<td>• Greater sigmoid notch: olecranon &amp; coronoid</td>
</tr>
<tr>
<td>• Lesser sigmoid notch</td>
<td></td>
<td>• Lesser sigmoid (radial) notch: articulates with RH</td>
</tr>
</tbody>
</table>
**RADIOLOGY • Arm**

**RADIOLOGY TECHNIQUE FINDINGS CLINICAL APPLICATION**

<table>
<thead>
<tr>
<th>RADIOGRAPH</th>
<th>TECHNIQUE</th>
<th>FINDINGS</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anteroposterior</td>
<td>Elbow extended, beam perpendicular to plate</td>
<td>Elbow joint, distal humerus, proximal radius and ulna</td>
<td>Fractures, dislocations, arthritis/DJD, supracondylar process</td>
</tr>
<tr>
<td>Lateral</td>
<td>Elbow flexed 90°, beam from lateral to radial head</td>
<td>Elbow joint, fat pads (fat is displaced by fracture hematoma)</td>
<td>Fractures (esp. peds: fat pads, anterior humeral line), DJD (osteophytes)</td>
</tr>
<tr>
<td>Oblique</td>
<td>Elbow extended, rotated 30°</td>
<td>Alignment &amp; position of bones</td>
<td>Subtle fx (radial head, occult fx)</td>
</tr>
<tr>
<td>Radiocapitellar</td>
<td>Lateral, beam 45° to elbow</td>
<td>Isolates capitellum/radial head</td>
<td>Fx: radial head, capitellum, coronoid</td>
</tr>
</tbody>
</table>

**OTHER STUDIES**

| CT | Axial, coronal, and sagittal | Articular congruity, bone healing, bone alignment | Fractures (esp. coronoid, comminuted intraarticular fx) |
| MR | Sequence protocols vary | Soft tissues (ligaments, tendons, cartilage, bones) | Ligament (e.g., MCL) & tendon (e.g., biceps) rupture, OCD |
| Bone scan | All bones evaluated | Infection, stress fractures, tumors |
**Humeral Shaft Fracture**

A. Transverse fracture of midshaft
B. Oblique (spiral) fracture
C. Comminuted fracture with marked angulation

After initial swelling subsides, most fractures of shaft of humerus can be treated with functional brace of interlocking anterior and posterior components held together with Velcro straps.

Open reduction and fixation with compression plate indicated under special conditions.

Fracture aligned and held with external fixator. Most useful for wounds requiring frequent changes of dressing.

Entrapment of radial nerve in fracture of shaft of distal humerus may occur at time of fracture; must also be avoided during reduction.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Common long bone fracture</td>
<td>Hx: Trauma/fall, pain and swelling</td>
<td>Descriptive:</td>
<td>• Cast/brace: minimally displaced/acceptable alignment</td>
</tr>
<tr>
<td>• Mechanism: fall or direct blow</td>
<td>PE: Swelling +/- deformity, humerus is TTP</td>
<td>• Location: site of fracture</td>
<td>• Acceptable: &lt;3cm shortening</td>
</tr>
<tr>
<td>• Displacement based on fracture location and muscle insertion sites. Pectoralis and deltoid are primary deforming forces.</td>
<td>Good neuro. exam (esp. radial n.)</td>
<td>• Displaced, angulated, or comminuted</td>
<td>• &lt;20° A/P angulation</td>
</tr>
<tr>
<td>• High union rates</td>
<td>XR: AP &amp; lateral of arm (also shoulder &amp; elbow series)</td>
<td>• Pattern: transverse, spiral, oblique</td>
<td>• &lt;30° varus/valgus angulation</td>
</tr>
<tr>
<td>• Site of pathologic fractures</td>
<td>CT: Not usually needed</td>
<td></td>
<td>• Surgical treatment: open fx, floating elbow, segmental fx, polytrauma, vascular injury</td>
</tr>
</tbody>
</table>

COMPLICATIONS: Radial nerve palsy (esp. distal 1/3 fractures [Holstein-Lewis]): most are neurapraxia and resolve spontaneously; nerve exploration is controversial; nonunion/malunion are uncommon.
Distal Humerus Fracture

**DESCRIPTION**
- Most often intraarticular (adults); extraarticular (supracondylar) fx uncommon in adults
- Mechanism: fall
- Unicondylar or bicondylar
- Other: epicondyle, capitellum, trochlea fx all less common

**EVALUATION**
- Hx: Trauma/fall, pain, esp. w/ elbow ROM (decreased)
- PE: Swelling & tenderness
- Good neurovascular exam
- XR: Elbow series

**CLASSIFICATION**
- Descriptive: Uni or bicondylar
- T, Y, λ type
- Displaced, angulated comminuted (esp. coronal split)

**TREATMENT**
- Nonoperative: rarely indicated
- Surgical: ORIF (plates & screws)
- Ulnar nerve often needs to be transposed anteriorly
- Early ROM is important
- Total elbow arthroplasty: if fx is too comminuted for ORIF

**COMPLICATIONS:** Elbow stiffness, heterotopic ossification (prophylaxis is indicated), ulnar nerve palsy, nonunion

---

**Distal Humerus Fracture**

Fracture of lateral condyle of humerus. Fracture of medial condyle less common

Fractured condyle fixed with one or two compression screws

Olecranon reattached with longitudinal Kirschner wires and tension band wire wrapped around them and through hole drilled in ulna.

Olecranon osteotomized and reflected proximally with triceps brachii tendon.

Articular surface of distal humerus reconstructed and fixed with transverse screw and buttress plates with screws. Ulnar nerve may be transposed anteriorly to prevent injury. Lateral column fixed with posterior plate and medial column fixed with plate on the medial ridge.
Supracondylar Fractures

**Extension type**
Posterior displacement of distal fragment (most common)

**Lateral radiograph**

**Flexion type**
Anterior displacement of distal fragment (uncommon)

Lateral radiograph of elbow in a 5-year-old sustaining injury to left elbow. Radiograph shows elevation of anterior and posterior fat pads. No apparent fracture on this view, but subsequent radiographs confirmed presence of a nondisplaced supracondylar humerus fracture.

### Table: Supracondylar Humerus Fracture

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Common pediatric fracture</td>
<td>• Hx: Fall, pain, will not move arm, +/- deformity</td>
<td>• Extension type (Gartland)</td>
<td>• Type I: Long arm cast</td>
</tr>
<tr>
<td>• Extraphyseal fx at thin portion of bone (1mm) between distal humeral fossae</td>
<td>• PE: Swelling +/- deformity. Good neurovascular exam (esp. AIN, radial n., pulses)</td>
<td>• I: Nondisplaced</td>
<td>• Types II &amp; III: Closed reduction &amp; percutaneous pinning, 2 or 3 pins (crossed or divergent) Medial pins can injure ulnar nerve</td>
</tr>
<tr>
<td>• Extension type most common</td>
<td>• XR: Elbow series. Lateral view: anterior humeral line is anterior to capitellum center in displaced fx. Posterior fat pad indicates fx.</td>
<td>• II: Partially displaced (post. cortex intact)</td>
<td>• Open reduction for irreducible fractures (uncommon)</td>
</tr>
<tr>
<td>• Malreduction leads to deformity: cubitus varus is most common</td>
<td></td>
<td>• III: Displaced (no cortical continuity)</td>
<td>• Explore pulseless/unperfused extremity for artery entrapment</td>
</tr>
<tr>
<td>• Relatively high incidence of neurovascular injury</td>
<td></td>
<td>• Flexion type (uncommon)</td>
<td></td>
</tr>
</tbody>
</table>

**COMPLICATIONS:** Malunion (cubitus varus #1); neurovascular (median nerve/AIN #1, radial nerve, brachial artery)
Olecranon fracture

Open reduction of olecranon fracture. Fracture secured with two Kirschner wires plus tension band wire passed around bent ends of Kirschner wires and through drill.

Fracture of head and neck of radius

Comminuted fracture of radial head with dislocation of distal radioulnar joint, proximal migration of radius, and tear of interosseous membrane (Essex-Lopresti fracture).

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLECRANON FRACTURE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Mechanism: fall directly onto elbow or onto hand</td>
<td>Hx: Trauma (usually fall), pain and swelling</td>
<td>Colton:</td>
<td>• Nondisplaced: Long arm cast 3 weeks, then gentle ROM</td>
</tr>
<tr>
<td>• Intraarticular fracture: congruity important for good results</td>
<td>PE: Tenderness, limited elbow extension. Neuro exam, esp. ulnar nerve</td>
<td>• I. Nondisplaced: &lt;2mm</td>
<td>• Displaced:</td>
</tr>
<tr>
<td>• Triceps tendon is a deforming force on proximal fragment</td>
<td>XR: Elbow series</td>
<td>• II. Displaced</td>
<td>○ Transverse: ORIF tension band or IM screw.</td>
</tr>
<tr>
<td></td>
<td>CT: Better defines fracture</td>
<td>• III: Comminuted</td>
<td>○ Oblique/comminuted: ORIF with contoured plate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• IV: Fracture with elbow dislocation</td>
<td>• Excise &amp; reattach tendon</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMPLICATIONS: Painful hardware, elbow stiffness, nonunion, arthritis (posttraumatic), ulnar nerve injury</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RADIAL HEAD FRACTURE

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Mechanism: fall onto hand</td>
<td>Hx: Trauma/fall, pain</td>
<td>Mason: 4 types</td>
<td>• Type I: Elbow aspiration, sling for 3 days, early ROM</td>
</tr>
<tr>
<td>• Intraarticular fracture: anterolateral portion is weaker and is most common fracture site</td>
<td>PE: Decreased motion (esp. pronosupination) Check DRUJ stability</td>
<td>• I: Nondisplaced (&lt;2mm)</td>
<td>• Type II: ORIF (esp. for mechanical block to motion)</td>
</tr>
<tr>
<td>• Essex-Lopresti: RH fx w/ disruption of IM membrane &amp; DRUJ</td>
<td>XR: Elbow series; radiocapitellar view is helpful, +/- fat pad sign</td>
<td>• II: Single displaced fragment</td>
<td>• Type III: Radial head excision and/or RH arthroplasty</td>
</tr>
<tr>
<td>• Associated w/ elbow dislocation</td>
<td>CT: Useful in types II-IV</td>
<td>• III: Comminuted</td>
<td>• Essex-Lopresti: radial head arthroplasty is required</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• IV: Fracture with elbow dislocation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMPLICATIONS: Elbow stiffness or instability; Wrist instability (Essex-Lopresti)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Elbow Dislocation

- **Mechanism:** Usually a fall in young patient. 
- **#3 most common dislocation.**
- **Associated with fractures:** "Terrible triad" = elbow dx with radial head & coronoid fractures.
- **Collateral ligaments & anterior capsule are typically all torn.**

**Description:**

- Posterior dislocation: Note prominence of olecranon posteriorly and distal humerus anteriorly.
- Divergent dislocation, anterior-posterior type (rare). Medial-lateral type may also occur (extremely rare).
- Lateral dislocation (uncommon).

**Reduction:**

- With thumb in antecubital space as a fulcrum, the forearm is supinated and flexed.

**Classification:** By direction of forearm bones:

- Posterior (80%)
- Medial
- Lateral (rare)
- Anterior (rare)
- Divergent (rare)

**Treatment:**

- Acute: closed reduction
  - Stable: splint for 7-10d
  - Unstable: splint for 2-3wk
- Open reduction for irreducible dxs and/or ORIF fxs
- Hinged external fixation for grossly unstable elbows

**Complications:** Elbow stiffness and instability, neurovascular injury (median and ulnar nerves, brachial artery).

### Radial Head Subluxation (Nursemaid’s Elbow)

- **Mechanism:** Usually a pull on the hand by an adult.
- Very common in toddlers.
- Decreased with increasing age.
- Annular ligament stretches & radial head subluxates.

**Description:**

- Child pulled by hand, child will not use arm.
- Elbow flexed, pronated, RH tender.
- Elbow series; normal, often not needed.

**Reduction:**

- Fully extend elbow, fully supinate, then flex with gentle pressure on radial head. Usually a click or pop is felt as it reduces.
- Immobilization rarely indicated.

**Complications:** Recurrence.
### JOINTS • Arm

#### MRI coronal, elbow

- Olecranon
- Capitellum
- Radial head
- Ulna
- Joint capsule

#### In 90° flexion: lateral view

- Joint capsule
- Lateral collateral ligament
- Medial collateral ligament
- Insertion of brachialis muscle
- Biceps brachii tendon
- Oblique cord
- Ulna
- Radius

#### In 90° flexion: medial view

- Joint capsule
- Anterior bundle of MCL
- Posterior bundle of MCL
- Medial collateral ligament
- Medial epicondyle
- Lateral epicondyle
- Medial collateral ligament
- Ulna
- Radius

---

### Ligaments

<table>
<thead>
<tr>
<th>Ligaments</th>
<th>Attachments</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELBOW</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| - The elbow comprises three articulations: 1. Ulnohumeral (trochlea and greater sigmoid notch): Ginglymus (hinge) joint  
2. Radiocapitellar (radial head and capitellum): Trochoid (pivot) joint  
3. Proximal radioulnar (radial head and lesser sigmoid notch) | | |
| - Primary function is as a lever for lifting and placing the hand appropriately in space  
2. Pronosupination: 70° pro. – 80° sup. (functional ROM: 100° [50° pro. – 50° sup.]); axis is RC joint | | |
| - Stability provided by combination of osseous (articulations) and ligamentous restraints; carrying angle 11-16° valgus | | |
| **Medial (Ulnar) Collateral (MCL)** | | |
| Anterior bundle | Inf. medial epicondylo to medial coronoid process ("sublime tubercle") | Most important restraint to valgus stress, always taut; usually ruptures off coronoid |
| Posterior bundle | Medial epicondylo to sigmoid notch | Taut in/resists valgus in flexion (>90°) |
| Transverse bundle | Med. olecranon to inf. medial coronoid | Stabilizes the greater sigmoid notch |
| **Lateral (Radial) Collateral (LCL)** | | |
| Lateral collateral (LCL) | Lat. epicondylo to ant. annular lig. | Varus restraint; stabilizes annular ligament |
| Lateral ulnar collateral (LUCL) | Lateral epicondylo to supinator crest of the ulna | Buttress to radial head subluxation; injury results in posterolateral rotatory instability |
| Accessory lateral collateral | Annular ligament to supinator crest | Stabilizes annular ligament during varus stress |
| Annular ligament | Anterior and posterior portions of sigmoid notch | Allows radial head rotation; stretched or torn in radial head subluxation or dislocation |
| **Other** | | |
| Capsule | Surrounds joint | Secondary stabilizer, prone to contracture |
| Quadrante ligament | Anterolateral ulna to anterior radial neck (under the annular ligament) | Tight in supination, stabilizes the proximal radio-ulnar joint (PRUJ) |
| Oblique cord | Proximal lateral ulna to radial neck | Stabilizes joint during pronosupination |
**ELBOW STABILITY**

### Primary Stabilizers

<table>
<thead>
<tr>
<th>Structure</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulnohumeral articulation</td>
<td>Primary restraint to valgus &lt; 20° or &gt; 120° of flexion</td>
</tr>
<tr>
<td>Medial collateral ligament (MCL)</td>
<td>Primary restraint to varus in extension (2° in flexion)</td>
</tr>
<tr>
<td>(esp. anterior bundle)</td>
<td>Primary restraint to valgus between 20-120° of flexion</td>
</tr>
<tr>
<td>Lateral collateral ligament (LCL)</td>
<td>Anterior bundle is always taut, post. bundle taut &gt; 90°</td>
</tr>
<tr>
<td>(esp. LUCL)</td>
<td>Primary restraint to varus in flexion (2° in extension)</td>
</tr>
<tr>
<td></td>
<td>LUCL prevents subluxation of radial head (e.g., PLRI)</td>
</tr>
</tbody>
</table>

### Secondary Stabilizers

<table>
<thead>
<tr>
<th>Structure</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiocapitellar articulation</td>
<td>Restraint to valgus from 0-30° of flexion</td>
</tr>
<tr>
<td>(radial head)</td>
<td>Restraint to both varus and valgus stress</td>
</tr>
<tr>
<td>Anterior and posterior capsule</td>
<td>Dynamic forces act to restrain both varus and valgus stress</td>
</tr>
<tr>
<td>Common flexor and extensor origins</td>
<td></td>
</tr>
</tbody>
</table>

### STRUCTURE COMPONENTS COMMENTS

<table>
<thead>
<tr>
<th>Structure</th>
<th>Components</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CUBITAL TUNNEL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Borders</td>
<td>• Roof: Arcuate (Osborne’s) ligament</td>
<td>Tightens in flexion, compresses ulnar nerve within cubital tunnel</td>
</tr>
<tr>
<td></td>
<td>From med. epicondyle to olecranon</td>
<td>Can be injured in decompression surgery</td>
</tr>
<tr>
<td></td>
<td>• Floor: Medial collateral ligament (MCL)</td>
<td>Does not typically compress the nerve</td>
</tr>
<tr>
<td></td>
<td>• Posterior: Medial head of the triceps</td>
<td>Medial epicondylectomy occasionally indicated</td>
</tr>
<tr>
<td></td>
<td>• Anterior: Medial epicondyle</td>
<td>Does not compress nerve</td>
</tr>
<tr>
<td></td>
<td>• Lateral: Olecranon</td>
<td></td>
</tr>
<tr>
<td>Contents</td>
<td>• Nerve: Ulnar nerve</td>
<td>Compressed in cubital tunnel syndrome</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Fractures (malunion) of the medial condyle can cause ulnar nerve</td>
<td></td>
</tr>
<tr>
<td></td>
<td>entrapment in the cubital tunnel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Arcuate ligament is also known as Osborne’s ligament/fascia and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the cubital tunnel retinaculum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• See Forearm chapter for radial tunnel</td>
<td></td>
</tr>
</tbody>
</table>
**Other Structures**

- **Arcade of Struthers**: Thickened fascia from IM septum to triceps (medial head), 8cm proximal to epicondyle. Occurs in 70% of population; can compress ulnar nerve proximal to cubital tunnel.

- **Fat pads**: Located in both the coronoid and olecranon fossae, engaged in full flexion or extension. Can be displaced by fracture hematoma and seen on x-ray as a lucency (“sail sign”).

- **Olecranon bursa**: At the tip of the olecranon process. Can become inflamed or infected.

- **Ligament of Struthers**: A fibrous band running from an anomalous supracondylar process to medial epicondyle. Can compress the median nerve proximally.

- **Biceps aponeurosis (lacertus fibrosus)**: Fascial band from distal biceps and tendon that runs to deep forearm fascia. Covers median nerve and brachial artery and can compress median nerve.

- **Arcade of Frohse**: Branches of recurrent radial artery. Can compress radial nerve/PIN.
### MINOR PROCEDURES

#### STEPS

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Steps</th>
</tr>
</thead>
</table>
| **ELBOW ARTHROCENTESIS**         | 1. Flex and extend elbow, palpate lateral condyle, radial head, and olecranon laterally; feel triangular sulcus ("soft spot") between all three  
2. Prep skin over sulcus (iodine/antiseptic soap)  
3. Anesthetize skin locally (quarter size spot)  
4. May keep arm in extension or flex it. Insert needle in "triangle" between bony landmarks (aim to medial epicondyle)  
5. Fluid should aspirate easily  
6. Dress injection site |
| **OLECRANON BURSA ASPIRATION**   | 1. Prep skin over olecranon (iodine/antiseptic soap)  
2. Anesthetize skin locally (quarter size spot)  
3. Insert 18-gauge needle into fluctuant portion of the bursa and aspirate fluid  
4. If suspicious of infection, send fluid for Gram stain and culture  
5. Dress injection site |
| **TENNIS ELBOW INJECTION**       | 1. Ask patient about allergies  
2. Flex elbow 90°, palpate ECRB insertion (point of maximal tenderness) on the lateral epicondyle  
3. Prep skin over lateral elbow (iodine/antiseptic soap)  
4. Anesthetize skin locally (quarter size spot)  
5. Insert 22-gauge or smaller needle into ECRB tendon at its insertion on the lateral epicondyle. **Aspirate to ensure needle is not in a vessel**, then inject 2-3ml of 1:1 local/corticosteroid preparation (fan out injection in broad tendon).  
6. Dress insertion site  
7. Annotate improvement in symptoms |
**Elbow fractures and dislocations** can result from fall on outstretched dorsiflexed hand.

**Ulnar Nerve Compression**
Compressing of nerve on hard surface (chair arm, desk, operating table, etc.)

Numbness and tingling in ulnar nerve distribution in hand. Interosseous wasting between thumb and index finger.

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>Young, Middle aged, elderly</td>
<td>Dislocation, fracture, Tennis elbow (epicondylitis), nerve compression, arthritis</td>
</tr>
<tr>
<td>2. Pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Onset</td>
<td>Acute, Chronic</td>
<td>Dislocation, fracture, tendon avulsion/rupture, ligament injury</td>
</tr>
<tr>
<td>b. Location</td>
<td>Anterior, Posterior, Lateral</td>
<td>Biceps tendon rupture, arthritis, elbow contracture, Lateral epicondylitis, fracture (especially radial head)</td>
</tr>
<tr>
<td>c. Occurrence</td>
<td>Medial, Night pain/at rest, With activity</td>
<td>Medial epicondylitis, nerve entrapment, fracture, MCL strain, Infection, tumor</td>
</tr>
<tr>
<td>3. Stiffness</td>
<td>Without locking, With locking</td>
<td>Arthritis, effusions (trauma), contracture, Loose body, lateral collateral ligament injury</td>
</tr>
<tr>
<td>4. Swelling</td>
<td>Over olecranon</td>
<td>Olecranon bursitis, Other: dislocation, fracture, gout</td>
</tr>
<tr>
<td>5. Trauma</td>
<td>Fall on elbow, hand</td>
<td>Dislocation, fracture</td>
</tr>
<tr>
<td>6. Activity</td>
<td>Sports, repetitive motion, Throwing</td>
<td>Epicondylitis, ulnar nerve palsy, MCL strain or rupture</td>
</tr>
<tr>
<td>7. Neurologic symptoms</td>
<td>Pain, numbness, tingling</td>
<td>Nerve entrapments (multiple possible sites), cervical spine pathology, thoracic outlet syndrome</td>
</tr>
<tr>
<td>8. History of arthritides</td>
<td>Multiple joints involved</td>
<td>Lupus, rheumatoid arthritis, psoriasis, gout</td>
</tr>
</tbody>
</table>
**Subluxation of head of radius**

(“pulled elbow”/“nursemaid’s”)

**Olecranon bursitis**

(student’s elbow)

**Epicondylitis**

(tennis elbow)

**Exquisite tenderness**

over lateral or medial epicondyle of humerus

**Cubitus varus deformity**

Malunion of a supracondylar fracture can result in this deformity.

---

**EXAM/OBSERVATION** | **TECHNIQUE** | **CLINICAL APPLICATION**
--- | --- | ---

**INSPECTION**

Unwilling to use arm | Observe patient (child) | Fracture, dislocation, radial head subluxation (nursemaid’s elbow)

Gross deformity, swelling | Compare both sides | Dislocation, fracture, bursitis

Carrying angle (normal 5-15°)

- Negative (<5°)
- Positive (>15°) | Cubitus varus (e.g., supracondylar fracture)
Cubitus valgus (e.g., lateral epicondyle fracture)

Muscle wasting | Inspect hand muscles | Nerve entrapment (e.g., cubital tunnel syndrome)

**PALPATION**

Medial | Epicondyle and supracondylar line
Ulnar nerve in ulnar groove | Pain: medial epicondylitis (golfer’s elbow), fracture, MCL rupture/strain
Paresthesias indicate ulnar nerve entrapment

Lateral | Epicondyle and supracondylar line
Radial head | Pain: lateral epicondylitis (tennis elbow), fracture
Pain: arthritis, fracture, synovitis

Anterior | Biceps tendon in antecubital fossa | Pain: absence of tendon indicates biceps tendon rupture

Posterior | Flex elbow: olecranon, olecranon fossa, triceps tendon | Olecranon bursitis, triceps tendon rupture
### PHYSICAL EXAM • Arm

**RANGE OF MOTION**

<table>
<thead>
<tr>
<th>EXAM/OBSERVATION</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flex and extend</td>
<td>Elbow at side: flex and extend at elbow</td>
<td>Normal: 0° to 140-150°; note if PROM &gt; AROM</td>
</tr>
<tr>
<td>Pronate and supinate</td>
<td>Tuck elbows, thumbs up, rotate forearm</td>
<td>Normal: supinate 80-85°, pronate 75-80°</td>
</tr>
</tbody>
</table>

**Arm stabilized against chest wall with elbow flexed at 90°**

- **Supination**
  - 0°
  - 75°
  - 85°

- **Pronation**
  - 0°
  - 75°

**Thumb in line with humerus**

- **Flexion**
  - 90°
  - 140°

- **Extension**
  - 0°
  - 10°
  - 15°

In children, normal elbow extension is 10°–15°
Elbow flexion test

<table>
<thead>
<tr>
<th>EXAM</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NEUROVASCULAR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Axillary n. (C5)</td>
<td>Proximal lateral arm</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Radial n. (C5)</td>
<td>Inferolateral and posterior arm</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Medial cutaneous n. of arm (T1)</td>
<td>Medial arm</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td><strong>Motor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Musculocutaneous n. (C5-6)</td>
<td>Resisted elbow flexion</td>
<td>Weakness = Brachialis/biceps or nerve/root lesion</td>
</tr>
<tr>
<td>Musculocutaneous n. (C6)</td>
<td>Resisted supination</td>
<td>Weakness = Biceps or corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Median n. (C6)</td>
<td>Resisted pronation</td>
<td>Weakness = Pronator teres or nerve/root lesion</td>
</tr>
<tr>
<td>Radial n. (C7)</td>
<td>Resisted elbow extension</td>
<td>Weakness = Triceps or nerve/root lesion</td>
</tr>
<tr>
<td><strong>Reflexes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>Biceps</td>
<td>Hypoactive/absence indicates radiculopathy</td>
</tr>
<tr>
<td>C6</td>
<td>Brachioradialis</td>
<td>Hypoactive/absence indicates radiculopathy</td>
</tr>
<tr>
<td>C7</td>
<td>Triceps</td>
<td>Hypoactive/absence indicates radiculopathy</td>
</tr>
<tr>
<td><strong>Pulses:</strong></td>
<td>brachial, radial, ulnar</td>
<td></td>
</tr>
<tr>
<td><strong>SPECIAL TESTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tennis elbow</td>
<td>Make fist, pronate, extend wrist and fingers against resistance</td>
<td>Pain at lateral epicondyly suggests lateral epicondylitis</td>
</tr>
<tr>
<td>Golfer’s elbow</td>
<td>Supinate arm, extend wrist and elbow</td>
<td>Pain at medial epicondylage suggests medial epicondylitis</td>
</tr>
<tr>
<td>Ligament instability</td>
<td>25° flexion, apply varus/valgus stress</td>
<td>Pain or laxity indicates LCL/MCL injury</td>
</tr>
<tr>
<td>Pivot shift (PLRI)</td>
<td>Supine, extend elbow, flex shoulder above head. Supinate, axial load, valgus and flex elbow</td>
<td>Apprehension, palpable subluxation of radial head, or dimpling of skin over radial head positive test for posterolateral rotatory instability (PLRI)</td>
</tr>
<tr>
<td>Tinel’s sign</td>
<td>Tap on ulnar groove (nerve)</td>
<td>Tingling in ulnar distribution indicates entrapment</td>
</tr>
<tr>
<td>Elbow flexion</td>
<td>Maximal elbow flexion for 3 min</td>
<td>Tingling in ulnar distribution indicates entrapment</td>
</tr>
<tr>
<td>Pinch grip</td>
<td>Pinch tips of thumb and index finger</td>
<td>Inability (or pinching of pads, not tips): AIN pathology</td>
</tr>
</tbody>
</table>
### MUSCLES: ORIGINS AND INSERTIONS • Arm

#### Anterior view
- **Coracobrachialis**
- **Biceps brachii muscle** (long head)
- **Supraspinatus muscle**
- **Subscapularis muscle**
- **Pectoralis major muscle**
- **Latissimus dorsi muscle**
- **Teres major muscle**
- **Deltoid muscle**

#### Posterior view
- **Deltoideus muscle**
- **Supraspinatus muscle**
- **Infraspinatus muscle**
- **Teres minor muscle**
- **Triceps brachii muscle (lateral head)**
- **Deltoid muscle**
- **Brachialis muscle**
- **Triceps brachii muscle (medial head)**
- **Common extensor tendon**
- **Anconeus muscle**
- **Triceps brachii muscle**

#### Muscle attachments
- **Origins**
- **Insertions**

<table>
<thead>
<tr>
<th>CORACOID PROCESS</th>
<th>GREATER TUBerosity</th>
<th>ANTERIOR PROXIMAL HUMERUS</th>
<th>MEDIAL EPICONdyle</th>
<th>LATERAL EPICONdyle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ORIGINS</strong></td>
<td></td>
<td></td>
<td>Pronator teres</td>
<td>Anconeus extensor</td>
</tr>
<tr>
<td>Biceps (SH)</td>
<td>Coracobrachialis</td>
<td></td>
<td>Common flex. tendon (FCR, PL, FCU, FDS)</td>
<td>Common extensor tendon (ECRB, EDC, EDQ, ECU)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pronator teres muscle (humeral head)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Common flexor tendon</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>flexor carpi radialis, palmaris longus, flexor carpi ulnaris and flexor digitorum superficialis [humeroulnar head] muscles)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flexor digitorum superficialis muscle (humeroulnar head)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flexor pollicis longus muscle (ulnar head)</td>
<td></td>
</tr>
</tbody>
</table>

| INSERTIONS       |                    |                           | Pectoralis major | Teres major |
| Pectoralis minor | Supraspinatus       |                           |                  |            |
|                  | Infraspinatus       |                           |                  |            |
|                  | Teres minor         |                           |                  |            |
|                  | Latissimus dorsi    |                           |                  |            |

NETTER’S CONCISE ORTHOPAEDIC ANATOMY 127
### MUSCLES: ANTERIOR

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coracobrachialis</td>
<td>Coracoid process</td>
<td>Middle humerus</td>
<td>Musculocutaneous nerve</td>
<td>Flex and adduct</td>
<td>Part of “conjoined” tendon</td>
</tr>
<tr>
<td>Brachialis</td>
<td>Distal anterior</td>
<td>Ulnar tuberosity (proximal ulna)</td>
<td>Medial: MSC n.</td>
<td>Flex forearm</td>
<td>Split in anterior surgical approach</td>
</tr>
<tr>
<td>Biceps brachii</td>
<td>Long head</td>
<td>Supraglenoid tubercle</td>
<td>Radial tuberosity (proximal radius)</td>
<td>Supinate and flex forearm</td>
<td>Rupture, results in “Popeye arm”</td>
</tr>
<tr>
<td></td>
<td>Short head</td>
<td>Coracoid process</td>
<td>Radial tuberosity (proximal radius)</td>
<td>Supinate and flex forearm</td>
<td>Part of “conjoined” tendon</td>
</tr>
</tbody>
</table>
**NETTER'S CONCISE ORTHOPAEDIC ANATOMY**

**MUSCLES: POSTERIOR • Arm**

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triceps brachii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long head</td>
<td>Infraglenoid tubercle</td>
<td>Olecranon</td>
<td>Radial nerve</td>
<td>Extends elbow</td>
<td>Border of quadrangular &amp; triangular space &amp; interval</td>
</tr>
<tr>
<td>Lateral head</td>
<td>Posterior humerus (proximal)</td>
<td>Olecranon</td>
<td>Radial nerve</td>
<td>Extends elbow</td>
<td>Border in lateral approach</td>
</tr>
<tr>
<td>Medial head</td>
<td>Posterior humerus (distal)</td>
<td>Olecranon</td>
<td>Radial nerve</td>
<td>Extends elbow</td>
<td>One muscular plane in posterior approach</td>
</tr>
</tbody>
</table>
**RELATIONSHIPS**

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>RELATIONSHIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musculocutaneous n.</td>
<td>Pierces coracobrachialis 8cm distal to coracoid, then lies b/w the biceps and brachialis muscles where lateral antebrachial cutaneous nerve (terminal branch) emerges</td>
</tr>
<tr>
<td>Radial n.</td>
<td>Starts medial, then spirals posteriorly and laterally around humerus (in spiral groove) and emerges b/w brachialis and brachioradialis muscles in distal lateral arm</td>
</tr>
<tr>
<td>Ulnar n.</td>
<td>In medial arm, from anterior to posterior compartment (across IM septum) into cubital tunnel</td>
</tr>
<tr>
<td>Median n.</td>
<td>In anteromedial arm, initially lateral to brachial artery, but crosses over it to become medial</td>
</tr>
<tr>
<td>Brachial artery</td>
<td>Runs with median nerve, then crosses under it to become more midline in distal arm/elbow</td>
</tr>
</tbody>
</table>

**COMPARTMENTS**

| Anterior                         | Muscles: brachialis, biceps brachii, coracobrachialis  
|                                 | Neurovascular: musculocutaneous nerve, median nerve, brachial artery, radial nerve (distally) |
| Posterior                        | Muscles: triceps brachii  
|                                 | Neurovascular: radial nerve (mid arm), ulnar nerve (distal arm), radial recurrent arteries |
NERVES • Arm

BRACHIAL PLEXUS

Lateral and Medial Cord

**Median** (C(5)6-T1): runs in medial arm (anterior compartment), medial to biceps and brachialis (lateral to brachial artery), then crosses over (medial) to artery and enters forearm under biceps aponeurosis (lacertus fibrosus)

- **Sensory:** None (in arm, see Hand chapter)
- **Motor:** None (in arm, see Forearm & Hand chapters)

**Radial** (C5-T1): starts medial to humerus, crosses posterior into spiral groove (where it can be entrapped in a humerus fracture, esp. *distal* 2/3 fractures) with deep artery of the arm, then exits between the brachioradialis & brachialis, then divides into deep (motor–PIN) and superficial (sensory) branches

- **Sensory:** Posterior arm: via *posterior cutaneous n. of arm* (posterior brachial cutaneous)
- **Motor:** *Posterior compartment*
  - Triceps brachii
  - Anterior compartment
    - Brachialis (lateral portion)
**BRACHIAL PLEXUS**

### Lateral Cord

**Musculocutaneous (C5-7):** pierces coracobrachialis (6-8cm below coracoid, where it is at risk from retraction of the conjoined tendon), then runs between the biceps & brachialis, innervating both. Sensory terminal branch exits between the biceps & brachialis at elbow.

- **Sensory:** None (in arm, see Forearm chapter)
- **Motor:**
  - Anterior compartment
    - Coracobrachialis
    - Biceps brachii
    - Brachialis (medial portion)

### Medial Cord

**Medial cutaneous n. of arm (brachial cutaneous [C8-T1]):** branches from the cord, joins intercostobrachial nerve, and runs subcutaneously in the medial arm.

- **Sensory:** Medial arm
- **Motor:** None

**Ulnar (C[7]8-T1):** runs from anterior to posterior compartment in medial arm over the IM septum, then under the arcade of Struthers onto the triceps (medial head), then into cubital tunnel posterior to the medial epicondyle

- **Sensory:** None (in arm, see Forearm & Hand)
- **Motor:** None (in arm, see Forearm & Hand)
### ARTERIES • Arm

#### BRACHIAL ARTERY

<table>
<thead>
<tr>
<th>BRANCHES</th>
<th>COURSE</th>
<th>COMMENT/SUPPLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep artery (profunda brachii)</td>
<td>In the spiral groove</td>
<td>Runs with the radial nerve, can be injured there</td>
</tr>
<tr>
<td>Nutrient humeral artery</td>
<td>Enters the nutrient canal</td>
<td>Supplies the humerus</td>
</tr>
<tr>
<td>Superior ulnar collateral</td>
<td>With ulnar n. in medial arm</td>
<td>Anastomosis with posterior ulnar recurrent artery</td>
</tr>
<tr>
<td>Inferior ulnar collateral</td>
<td>Branches in distal arm</td>
<td>Anastomosis with anterior ulnar recurrent artery</td>
</tr>
<tr>
<td>Muscular branches</td>
<td>Usually branch laterally</td>
<td>Supply musculature of the arm</td>
</tr>
<tr>
<td>Radial</td>
<td>Terminal branch</td>
<td>One of 2 terminal branches</td>
</tr>
<tr>
<td>Ulnar</td>
<td>Terminal branch</td>
<td>One of 2 terminal branches</td>
</tr>
</tbody>
</table>

#### DEEP ARTERY

<table>
<thead>
<tr>
<th>BRANCHES</th>
<th>COURSE</th>
<th>COMMENT/SUPPLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior radial collateral</td>
<td>In anterolateral arm</td>
<td>Anastomosis with radial recurrent artery</td>
</tr>
<tr>
<td>Posterior (middle) radial</td>
<td>Posterior to humerus</td>
<td>Anastomosis with recurrent interosseous artery Used as pedicle in lateral arm flap</td>
</tr>
<tr>
<td>collateral</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### RADIAL ARTERY

<table>
<thead>
<tr>
<th>BRANCHES</th>
<th>COURSE</th>
<th>COMMENT/SUPPLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial recurrent</td>
<td>Runs in anterolateral portion of the arm</td>
<td>Anastomosis with anterior radial collateral artery Branches (leash of Henry) can compress radial n.</td>
</tr>
</tbody>
</table>

#### ULNAR ARTERY

<table>
<thead>
<tr>
<th>BRANCHES</th>
<th>COURSE</th>
<th>COMMENT/SUPPLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior ulnar recurrent</td>
<td>In anteromedial arm</td>
<td>Anastomosis with inferior ulnar collateral artery</td>
</tr>
<tr>
<td>Posterior ulnar recurrent</td>
<td>In posteromedial arm</td>
<td>Anastomosis with superior ulnar collateral artery</td>
</tr>
<tr>
<td>Common interosseous</td>
<td>Midline branch</td>
<td>Is a trunk with multiple branches</td>
</tr>
<tr>
<td>Recurrent interosseous</td>
<td>Posterior to elbow</td>
<td>Anastomosis w/ post. radial (middle) collateral artery</td>
</tr>
<tr>
<td>Anterior &amp; posterior interosseous</td>
<td>Along intermuscular septum</td>
<td>Supplies forearm musculature</td>
</tr>
</tbody>
</table>
Inherent stability by mechanical locking of components with hinge arrangement

Three types of total elbow arthroplasty have been used. Results were better with an unrestrained prosthesis but with 5%–20% incidence of postoperative instability, most patients are now treated with a semi-constrained prosthesis, which has inherent stability by linking of the component usually with a hinge (shown above) or a snap-fit axis arrangement.

**Submuscular tranposition of ulnar nerve**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP/FINDINGS</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARTHRITIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Less common condition</td>
<td>Hx: Chronic pain, stiffness, +/- previous trauma</td>
<td>• XR: OA vs inflammatory</td>
<td>1. Conservative (rest, NSAID)</td>
</tr>
<tr>
<td>• Osteoarthritis seen in athletes/laborers</td>
<td>PE: Decreased ROM &amp; tenderness (especially in extension)</td>
<td>• Blood: RF, ESR, ANA</td>
<td>2. Debridement (osteophytes, loose bodies)</td>
</tr>
<tr>
<td>• Site for arthritides (RA, gout, etc)</td>
<td></td>
<td>• Joint fluid: crystals, cells, culture</td>
<td>3. Unihumeral arthroplasty</td>
</tr>
<tr>
<td>CUBITAL TUNNEL SYNDROME</td>
<td>Hx: Numbness/tingling in ulnar distribution, +/- elbow pain</td>
<td>XR: Look for abnormal medial epicondyle</td>
<td>4. Total elbow arthroplasty</td>
</tr>
<tr>
<td>• Entrapment of ulnar nerve at elbow</td>
<td>PE: +/- decreased grip strength, intrinsic atrophy, + Tinel’s and/or elbow flexion text</td>
<td>EMG: Confirms diagnosis</td>
<td></td>
</tr>
<tr>
<td>Site:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>○ IM septum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>○ Arcade of Struthers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>○ Cubital tunnel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>○ FCU fascia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LATERAL EPICONDYLITIS (TENNIS ELBOW)</td>
<td>Hx: Age 30-60, chronic pain at lateral elbow, worse w/wrist extension</td>
<td>XR: Rule out fracture &amp; OA. Calcification of tendons can occur (esp. ECRB)</td>
<td>1. Activity modification, NSAIDs</td>
</tr>
<tr>
<td>• Degenerative of common extensor tendons (esp. ECRB)</td>
<td>PE: Lateral epicondytle TTP; pain with resisted wrist extension</td>
<td></td>
<td>2. Use of brace/strap</td>
</tr>
<tr>
<td>• Due to overuse (e.g., tennis) and/or injury (microtrauma) to tendon</td>
<td></td>
<td></td>
<td>3. Stretching/strengthening</td>
</tr>
<tr>
<td>OLECRANON BURSITIS</td>
<td>Hx: Swelling, acute or chronic pain</td>
<td>LAB: Aspirate bursa, send fluid for culture, cell count, Gram stain and crystals</td>
<td>4. Corticosteroid injection</td>
</tr>
<tr>
<td>• Inflammation of bursa (infection/trauma/other)</td>
<td>PE: Palpable/fluctuant mass at olecranon</td>
<td></td>
<td>5. Surgical debridement of tendon (ECRB #1)</td>
</tr>
</tbody>
</table>
Osteochondral lesion of the capitellum

Bone resorption seen as radiolucent areas and irregular surface of capitellum of humerus

Characteristic changes in capitellum of left humerus (arrow) compared with normal right elbow

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP/FINDINGS</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DISTAL BICEPS TENDON RUPTURE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Mechanism: eccentric overload of partially flexed elbow</td>
<td>Hx: Acute injury/“pop” PE: No palpable tendon, weak and/or painful flexion &amp; supination</td>
<td>XR: Usually normal MR: Can confirm diagnosis but usually not needed</td>
<td>1. Early; primary repair (1 or 2 incision techniques) 2. Late: no surgery; physical therapy</td>
</tr>
<tr>
<td>• Usually male 40-60 y.o.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Early diagnosis important</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MEDIAL ELBOW INSTABILITY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• MCL (anterior bundle) injury from repetitive valgus stress</td>
<td>Hx: Pain with throwing or inability to throw PE: MCL tenderness, +/- valgus laxity (at &gt;30°)</td>
<td>XR: Stress view may show widening (usu. dynamic) postmedial osteophytes. MR: Avulsion and tears</td>
<td>1. Rest, activity modification 2. Physical therapy (ROM) 3. Ligament reconstruction &amp; debridement of osteophytes/loose bodies</td>
</tr>
<tr>
<td>• Acute or chronic, associated with throwers (baseball, javelin)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>OSTEOCHONDROIS DISSECGANS OF ELBOW</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>• Vascular insufficiency or microtrauma to capitellum</td>
<td>Hx: Lateral elbow pain, +/- catching, stiffness PE: Capitellum TTP, pain w/ valgus stress</td>
<td>XR: Lucency, +/- fragmentation of the capitellum CT: Helpful to identify loose bodies</td>
<td>1. Rest &amp; physical therapy 2. ORIF of fragments or arthroscopic debridement of loose bodies &amp; chondroplasty</td>
</tr>
<tr>
<td>• Adolescent throwers/gymnasts with valgus/compressive loads</td>
<td></td>
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<tr>
<td><strong>POSTEROLATERAL ROTATORY INSTABILITY</strong></td>
<td></td>
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</tr>
<tr>
<td>• Lateral ulnar collateral ligament (LUC) injury</td>
<td>Hx: Hx of trauma or surgery, pain, +/- clicking PE: + lateral pivot shift test (often needs EUA)</td>
<td>XR: Often normal Stress XR: Shows radial head subluxation MR: Identifies LUC tear</td>
<td>1. Rest, activity modification 2. Physical therapy (ROM) 3. LUC reconstruction (usually with a palmaris graft)</td>
</tr>
<tr>
<td>• Allows radial head to subluxate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Mech: traumatic (elbow dx) or iatrogenic (elbow surgery)</td>
<td></td>
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<tr>
<td><strong>STIFF ELBOW</strong></td>
<td></td>
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<tr>
<td>• &lt;30-120°</td>
<td>Hx: Trauma, stiffness, minimal pain PE: Limited ROM (esp. in flexion and extension)</td>
<td>XR: AP/lateral/oblique Look for osteophytes or other signs of intrinsic joint arthrosis</td>
<td>1. Physical therapy: ROM 2. Operative: Intrinsic: excise osteophytes, LBs Extrinsic: capsular release</td>
</tr>
<tr>
<td>• Intrinsic vs extrinsic etiology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Intrinsic: articular changes/arthrosis (posttraumatic, etc)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Extrinsic: capsule contracture</td>
<td></td>
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</tr>
</tbody>
</table>

**DISORDERS** • Arm
Lateral view of upper extremity reveals posterior bulge of head of radius and inability to fully extend elbow.

Anteroposterior and lateral radiographs reveal posterior dislocation of radial head, most evident on elbow flexion. Note also hypoplastic capitulum of humerus.

**CONGENITAL RADIAL HEAD DISLOCATION**

- Radial head congenitally dislocated
- Usually diagnosed from 2-5y.o.
- Patients are typically very functional
- Unilateral or bilateral
- Associated with other syndromes

**DESCRIPTION**

- Hx: Parents notice decreased ROM, +/- pain or deformity (late)
- PE: Decreased ROM, +/- visible radial head and/or tenderness
- XR: Malformed radial head & capitellum

**EVALUATION**

- Asymptomatic: observation
- Symptomatic (pain): excision of radial head at skeletal maturity (decreases pain, but does not typically increase ROM)

**TREATMENT**

**RADIOULNAR SYNOSTOSIS**

- Failure of separation of radius & ulna
- Forearm rotation is absent
- Can be assoc. with other syndromes
- Bilateral in 60% of cases

**DESCRIPTION**

- Hx/PE: Absent pronosupination of the elbow/forearm. Varying degrees of fixed deformity (>=60° is severe)
- XR: Radius is thickened, ulna is narrow

**EVALUATION**

- Synostosis resection unsuccessful Mild/unilateral: observation
- Osteotomy: dominant hand 20° of pronation, nondominant 30° of supination

**OSTEOCHONDROSIS OF CAPITELLUM (PANNER’S DISEASE)**

- Disordered enchondral ossification
- Mech: valgus (pitcher’s) compression or axial overload (gymnasts)
- Usually <10 y.o.; male > female
- Favorable long-term prognosis

**DESCRIPTION**

- Hx: Insidious onset lateral elbow pain and overuse (baseball, gymnastics)
- PE: Capitellum TTP, decreased ROM
- XR: Irregular borders, +/- fissuring, fragmentation (rarely loose bodies)

**EVALUATION**

1. Rest (no pitching, tumbling, etc)
2. NSAIDs
3. Immobilization (3-4 weeks)

Symptoms may persist for months, but most completely resolve
### Lateral (Kocher) Approach to Elbow Joint

#### Incision site

- Extensor carpi ulnaris
- Anconeus

#### Posterior

- Olecranon
- Ulnar nerve

#### Anterior

- Capitulum
- Radial head

### Anterolateral Approach to Humerus

#### Incision site

- Biceps brachii (retracted)

#### Head of humerus

- Biceps brachii (long head)
- Periosteum (opened)
- Humerus

#### Deltoid

- (retracted)

#### Conjoined tendon

- Periosteum (opened)

#### Brachialis

- (split)

#### Biceps brachii

- (retracted)

#### Pectoralis major

- Deltoid

### SURGICAL APPROACHES • Arm

#### HUMERUS: ANTERIOR APPROACH

<table>
<thead>
<tr>
<th>USES</th>
<th>INTERNERVOUS PLANES</th>
<th>DANGERS</th>
<th>COMMENT</th>
</tr>
</thead>
</table>
| • ORIF of fractures  
  • Bone biopsy/tumor removal | Proximal  
  • Deltoid (axillary)  
  • Pectoralis major (pectoral)  
  Distal  
  • Brachialis splitting  
  ◦ Lateral (radial)  
  ◦ Medial (MSC) | Proximal  
  • Axillary nerve  
  • Humeral circumflex artery  
  Distal  
  • Radial nerve  
  • Musculocutaneous nerve | • Anterior humeral circumflex artery may need ligation.  
  • The brachialis has a split innervation that can be used for an internervous plane. |

#### ELBOW: LATERAL APPROACH (KOCHER)

<table>
<thead>
<tr>
<th>USES</th>
<th>INTERNERVOUS PLANES</th>
<th>DANGERS</th>
<th>COMMENT</th>
</tr>
</thead>
</table>
| Most radial head & lateral condyle procedures | • Anconeus (radial)  
  • ECU (PIN) | • PIN  
  • Radial nerve | • Protect PIN: stay above annular ligament; keep forearm pronated |

#### POSTERIOR APPROACH: BRYAN/MORREY

<table>
<thead>
<tr>
<th>Uses: Loose body removal/articular injuries, debridements and capsular release, fracture reduction, limited arthroplasty</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Uses</strong></td>
</tr>
<tr>
<td><strong>Internervous Plane</strong></td>
</tr>
<tr>
<td><strong>Dangers</strong></td>
</tr>
<tr>
<td><strong>Comment</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Posterior Approach with Olecranon Osteotomy</strong></th>
</tr>
</thead>
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**Arthroscopy Portals**

- **Proximal Anteromedial**
  - 2cm prox. to med. epicondydal anterior to IM septum
  - Ulnar nerve MAC nerve
  - Anterior compartment, radial head & capitellum, capsule

- **Proximal Anterolateral**
  - 2cm prox. to lat. epicondydal anterior to humerus
  - Radial nerve
  - Medial joint, lateral recess, and radiocapitellar joint

- **Posterocentral**
  - 3cm from olecranon tip
  - Safe (thru tendon)
  - Posterior compartment, gutters

- **Posterolateral**
  - 3cm from olecranon tip at lat. edge of triceps tendon
  - Med. & post. ante-brachial cutaneous n.
  - Olecranon tip & fossa, posterior trochlea

- **Direct Lateral (“soft spot”)**
  - Between lat. epicondydal, radial head & olecranon
  - Posterior antibrachial cutaneous nerve
  - Inferior capitellum and radiocapitellar joint
# CHAPTER 5

Forearm

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<td>Surgical Approaches</td>
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</table>
**STRUCTURE** | **CLINICAL APPLICATION**
--- | ---
Olecranon | Proximal tip of ulna. Tenderness can indicate fracture.
Radial head | Proximal end of radius. Tenderness can indicate fracture.
Flexor radialis tendon | Landmark for volar approach to wrist. Radial pulse is just radial to tendon.
Lister’s tubercle | Tubercle on dorsal radius. “Lighthouse of the wrist.” EPL tendon runs around it.
Ulnar styloid | Prominent distal end of ulna. Tenderness can indicate fracture.
Palmaris longus tendon | Not present in all people. Can be used for tendon grafts.
Anatomic snuffbox | Site of scaphoid. Tenderness can indicate a scaphoid fracture.
**OSTEOLOGY • Forearm**

**CHARACTERISTICS OSSIFY FUSE COMMENTS**

### RADIUS
- Cylindrical long bone
- Head is intraarticular
- Tuberosity: biceps inserts
- Shaft has a bow
- Distal end widens, is made of cancellous bone, has scaphoid & lunate facets, & radial styloid
- Ulnar (sigmoid) notch: DRUJ

<table>
<thead>
<tr>
<th>Primary</th>
<th>OSSIFY</th>
<th>FUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft</td>
<td>8-9wk</td>
<td>14yr</td>
</tr>
<tr>
<td>Head</td>
<td>2-3yr</td>
<td>16-18yr</td>
</tr>
<tr>
<td>Distal</td>
<td>epiphysis</td>
<td>4yr</td>
</tr>
</tbody>
</table>

- Anterolateral portion of RH has less subchondral bone (susceptible to fracture)
- Tuberosity points ulnarly in supination
- Bow allows rotation around ulna
- Cancellous distal radius common fracture site (esp. in pts & older pts)
- Distal radius x-ray measurements: 11° volar tilt, 22° radial inclination, 11-12mm radial height

### ULNA
- Long bone: straight bone
- Triangular cross-section
- Tuberosity: brachialis insertion
- Proximal: olecranon, coronoid process, radial (sigmoid) notch
- Distal: ulnar styloid

<table>
<thead>
<tr>
<th>Primary</th>
<th>OSSIFY</th>
<th>FUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft</td>
<td>8-9wk</td>
<td>16-18yr</td>
</tr>
<tr>
<td>Olecranon</td>
<td>9yr</td>
<td>16-20yr</td>
</tr>
<tr>
<td>Distal</td>
<td>epiphysis</td>
<td>5-6yr</td>
</tr>
</tbody>
</table>

- The radius rotates around the stationary ulna through proximal & distal notches during pronation/supination
- 75% of growth from distal epiphysis
- Olecranon & coronoid provide primary bony stability to elbow joint
- Coronoid fx can result in instability
- Common site of fx (often w/DR fx)
<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>OSSIFY</th>
<th>FUSE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROXIMAL ROW</strong></td>
<td></td>
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</tr>
</tbody>
</table>
| Scaphoid: boat shape, 80% covered with articular cartilage (not waist) | 5th 5yr | 14-16yr | • Blood supply enters dorsal waist, bridges both rows  
• #1 carpal fx. Proximal fractures are at risk of nonunion/AVN |
| Lunate: moon shape. Four articulations: 1. radius (lunate facet), 2. scaphoid, 3. triquetrum, 4. capitale | 4th 4yr | 14-16yr | • Dislocations: rare but often missed  
• Will rotate (carpal instability) if ligamentous attachments to adjacent bones are disrupted |
| Triquetrum: pyramid shape. Lies under the pisiform and ulnar styloid | 3rd 3yr | 14-16yr | • 3rd most common carpal fracture  
• Articulates with TFCC |
| Pisiform: large sesamoid bone. In FCU tendon, anterolateral to triquetrum | 8th 9-10yr | 14-16yr | • Multiple attachments: FCU, transverse carpal ligament (TCL), abductor digit minimi, multiple ligaments |
| **DISTAL ROW** |
| Trapezium: saddle shape | 6th 5-6yr | 14-16yr | • Has groove for FCR tendon |
| Trapezoid: trapezoidal/wedge shape | 7th 6-7yr | 14-16yr | • Articulates with second metacarpal |
| Capitate: largest carpal bone, 1st carpal bone to ossify | 1st 1yr | 14-16yr | • Keystone to carpal arch, floor of CT  
• Retrograde blood supply |
| Hamate: has volar-oriented hook that is distal and radial to pisiform | 2nd 2yr | 14-16yr | • Hook can fx, ulnar a. can be injured  
• TCL attaches border of Guyon’s canal |

- Ossification: each from a single center in a counter-clockwise direction (anatomic position) starting with the capitate.  
- Each bone has multiple (4-7) tight articulations with adjacent bones.  
- Proximal row is considered the “intercalated segment” between the distal radius/TFCC and distal carpal row.  
- Scaphoid-lunate angle (measured on lateral x-ray): avg. 47° (range 30-60°; <30=VSI, >60=DII).
RADIOGRAPH TECHNIQUE FINDINGS CLINICAL APPLICATION

<table>
<thead>
<tr>
<th>RADIOGRAPH</th>
<th>TECHNIQUE</th>
<th>FINDINGS</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP (anteroposterior)</td>
<td>Palm down on plate, beam perpendicular to plate</td>
<td>Carpal bones, radiocarpal joint</td>
<td>Distal radius, ulnar, carpal fractures or dislocation</td>
</tr>
<tr>
<td>Lateral</td>
<td>Ulnar border of wrist &amp; hand on plate</td>
<td>Alignment of bones, joints</td>
<td>Same as above, carpal (lunate) instability</td>
</tr>
<tr>
<td>Oblique</td>
<td>Lateral with 40° rotation</td>
<td>Alignment &amp; position of bones</td>
<td>Same as above</td>
</tr>
<tr>
<td>AP-ulnar deviation</td>
<td>AP, deviate wrist ulnarily</td>
<td>Isolates scaphoid</td>
<td>Scaphoid fractures</td>
</tr>
<tr>
<td>Carpal tunnel view</td>
<td>Maximal wrist extension, beam at 15°</td>
<td>Hamate, pisiform, trapezium</td>
<td>Fractures (esp. hook of the hamate)</td>
</tr>
</tbody>
</table>

OTHER STUDIES

<table>
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<tr>
<th>STUDY</th>
<th>TECHNIQUE</th>
<th>FINDINGS</th>
<th>CLINICAL APPLICATION</th>
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</thead>
<tbody>
<tr>
<td>CT</td>
<td>Axial, coronal, &amp; sagittal</td>
<td>Articular congruity, bone healing, bone alignment</td>
<td>Fractures (scaphoid, hook of hamate), nonunions</td>
</tr>
<tr>
<td>MRI</td>
<td>Sequence protocols vary</td>
<td>Soft tissues (ligaments, tendons, cartilage), bones</td>
<td>Occult fractures (e.g., scaphoid), tears (e.g., TFCC, S-L ligament)</td>
</tr>
<tr>
<td>Bone scan</td>
<td>All bones evaluated</td>
<td></td>
<td>Infection, stress fxs, tumors</td>
</tr>
</tbody>
</table>
### Both-Bone Fracture

- **Mech:** fall or high energy
- **Both bones usually fracture as energy passes thru both bones**
- **Fractures can be at different levels**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture of Both Forearm Bones</td>
<td>• Hx: Trauma, pain and swelling, +/-- deformity</td>
<td>• Descriptive:</td>
<td>• Peds (&lt;10-12y.o.): closed reduction and casting</td>
</tr>
<tr>
<td></td>
<td>• PE: Swelling, tenderness, +/-- clinical deformity</td>
<td>• Proximal, middle, distal 1/3</td>
<td>• Adults: ORIF (plates &amp; screws) through separate incisions</td>
</tr>
<tr>
<td></td>
<td>• XR: AP &amp; lateral forearm</td>
<td>• Displaced/angled</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Comminuted</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Open or closed</td>
<td></td>
</tr>
</tbody>
</table>

**COMPLICATIONS:** Malunion (loss of radial bow leads to decreased pronosupination), decreased range of motion

### Single-Bone Fracture

- **Mechanism:** direct blow; aka “nightstick fracture”
- **Ulna most common**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture of Both Forearm Bones</td>
<td>• Hx: Direct blow to forearm</td>
<td>• Descriptive:</td>
<td>• Nondisplaced: cast</td>
</tr>
<tr>
<td></td>
<td>• PE: Swelling, tenderness</td>
<td>• Displaced, shortened, angulated, comminuted</td>
<td>• Displaced: ORIF</td>
</tr>
<tr>
<td></td>
<td>• XR: AP &amp; lateral forearm</td>
<td></td>
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</tr>
</tbody>
</table>

**COMPLICATIONS:** Nonunion, malunion
**Monteggia Fracture**

- **DESCRIPTION**: Proximal ulna fracture, shortening forces result in radial head dislocation.
- **Mechanism**: Direct blow or fall on outstretched hand.
- **Hx**: Fall, pain and swelling.
- **PE**: Tenderness, deformity. Check compartments and do neurovascular exam.
- **XR**: AP/lateral: forearm; also, wrist and elbow.
- **TREATMENT**: Ulna: ORIF (plate/screws), Radial head: closed reduction (open if irreducible or unstable), Peds: closed reduction and cast.

**COMPLICATIONS**: Radial nerve/PIN injury (most resolve), decreased ROM, compartment syndrome, nonunion.

**Galeazzi Fracture**

- **DESCRIPTION**: Distal 1/3 radial shaft fracture, shortening forces result in distal radioulnar dislocation.
- **Mechanism**: Fall on outstretched hand.
- **Hx**: Fall, pain and swelling.
- **PE**: Tenderness, deformity. Check compartments and do neurovascular exam.
- **XR**: AP/lateral forearm: ulna usually dorsal. Also, wrist and elbow.
- **CLASSIFICATION**: By mechanism: Pronation: Galeazzi, Supination: Reverse Galeazzi (ulna shaft fx with DRUJ dislocation).
- **TREATMENT**: Radius: ORIF, DRUJ: closed reduction, +/- percutaneous pins in supination if unstable (open if unstable), Cast for 4-6wk, Peds: reduce & cast.

**COMPLICATIONS**: Nerve injury, decreased ROM, nonunion, DRUJ arthrosis.
**Frykman Classification of Fractures of Distal Radius**

- **Extraarticular radius:** I
- **Ulnar styloid:** II
- **Radiocarpal intraarticular:** III
- **Ulnar styloid:** IV
- **Intraarticular distal radioulnar:** V
- **Ulnar styloid:** VI
- **Intraarticular radiocarpal and distal radioulnar:** VII
- **Ulnar styloid:** VIII

Fractures can usually be reduced by closed manipulation. Wrist first dorsiflexed; traction initiated as distal and volar thumb pressure applied over distal fragments.

**Reduction of a Colles Fracture**

With pressure and traction maintained, wrist gently straightened.

**DESCRIPTION** | **EVALUATION** | **CLASSIFICATION** | **TREATMENT**
--- | --- | --- | ---
**DISTAL RADIUS FRACTURE**
- Mechanism: fall on outstretched hand
- Very common (Colles #1)
- Cancellous bone susceptible to fx (incl. osteoporotic fx)
- Colles (#1): dorsal displacement (apex volar angulation)
- Smith fx: volar displacement
- Barton fx: articul ar rim fx
- Radial styloid (“chauffeur fx”)
- Hx: Trauma (usually fall), pain and swelling
- PE: Swelling, tenderness, +/- deformity. Do thorough neurovascular exam.
- XR: Wrist series (3 views)
  - Normal measurements
    - 11° volar tilt
    - 11-12mm radial height
    - 23° radial inclination
  - CT: For intraarticular fxs
- Frykman (for Colles):
  - Type I, II: extraarticular
  - Type III, IV: RC joint
  - Type V, VI: RC joint
  - Type VII, VIII: both radio-ulnar & radiocarpal (RC) joints involved
- Even # fxs have associated ulnar styloid fx
- Other fxs, descriptive: displaced, angulated
- Nondisplaced: cast
- Displaced:
  - Stable: closed reduction, well-molded cast, 4-6wk
  - Unstable: closed reduction, percutaneous pinning +/- ext. fx. or ORIF
  - Intraarticular: ORIF (e.g., volar plate)
  - Elderly: cast, early ROM

**COMPLICATIONS:** Malunion, posttraumatic osteoarthritis, stiffness/loss of range of motion.
Scaphoid Fracture

- **Mechanism:** Fall on out-stretched hand
- **Most common carpal fx**
- **Retrograde blood supply to proximal pole is injured in waist fx,** can lead to nonunion or AVN
- **Distal pole usually heals**
- **High index of suspicion will decrease missed fx**

**Location:**
- Proximal pole
- Middle/"waist" (#1)
- Distal pole

**Position:**
- Displaced
- Angulated/shortened

**TREATMENT**

- **Nondisplaced:**
  1. Casting (LAC & SAC) average 10-12wk;
  2. Percutaneous screw
- **Displaced:** ORIF +/− bone graft
- **Nonunion:** ORIF with tricortical bone graft or vascularized bone graft

**COMPLICATIONS:**
- Nonunion, wrist arthrosis (SLAC wrist from chronic nonunion), osteonecrosis (esp. proximal pole)

Perilunate Dislocation

- **Mech:** Fall; axial compression & hyperextension
- **Instability progresses through 4 stages (Mayfield) as various ligaments are disrupted**
- **Dislocation (stage 4) occurs through weak spot (space of Poirier)**
- **Transscaphoid dislocation is #1 injury pattern**

**TREATMENT**

- **Instability:**
  - Closed vs open reduction, percutaneous pinning & primary ligament repair
  - Dislocation: open reduction of lunate, percutaneous pinning +/− ORIF of carpal fx
  - Late/wrist arthrosis: proximal row carpectomy or STT fusion

**COMPLICATIONS:**
- Wrist arthrosis (e.g., SLAC from instability), nonunion of fracture, chronic pain and/or instability
### Incomplete Fracture: Torus and Greenstick Fracture

**Description**
- Common in children (usually 3-12y.o.)
- Mechanism: fall on outstretched hand most common
- Distal radius most common
- Increased elasticity of pediatric bone allows for plastic deformity and/or unicortical fx

**Evaluation**
- Hx: Trauma, pain, inability/unwilling to use hand/extremity
- PE: +/− deformity. Point tenderness & swelling

**Classification**
- Torus (buckle): concave cortex compresses (buckles), convex/tension side: intact
- Greenstick: concave, cortex intact or buckled, convex/tension side fracture or plastic deformity

**Treatment**
- Torus: reduction rarely needed, cast 2-4wk
- Greenstick: nondisplaced—SAC 2-4wk. Reduce if >10º of angulation—well-molded LAC 3-4wk

### Complications
- Deformity, malunion, neurovascular injury (rare)
• The wrist is a complex joint comprising 3 main articulations: 1. Radiocarpal (distal radius/TFCC to proximal row), 2. Distal radioulnar joint (DRLJ), 3. Midcarpal (between carpal rows)
• Other articulations: pisotriquetral and multiple intercarpal (between 2 adjacent bones in the same row)
• Proximal row has no muscular attachments, considered the “intercalated segment,” & responds to transmitted forces. Distal row bones are tightly connected and act as a single unit in a normal wrist.
• Range of motion:
  - Flexion 65-80° (40% from radiocarpal, 60% midcarpal); extension 55-75° (65% radiocarpal, 35% midcarpal)
  - Radial deviation: 15-25°; ulnar deviation: 30-45° (55% midcarpal, 45% radiocarpal)
• Types of ligaments
  - Extrinsic: connect the distal forearm (radius & ulna) to the carpus
  - Intrinsic: connect carpal bones to each other (i.e., origin and insertion of ligament both within the carpus)
    - Interosseous: ligaments connecting carpal bones within the same row (proximal or distal)
    - Midcarpal/Intercarpal: ligaments connecting carpal bones between the proximal and distal rows.
• Palmar (volar) ligaments are stronger and more developed, most are intracapsular.
# Ligaments of the Radio-Carpal Joint

<table>
<thead>
<tr>
<th>Ligaments</th>
<th>Attachments</th>
<th>Function/Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extrinsic—Palmar</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radioscaphocapitate</td>
<td>Radial styloid to scaphoid</td>
<td>Blends with UC to form distal border of space of Poirier</td>
</tr>
<tr>
<td>Radioscaphoid (RS)</td>
<td>Radius to capitate body</td>
<td>Aka “radial collateral” lig. Stabilizes proximal pole</td>
</tr>
<tr>
<td>Radiocapitate (RC)</td>
<td></td>
<td>Forms a fulcrum around which the scaphoid rotates</td>
</tr>
<tr>
<td>Long radiolunate (sRL)</td>
<td>Volar radius to lunate</td>
<td>Blends with palmar LT intersosseous ligament</td>
</tr>
<tr>
<td>Unlunate (UC)</td>
<td>Ulna/TFC to capitate</td>
<td>Blends with RSC laterally. Distal border of space of Poirier</td>
</tr>
<tr>
<td><strong>Extrinsic—Dorsal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short radiolunate (sRL)</td>
<td>Distal radius to lunate</td>
<td>Stout &amp; vertical. Prevents dx in hyperextension</td>
</tr>
<tr>
<td>Ulnolunate (UL)</td>
<td>TFC to lunate</td>
<td>UL &amp; UT blend with UC to help stabilize the DRUJ</td>
</tr>
<tr>
<td>Unnotriquetral (UT)</td>
<td>TFC to triquetrum</td>
<td>UL &amp; UT considered by some to be part of the TFCC</td>
</tr>
<tr>
<td>Radioscapholunate</td>
<td>Radius to SL joint</td>
<td>“Ligament of Testut,” a neurovascular bundle to SL jt.</td>
</tr>
<tr>
<td><strong>Dorsal radiocarpal (DRC)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superficial bundle</td>
<td>Radius to lunate/triquetrum</td>
<td>Aka radiolunotriquetral (RLT); main dorsal stabilizer</td>
</tr>
<tr>
<td>Deep bundle</td>
<td>Radius to triquetrum</td>
<td>The two bundles are typically indistinguishable</td>
</tr>
<tr>
<td></td>
<td>Radius to LT joint</td>
<td>Fibers attach to lunate and/or lunotriquetral ligament</td>
</tr>
</tbody>
</table>

- **Space of Poirier:** weak spot volarly where perilunate dislocations occur (between the proximal edge of RSC & UC ligaments distally and distal edge of IRL ligament proximally).
- No true ulnar collateral ligament exists in the wrist. The ECU & sheath provide some ulnar collateral support.
- Deep volar extrinsic ligaments can be seen easily during wrist arthroscopy; the superficial ones are difficult to visualize.
- The UC, UL, and UT form the ulnocarpal ligamentous complex.
### Intrinsic Ligaments

#### Midcarpal Joint

<table>
<thead>
<tr>
<th>Ligament</th>
<th>Attachments</th>
<th>Function / Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triquetrohamocapitate (THC)</td>
<td>Triquetrum to: Hamate</td>
<td>Medial/ulnar portion of arcuate ligament</td>
</tr>
<tr>
<td>Triquetrohamate (TH)</td>
<td>Hamate</td>
<td>Short, stout ligament</td>
</tr>
<tr>
<td>Triquetrocapitate (TC)</td>
<td>Capitate</td>
<td>Often confluent with the ulnocapitate part (UC) ligament</td>
</tr>
<tr>
<td>Scaphocapitate (SC)</td>
<td>Scaphoid to capitate</td>
<td>Stabilizes distal scaphoid. Radial part of arcuate lig.</td>
</tr>
</tbody>
</table>

#### Dorsal Intercarpal (DIC)

<table>
<thead>
<tr>
<th>Ligament</th>
<th>Attachments</th>
<th>Function / Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaphotrapeziotrapezoid (STT)</td>
<td>Scaphoid to tpzm./tpzd.</td>
<td>Lateral (radial) and scaphotrapezoid joint support</td>
</tr>
</tbody>
</table>

#### Interosseous Joints

**Proximal Row**: 2 joints. Ligaments are "C" shaped with dorsal and palmar limbs and a membranous portion between.

2. Lunotriquetral (LT) joint: Triquetrum provides an extension force to the lunate, which is resisted by the LT.

#### Distal Row: 3 joints as below. Strong interosseous ligaments keep distal row moving as a single unit.

<table>
<thead>
<tr>
<th>Ligament</th>
<th>Attachments</th>
<th>Function / Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapeziotrapezium</td>
<td>Trapezoid to trapezium</td>
<td>Each ligament has 3 parts (palmar, dorsal, deep/interosseous). Distal row ligaments are stronger than in proximal row. CH lig. is strongest distal row ligament.</td>
</tr>
<tr>
<td>Capitotrapezoid</td>
<td>Capitate to trapezium</td>
<td></td>
</tr>
<tr>
<td>Capitohamate</td>
<td>Capitate to hamate</td>
<td></td>
</tr>
</tbody>
</table>

### Pisotriquetral Articulation

<table>
<thead>
<tr>
<th>Ligament</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pisohamate</td>
<td>Inserts on hook of hamate; part of Guyon’s canal</td>
</tr>
<tr>
<td>Pisometacarpal</td>
<td>Assists in FCU flexion</td>
</tr>
</tbody>
</table>
Carpal tunnel: palmar view

- Palmaris longus tendon
- Radius
- Interosseous membrane
- Ulnar artery and nerve
- Flexor carpi ulnaris tendon
- Flexor digitorum profundus tendons
- Flexor digitorum superficialis tendons
- Pisiform
- Deep palmar branch of ulnar artery and deep branch of ulnar nerve
- Hook of hamate
- Flexor carpi radialis insertion

Radiocarpal joint

- Scapholunate lig.
- Radioscaphocapitate lig.
- Long radiolunate lig.
- Scaphoid fossa (of distal radius)
- Scapholunate ridge

Triangular fibrocartilage complex

- Prestyloid recess
- Triquetrum
- Ulnnotriquetral lig.
- Palmar distal radioulnar lig.
- Ulnolunate lig.
- Ulnar styloid
- ECU sheath
- Triangular fibrocartilage (disc)
- Dorsal distal radioulnar lig.
- Lunate fossa (of distal radius)
**LIGAMENTS**

**ATTACHMENTS**

**FUNCTION / COMMENT**

<table>
<thead>
<tr>
<th>DISTAL RADIOULNAR JOINT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• This joint (DRUJ) is stabilized by a combination of structures that form the triangular fibrocartilage complex (TFCC).</td>
<td></td>
</tr>
<tr>
<td>• Primary motion is pronation (60-80°) &amp; supination (60-85°); the radius rotates around the stationary ulna.</td>
<td></td>
</tr>
<tr>
<td>• 20% of an axial load is transmitted to ulna in an ulnar neutral wrist. The ulna takes more load when it is ulna positive.</td>
<td></td>
</tr>
</tbody>
</table>

**Triangular Fibrocartilage Complex**

<table>
<thead>
<tr>
<th>Triangular fibrocartilage</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• TFCC is interposed between the distal ulna and the ulnar proximal carpal row (triquetrum). It originates at the articular margin of the sigmoid notch (radius) and inserts at the base of the ulnar styloid.</td>
<td></td>
</tr>
<tr>
<td>• Vascular supply to TFCC (from ulnar artery &amp; anterior interosseous artery) penetrate the peripheral 10%-25%.</td>
<td></td>
</tr>
<tr>
<td>Radius to ulna fovea (deep fibers) &amp; styloid (superficial fibers)</td>
<td>TFC has 3 portions: central disc and 2 peripheral (radioulnar) ligaments</td>
</tr>
</tbody>
</table>
| Central (articular) disc | Blends w/ radial articular cartilage  
Resists compression and tension; avascular and aneural |
| Dorsal radioulnar | Dorsal radius to ulnar fovea (ligamentum subcruentum)  
Blends with TFC, tight in pronation, loose in supination |
| Palmar radioulnar | Volar radius to ulnar fovea (ligamentum subcruentum)  
Blends with TFC, tight in supination, loose in pronation |
| Meniscal homologue | Dorsal radius to volar triquetrum  
Highly vascular synovial fold |
| ECU tendon sheath | Ulna styloid, triquetrum, hamate  
Considered an “ulnar collateral ligament” |
| Other |  |
| • UL, UT, and prestyloid recess are considered by some to be a part of the TFCC. |  |
| Ulnolunate (UL)  
Ulnotriquetral (UT) | TFC to lunate  
TFC to triquetrum  
UL & UT blend with ulnocapitate lig. to contribute to fn of TFCC and stabilize the DRUJ. |
| Prestyloid recess | None  
Between palmar radioulnar ligament & meniscus homologue |
| • Other structures contributing to DRUJ stability: ECU, pronator quadratus, interosseous membrane. |  |
| • TFCC can be torn (degenerative or traumatic). Peripheral tears can be repaired, central tears need debridement. |  |
**CARPAL TUNNEL**

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>COMPONENTS</th>
<th>COMMENTS</th>
</tr>
</thead>
</table>
| Transverse carpal ligament (TCL, flexor retinaculum) | Attachments: Medial: pisiform and hamate  
Lateral: scaphoid and trapezium | • Roof of carpal tunnel, can compress median nerve.  
TCL is incised in a carpal tunnel release.  
Tunnel is narrowest at hook of hamate |
| Borders                    | Roof: transverse carpal ligament        | • See above  
• Especially capitate and trapezoid  
• Hook of hamate gives medial wall  
• Trapezium is primary wall structure |
| Contents                   | Tendons: FDS (4), FDP (4), FPL          | • 9 tendons within the carpal tunnel  
• Compressed in carpal tunnel syndrome |

- Thenar motor branch of median nerve can exit under, through, or distal to the transverse carpal ligament.  
- A persistent median artery or aberrant muscle can occur in the tunnel and may cause carpal tunnel syndrome.

**ULNAR TUNNEL / GUYON’S CANAL**

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>COMPONENTS</th>
<th>COMMENTS</th>
</tr>
</thead>
</table>
| Borders                    | Floor: transverse carpal ligament       | • Can be released simultaneously with CTR  
Root: volar carpal ligament  
Medial wall: pisiform  
Lateral wall: hook of hamate |  
• Continuous with deep antebrachial fascia  
• Neurovascular bundle is under pisohamate ligament  
• Fracture can cause nerve compression. |
| Contents                   | Ulnar nerve                             | • Divides in canal to deep & superficial branches  
Ulnar artery                | • Terminates as superficial arch around hamate |

- Fractures (malunion) or masses (e.g., ganglion cysts #1) can compress the ulnar nerve or artery within the canal.
**STRUCTURE FUNCTION COMMENTS**

### EXTENSOR COMPARTMENTS

- **Extensor retinaculum**
  - Covers the wrist dorsally
  - Forms six fibro-osseous compartments through which the extensor tendons pass

<table>
<thead>
<tr>
<th>Number</th>
<th>Tendon</th>
<th>Clinical Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>EPB, APL</td>
<td><em>de Quervain’s tenosynovitis</em> can develop here</td>
</tr>
<tr>
<td>II</td>
<td>ECRL, ECRB</td>
<td>Tendinitis can occur here</td>
</tr>
<tr>
<td>III</td>
<td>EPL</td>
<td>Travels around Lister’s tubercle, can rupture</td>
</tr>
<tr>
<td>IV</td>
<td>EDC, EIP</td>
<td>This compartment split in dorsal wrist approach</td>
</tr>
<tr>
<td>V</td>
<td>EDQ (EDM)</td>
<td>Rupture (Jackson-Vaughn syndrome) in RA</td>
</tr>
<tr>
<td>VI</td>
<td>ECU</td>
<td>Tendon can snap over ulnar styloid causing pain</td>
</tr>
</tbody>
</table>

- EIP and EDQ tendons are ulnar to EDC tendons to the index and small fingers, respectively.
- 1st compartment may have multiple slips that all need to be released in *de Quervain’s* disease for a full release.
**STEPS**

WRIST ASPIRATION/INJECTION

1. Ask patient about allergies
2. Palpate radiocarpal joint dorsally, find **Lister’s tubercle** and the space ulnar to it
3. Prep skin over dorsal wrist (iodine/antiseptic soap)
4. Anesthetize skin locally (quarter size spot)
5. **Aspiration:** insert 20-gauge needle into space ulnar to **Lister’s tubercle/EPL/ECRB** and radial to **EDC**, aspirate.
   **Injection:** insert 22-gauge needle into same space, aspirate to ensure not in vessel, then inject 1-2ml of local or local/steroid preparation into RC joint.
6. Dress injection site
7. If suspicious for infection, send fluid for Gram stain and culture

CARPAL TUNNEL INJECTION/MEDIAN NERVE BLOCK

1. Ask patient about allergies
2. Ask patient to pinch thumb and small finger tips; **palmaris longus (PL)** tendon will protrude (10% -20% do not have one). **Median nerve** is beneath PL, just ulnar to **FCR** within the carpal tunnel.
3. Prep skin over volar wrist (iodine/antiseptic soap)
4. Anesthetize skin locally (quarter size spot)
5. Insert 22-gauge or smaller needle into wrist ulnar to PL at flexion crease at 45º angle. Aspirate to ensure needle is not in vessel. Inject 1-2ml of local or local/steroid preparation.
6. Dress injection site

WRIST BLOCK

Four separate nerves are blocked. Based on the necessary anesthesia, a complete or partial block can be performed:

1. Ask patient about allergies
2. Prep skin over each landmark (iodine/antiseptic soap)
3. **Ulnar nerve:** palpate the FCU tendon just proximal to volar wrist crease. Insert needle under the FCU tendon. **Aspirate** to ensure needle is not in **ulnar artery** (nerve is ulnar to the artery). Inject 3-4ml of local anesthetic into the space dorsal to the FCU tendon.
4. **Dorsal cutaneous branch** of ulnar nerve: palpate the distal ulna/styloid. Inject a large subcutaneous wheal on the dorsal and ulnar aspect of the wrist, just proximal to the ulnar styloid.
5. **Superficial radial nerve:** block at radial styloid with a large subcutaneous wheal on the dorsoradial aspect of the wrist.
6. **Median nerve:** block in carpal tunnel as described above
7. **Palmar cutaneous branch** of median nerve: raise a wheal over the central volar wrist.

- **Median and superficial radial nerve blocks** are effective for thumb, index finger, and most middle finger injuries.
- **Ulnar and dorsal cutaneous branch blocks** are used for small finger injuries. Most ring finger injuries require complete wrist block.
**QUESTION** | **ANSWER** | **CLINICAL APPLICATION**
--- | --- | ---
1. Age | Young Middle aged, elderly | Trauma: fractures and dislocations, ganglions Arthritis, nerve entrapments, overuse
2. Pain | a. Onset | Acute Chronic | Trauma Arthritis
   b. Location | Dorsal Volar Radial Ulnar | Kienböck’s disease, ganglion Carpal tunnel syndrome (CTS), ganglion (esp. radiovolar) Scaphoid fracture, de Quervain’s tenosynovitis, arthritis Triangular fibrocartilage complex (TFCC) tear, tendinitis (e.g., ECU)
3. Stiffness | With dorsal pain With volar pain (at night) | Kienböck’s disease Carpal tunnel syndrome
4. Swelling | Joint: after trauma Joint: no trauma Along tendons | Fracture or sprain Arthritis, infection, gout Flexor or extensor tendinitis (calcific), de Quervain’s disease
5. Instability | Popping, snapping | Carpal instability (e.g., scapholunate dislocation)
6. Mass | Along wrist joint | Ganglion
7. Trauma | Fall on hand | Fractures: distal radius, scaphoid; dislocation: lunate; TFCC tear
8. Activity | Repetitive motion (e.g., typing) | CTS, de Quervain’s tenosynovitis
9. Neurologic symptoms | Numbness, tingling Weakness | Nerve entrapment (e.g., CTS), thoracic outlet syndrome, radiculopathy (cervical spine) Nerve entrapment (median, ulnar, radial)
10. History of arthritides | Multiple joints involved | Arthritis
**EXAMINATION** | **TECHNIQUE** | **CLINICAL APPLICATION**
--- | --- | ---
**INSPECTION**
Gross deformity | Bones and soft tissues | Fractures, dislocations: forearm and wrist
Swelling | Especially dorsal or radial | Ganglion cyst
Diffuse | Trauma (fracture/dislocation), infection
Wasting | Loss of muscle | Peripheral nerve compression (e.g., CTS)

**PALPATION**
Skin changes | Warm, red | Infection, gout
Cool, dry | Neurovascular compromise
Radial and ulnar styloids | Palpate each separately | Tenderness may indicate fracture
Carpal bones | Both proximal and distal row | Snuffbox tenderness: scaphoid fracture; lunate tenderness: Kienböck’s disease
Proximal row | Scapholunate dissociation
Pisiform | Tenderness: pisotriquetral arthritis or FCU tendinitis
Soft tissues | 6 dorsal extensor compartments | Tenderness over 1st compartment: *de Quervain’s disease*
TFCC: distal to ulnar styloid Compartments | Tenderness indicates TFCC injury
Firm/tense compartments = compartment synd.
### EXAMINATION TECHNIQUE CLINICAL APPLICATION

#### RANGE OF MOTION

<table>
<thead>
<tr>
<th>Technique</th>
<th>Description</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flex and extend</td>
<td>Flex (toward palm), extend opposite</td>
<td>Flexion 80°, extension 75°</td>
</tr>
<tr>
<td>Radial/ulnar deviation</td>
<td>In plane of the palm</td>
<td>Radial 15-25°, ulnar 30-45°</td>
</tr>
<tr>
<td>Pronate and supinate</td>
<td>Flex elbow 90°, rotate wrist</td>
<td>Normal: supinate 90°, pronate 80-90° (most motion is in elbow)</td>
</tr>
</tbody>
</table>

#### NEUROVASCULAR

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Description</th>
<th>Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral cutaneous nerve of forearm (C6)</td>
<td>Lateral forearm</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Medial cutaneous nerve of forearm (T1)</td>
<td>Medial forearm</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Posterior cutaneous nerve of forearm</td>
<td>Posterior forearm</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Description</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial nerve (C6-7)</td>
<td>Resisted wrist extension</td>
<td>ECRL/B or corresponding nerve/root lesion</td>
</tr>
<tr>
<td>PIN (C6-7)</td>
<td>Resisted ulnar deviation</td>
<td>ECU or corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Ulnar nerve (C8)</td>
<td>Resisted wrist flexion</td>
<td>FCU or corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Median nerve (C7)</td>
<td>Resisted wrist flexion</td>
<td>FCR or corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Median nerve (C6)</td>
<td>Resisted pronation</td>
<td>Pronator teres or corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Musculocutaneous (C6)</td>
<td>Resisted supination</td>
<td>Biceps or corresponding nerve/root lesion</td>
</tr>
</tbody>
</table>

#### Reflex

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Description</th>
<th>Hypoactive/absence</th>
</tr>
</thead>
<tbody>
<tr>
<td>C6</td>
<td>Brachioradialis</td>
<td>Indicates corresponding radiculopathy</td>
</tr>
</tbody>
</table>

#### Pulses

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Description</th>
<th>Vascular Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial, ulnar</td>
<td>Diminished/absent</td>
<td>Vascular injury or compromise (perform Allen test)</td>
</tr>
</tbody>
</table>
**EXAMINATION** | **TECHNIQUE** | **CLINICAL APPLICATION / DDX**
--- | --- | ---
**SPECIAL TESTS**
Durkan carpal compression | Manual pressure on median nerve at carpal tunnel | Reproduction of symptoms (e.g., tingling, numbness): median nerve compression (most sensitive test for carpal tunnel syndrome [CTS])
Phalen test | Flex both wrists for 1 minute | Reproduction of symptoms (e.g., tingling): median n. compression (CTS)
Tinel | Tap volar wrist (CT/TCL) | Reproduction of symptoms (e.g., tingling): median n. compression (CTS)
Finkelstein | Flex thumb into palm, ulnarly deviate the wrist | Pain in 1st dorsal compartment (APL/EPB tendons) suggests de Quervain’s tenosynovitis
“Piano key” | Stabilize ulnar and translate radius dorsal and volar | Laxity or subluxation (click) indicates instability of DRUJ
Watson (scaphoid shift) | Push dorsally on distal pole of scaphoid, bring wrist from ulnar to radial deviation | A click or clunk (scaphoid subluxating dorsally over rim of distal radius) is positive for carpal instability (scapholunate dissociation)
Allen test | Occlude both radial and ulnar arteries manually, pump fist, then release one artery only | Delay or absence of “pinking up” of the palm and fingers suggests arterial compromise of the artery released

The Finkelstein test exacerbates the pain; it is performed by flexing the thumb and then placing the wrist in ulnar deviation.

Provocative tests elicit paresthesias in hand.
MUSCLES: ORIGINS AND INSERTIONS • Forearm

### Anterior (volar)

**Origins**
- Flexor digitorum superficialis (1 head)
- Pronator teres
- Supinator
- Flexor digitorum profundus

**Insertions**
- Brachialis
- Biceps brachii
- Supinator
- Flexor digitorum superficialis muscle (radial head)

**Note:** Attachments of intrinsic muscles of hand not shown

### Table: Origins and Insertions

<table>
<thead>
<tr>
<th>Proximal Ulna</th>
<th>Proximal Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anterior</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Origins</strong></td>
<td><strong>Insertions</strong></td>
</tr>
<tr>
<td>Flexor digitorum superficialis (1 head)</td>
<td>Flexor digitorum superficialis (1 head)</td>
</tr>
<tr>
<td>Pronator teres</td>
<td>Pronator teres</td>
</tr>
<tr>
<td>Supinator</td>
<td>Flexor teres</td>
</tr>
<tr>
<td>Flexor digitorum profundus</td>
<td>Flexor digitorum profundus</td>
</tr>
<tr>
<td><strong>Insertions</strong></td>
<td><strong>Origins</strong></td>
</tr>
<tr>
<td>Brachialis</td>
<td>Biceps brachii</td>
</tr>
<tr>
<td></td>
<td>Supinator</td>
</tr>
</tbody>
</table>

**Common extensor tendon**
- Pronator teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, flexor digitorum superficialis (humeroulnar head) muscles

**Flexor digitorum superficialis muscle (humeroulnar head)**
- Pronator teres muscle (ulnar head)

**Flexor digitorum profundus muscle**
- Pronator teres muscle (humeroulnar head)

**Ulna**
- Pronator quadratus muscle
- Brachialis muscle
- Pronator teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, flexor digitorum superficialis (humeroulnar head) muscles

**Radius**
- Brachioradialis muscle
- Pronator quadratus muscle
- Abductor pollicis longus muscle
- Flexor carpi radialis muscle
- Flexor carpi ulnaris muscle
- Flexor digitorum superficialis muscle

**Flexor pollicis longus muscle**
Forearm • MUSCLES: ORIGINS AND INSERTIONS

Posterior (dorsal)

Note: Attachments of intrinsic muscles of hand not shown.

Flexor carpi ulnaris muscle (humeroradial joint)

Flexor carpi ulnaris muscle (ulnar origin)

Flexor digitorum profundus muscle

Extensor carpi ulnaris muscle (ulnar origin)

Extensor pollicis longus muscle

Extensor indicis muscle

Extensor digitorum muscle

Extensor carpi radialis longus muscle

Extensor carpi radialis brevis muscle

Extensor digitorum muscle (central bands)

Extensor digiti minimi muscle

Extensor digitorum muscle (lateral bands)

Origins

Insertions

<table>
<thead>
<tr>
<th>PROXIMAL ULNA</th>
<th>PROXIMAL RADIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>POSTERIOR</td>
<td>POSTERIOR</td>
</tr>
<tr>
<td>Origins</td>
<td>Origins</td>
</tr>
<tr>
<td>Flexor carpi ulnaris</td>
<td>Triceps brachii muscle</td>
</tr>
<tr>
<td>Flexor digitorum profundus</td>
<td>Anconeus muscle</td>
</tr>
<tr>
<td>Supinator</td>
<td>Biceps brachii muscle</td>
</tr>
<tr>
<td></td>
<td>Supinator</td>
</tr>
<tr>
<td>Insertions</td>
<td>Insertions</td>
</tr>
<tr>
<td>Triceps</td>
<td>Anconeus</td>
</tr>
<tr>
<td>Anconeus</td>
<td>Supinator</td>
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162 NETTER’S CONCISE ORTHOPAEDIC ANATOMY
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<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial flexors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pronator teres (PT)</td>
<td>Humeral head</td>
<td>Medial epicondyle</td>
<td>Lateral radius middle ⅓</td>
<td>Pronate and flex forearm</td>
<td>Can compress median nerve (pronator syndrome)</td>
</tr>
<tr>
<td></td>
<td>Ulnar (deep) head</td>
<td>Proximal ulna</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexor carpi radialis (FCR)</td>
<td>Medial epicondyle</td>
<td>Base of 2nd (and 3rd) metacarpal</td>
<td>Median</td>
<td>Flex wrist, radial deviation</td>
<td>Radial artery is immediately lateral</td>
</tr>
<tr>
<td>Palmaris longus (PL)</td>
<td>Medial epicondyle</td>
<td>Flexor retinaculum/palmar aponeurosis</td>
<td>Median</td>
<td>Flex wrist</td>
<td>Used for tendon transfers, 10% congenitally absent</td>
</tr>
<tr>
<td>Flexor carpi ulnaris (FCU)</td>
<td>1. Medial epicondyle</td>
<td>2. Posterior ulna</td>
<td>Pisiform, hook of hamate, 5th MC</td>
<td>Flex wrist, ulnar deviation</td>
<td>Most powerful wrist flexor. May compress ulnar nerve</td>
</tr>
</tbody>
</table>

**Netter's Concise Orthopaedic Anatomy** 163
<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexor digitorum superficialis (FDS)</td>
<td>1. Medial epicondyle proximal ulna 2. Anteroproximal radius</td>
<td>Middle phalanges of digits (not thumb)</td>
<td>Median</td>
<td>Flex PIPJ (also flex digit and wrist)</td>
<td>Sublimus test will isolate and test function</td>
</tr>
</tbody>
</table>

FDS is often considered a “middle flexor” because of its position between muscles.
### MUSCLES: ANTERIOR COMPARTMENT

#### Forearm

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexor digitorum profundus (FDP)</td>
<td>Anterior ulna &amp; interosseous membrane</td>
<td>Distal phalanx (IF, +/− MF) Distal phalanx (RF, SF, +/− MF)</td>
<td>Median/AIN</td>
<td>Flex DIPJ (also flex digit and wrist)</td>
<td>Avulsion: Jersey finger</td>
</tr>
<tr>
<td>Flexor pollicis longus (FPL)</td>
<td>Anterior radius &amp; proximal ulna</td>
<td>Distal phalanx of thumb</td>
<td>Median/AIN</td>
<td>Flex thumb IP</td>
<td>FDP and FPL are most susceptible to Volkman’s contracture</td>
</tr>
<tr>
<td>Pronator quadratus (PQ)</td>
<td>Medial distal ulna</td>
<td>Anterior distal radius</td>
<td>Median/AIN</td>
<td>Pronate forearm</td>
<td>Primary pronator (initiates pronation)</td>
</tr>
</tbody>
</table>

*AIN innervates all three deep flexors. It is tested by making “OK” signs.*
### MUSCLES: POSTERIOR COMPARTMENT

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SUPERFICIAL EXTENSORS</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Anconeus</td>
<td>Posterior-lateral epicondyle</td>
<td>Posterior-proximal ulna</td>
<td>Radial</td>
<td>Forearm extension</td>
<td>Muscular plane in Kocher approach</td>
</tr>
<tr>
<td>Extensor digiti minimi (EDM)</td>
<td>Lateral epicondyle</td>
<td>Same as above in small finger</td>
<td>Radial-PIN</td>
<td>SF extension</td>
<td>Aka EDQ: In 5th dorsal compartment</td>
</tr>
<tr>
<td>Extensor carpi ulnaris (ECU)</td>
<td>Lateral epicondyle</td>
<td>Base of 5th MC</td>
<td>Radial-PIN</td>
<td>Hand extension and adduction</td>
<td>Can cause painful snapping over ulna</td>
</tr>
<tr>
<td><strong>Mobile Wad</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brachioradialis (BR)</td>
<td>Lateral condyle</td>
<td>Lateral distal radius</td>
<td>Radial</td>
<td>Forearm flexion</td>
<td>Is a deforming force in radius fractures</td>
</tr>
<tr>
<td>Extensor carpi radialis longus</td>
<td>Lateral condyle</td>
<td>Base of 2nd MC</td>
<td>Radial</td>
<td>Wrist extension</td>
<td>Aka ECRL</td>
</tr>
<tr>
<td>Extensor carpi radialis brevis</td>
<td>Lateral epicondyle</td>
<td>Base of 3rd MC</td>
<td>Radial-PIN</td>
<td>Wrist extension</td>
<td>ECRB degenerates in tennis elbow</td>
</tr>
<tr>
<td>MUSCLE</td>
<td>ORIGIN</td>
<td>INSERTION</td>
<td>NERVE</td>
<td>ACTION</td>
<td>COMMENT</td>
</tr>
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</tr>
<tr>
<td>Supinator</td>
<td>Posterior medial ulna</td>
<td>Proximal lateral radius</td>
<td>Radial-PIN</td>
<td>Forearm supination</td>
<td>PIN pierces muscles, can be compressed</td>
</tr>
<tr>
<td>Abductor pollicis longus (APL)</td>
<td>Posterior radius/ulna</td>
<td>Base of 1st thumb metacarpal</td>
<td>Radial-PIN</td>
<td>Abduct and extend thumb (CMCJ)</td>
<td>de Quervain’s disease (may have multiple slips)</td>
</tr>
<tr>
<td>Extensor pollicis brevis (EPB)</td>
<td>Posterior radius</td>
<td>Base of thumb prox. phalanx</td>
<td>Radial-PIN</td>
<td>Extend thumb (MCPJ)</td>
<td>Radial border of snuffbox</td>
</tr>
<tr>
<td>Extensor pollicis longus (EPL)</td>
<td>Posterior ulna</td>
<td>Base of thumb distal phalanx</td>
<td>Radial-PIN</td>
<td>Extend thumb (IPJ)</td>
<td>Tendon turns 45° on Lister’s tubercle</td>
</tr>
<tr>
<td>Extensor indicis proprius (EIP)</td>
<td>Posterior ulna</td>
<td>Same as EDC &amp; EDM</td>
<td>Radial-PIN</td>
<td>Index finger extension</td>
<td>Ulnar to EDC tendon; last PIN muscle</td>
</tr>
</tbody>
</table>
Ulnar nerve/artery: Run under FDS on top of FDP muscles, ulnar to the artery.
Superior radial nerve: Runs under the brachioradialis muscle/tendon, radial to the artery.
Radial artery: Is radial (lateral) to FCR muscle and tendon.
Median nerve: Is radial (lateral) to ulnar nerve, runs between FDP and FPL muscles into the carpal tunnel.
Post. interosseous nerve (PIN): Pierces supinator muscle proximally, runs between APL & EPL along interosseous membrane.
Incisions for Compartment Syndrome of Forearm and Hand

**Volar incision**
- Wick catheter in volar compartment
- Antebrachial (encircling) fascia
- Radial a. and superficial branch of radial n.
- Antebrachial (encircling) fascia
- Radius
- Dorsal interosseous a. and n.
- Deep branch of radial n.
- Wick catheter in dorsal compartment

**Dorsal incision**
- Antebrachial (encircling) fascia
- Median n.
- Ulnar a. and n.
- Anterior interosseous a. and n.
- Interosseous membrane
- Radius
- Dorsal interosseous a. and n.
- Deep branch of radial n.
- Wick catheter in dorsal compartment

**Section through midforearm**
- Volar forearm incision
- Dorsal forearm incision
- Note: fascial incisions are the same lines as skin incisions

**Structured Contents**

<table>
<thead>
<tr>
<th>Structure</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anterior</strong></td>
<td></td>
</tr>
<tr>
<td>Superficial</td>
<td>Pronator teres (PT), flexor carpi radialis (FCR), palmaris longus (PL), flexor carpi ulnaris (FCU)</td>
</tr>
<tr>
<td>Middle</td>
<td>Flexor digitorum superficialis (FDS)</td>
</tr>
<tr>
<td>Deep</td>
<td>Flexor digitorum profundus (FDP), flexor pollicis longus (FPL), pronator quadratus (PQ)</td>
</tr>
<tr>
<td><strong>Posterior</strong></td>
<td></td>
</tr>
<tr>
<td>Superficial</td>
<td>Anconeus, ext. digit. communis (EDC), ext. digit. minimi (EDM), ext. carpi ulnaris (ECU)</td>
</tr>
<tr>
<td>Deep</td>
<td>Supinator, abd. poll. longus (APL), ext. poll. brevis (EPB), ext. poll. longus (EPL), ext. indicis proprius (EIP)</td>
</tr>
<tr>
<td><strong>Mobile Wad</strong></td>
<td></td>
</tr>
<tr>
<td>Brachioradialis, extensor carpi radialis longus (ECRL), extensor carpi radialis brevis (ECRB)</td>
<td></td>
</tr>
</tbody>
</table>

**Fasciotomies**

- Palmar incision: Releases the entire anterior compartment
- Dorsal incision: Releases the entire posterior compartment and mobile wad
Anterior view

Musculocutaneous nerve

Median nerve (C[5], 6, 7, 8, T1)

Inconstant contribution

Pronator teres muscle (humeral head)

Articular branch

Flexor carpi radialis muscle

Palmaris longus muscle

Pronator teres muscle (ulnar head)

Flexor digitorum superficialis muscle (turned up)

Flexor digitorum profundus muscle (lateral part supplied by median [anterior interosseous] nerve; medial part supplied by ulnar nerve)

Anterior interosseous nerve

Flexor pollicis longus muscle

Pronator quadratus muscle

Palmar cutaneous branch of median nerve

Medial and Lateral Cords of brachial plexus

Cords of brachial plexus

Median brachial cutaneous nerve

Medial antebrachial cutaneous nerve

Axillary nerve

Radial nerve

Ulnar nerve

BRACHIAL PLEXUS

Medial and Lateral Cords

Median Nerve (C[5]6-T1): In anterior forearm, under lacerus fibrosus* (biceps aponeurosis), between the 2 heads of pronator teres.* The AIN (anterior interosseous nerve) branches, then nerve passes under arch of FDS*; then on/between FDP and FPL into carpal tunnel*.

Palmar cutaneous branch divides 5cm proximal to wrist & runs b/w the FCR and PL. The motor recurrent branch divides after (50%), under (30%), or through (20%) the transverse carpal ligament (TCL).

Sensory: None (in forearm, see Hand)

Motor: • Anterior compartment

○ Pronator teres (PT)

○ Flexor carpi radialis (FCR)

○ Palmaris longus (PL)

○ Flexor dig. super. (FDS)

*Potential site of nerve compression.

Anterior Interosseous Nerve (AIN): Branches proximally, then runs along the interosseous membrane with anterior interosseous artery, between FPL & FDP

Sensory: Volar wrist capsule

Motor: • Anterior compartment—deep flexors

○ Flexor digitorum profundus (FDP) to 2nd (3rd) digits

○ Flexor pollicis longus (FPL)

○ Pronator quadratus (PQ)
**Inconstant contribution**

**Posterior view**

- Radial nerve (C5, 6, 7, 8, [T1])
- Superficial (terminal) branch
- Deep (terminal) branch (PIN)
- Lateral epicondyle
- Anconeus muscle
- Brachioradialis muscle
- Extensor carpi radialis longus muscle
- Supinator muscle
- Extensor carpi radialis brevis muscle
- Extensor carpi ulnaris muscle
- Extensor digitorum muscle and extensor digiti minimi muscle
- Extensor indicis muscle
- Extensor pollicis longus muscle
- Abductor pollicis longus muscle
- Extensor pollicis brevis muscle
- Extensor digitorum muscle and extensor digiti minimi muscle
- Extensor pollicis longus muscle
- Abductor pollicis longus muscle
- Extensor pollicis brevis muscle

**Superficial branch of radial nerve and dorsal digital branches**

**Posterior interosseous nerve** (continuation of deep branch of radial nerve distal to supinator muscle)

**Superficial nerve of forearm**

**Posterior cutaneous nerve of forearm**

**Cutaneous innervation from radial and axillary nerves**

---

**BRACHIAL PLEXUS**

**Posterior Cord**

**Radial** (C5-T1): Enters forearm b/w brachioradialis (BR) & brachialis, then divides into deep and superficial branches. **Superficial** br. runs under BR to thumb web space. It can be compressed under the **BR tendon**. It is lateral to the radial artery. **Deep** br. pierces the supinator, then becomes the **PIN**.

**Sensory:** Posterior forearm: via posterior cutaneous nerve of forearm

**Motor:** Anconeus
- Mobile wad
  - Brachioradialis (BR)
  - Extensor carpi radialis longus (ECRL)

---

**Posterior Interosseous Nerve** (PIN): Runs past vascular *Leash of Henry* (recurrent radial artery) and ECRB, through the **arcade of Frohse** (proximal supinator), into the supinator, past its **distal edge**,

**Sensory:** Dorsal wrist capsule (in 4th dorsal compartment)

**Motor:**
- Mobile wad
  - Extensor carpi radialis brevis (ECRB)
- Posterior compartment—superficial extensors
  - Supinator
  - Extensor digitorum communis (EDC)
  - Extensor digiti minimi (EDM or EDO)
  - Extensor carpi ulnaris (ECU)
- Posterior compartment—deep extensors
  - Abductor pollicis longus (APL)
  - Extensor pollicis brevis (EPB)
  - Extensor pollicis longus (EPL)
  - Extensor indicis proprius (EIP)

*Potential site of nerve compression.*
### BRACHIAL PLEXUS

#### Lateral Cord

**Musculocutaneous** (C5-7): Exits between biceps & brachialis, purely sensory, runs in subcutaneous tissues above the brachioradialis

- **Sensory:** Radial forearm: via lateral cutaneous nerve of forearm
- **Motor:** None (in forearm)

#### MEDIAL CORD

**Medial Cutaneous Nerve of Forearm** (Antebrachial Cutaneous) (C8-T1): Branches directly from the cord, runs subcutaneously anterior to medial epicondyle into the medial forearm

- **Sensory:** Medial forearm
- **Motor:** None

**Ulnar** (C7-8-T1): Runs posterior to medial epicondyle in cubital tunnel,* then through FCU heads/aponeurosis,* then runs on FDP (under FDS) to wrist. The **dorsal** and **palmar cutaneous branches** divide 4-5cm proximal to wrist, then the nerve runs into the ulnar tunnel (Guyon’s canal*), where it divides into deep/motor & superficial/sensory branches

- **Sensory:** None (in forearm)
- **Motor:**
  - Anterior compartment
    - Flexor carpi ulnaris (FCU)
    - Flexor digitorum profundus (FDP) to (3rd), 4th, 5th digits

*Potential site of nerve compression.
**COURSE BRANCHES**

### FOREARM

**Radial Artery**
- Runs over the pronator teres, on FDS & FPL lateral to the FCR
- Radial recurrent (leash of Henry)
- Muscular branches

**Ulnar Artery**
- Runs under the ulnar head of the pronator teres, on the FDP muscle, lateral and adjacent to the ulnar nerve
- Anterior ulnar recurrent
- Posterior ulnar recurrent
- Common interosseous
  - Anterior interosseous
  - Posterior interosseous
- Muscular branches

### WRIST

**Radial Artery**
- Lateral to FCR tendon, wraps dorsally, under the APL & EPB tendons, between the 2 heads of 1st dorsal interosseous muscles, to the palm ending in deep arch
- Palmar carpal branch
- Dorsal carpal branch
- Superficial palmar branch
  - Palmar scaphoid branch
  - Dorsal scaphoid branch
- Deep palmar arch
- Deep to flexor tendons
- Deep to extensor tendons
- Anastomoses w/super. palmar arch
- Supplies 25% of scaphoid (distal)
- Supplies 75% of scaphoid (proximal)
- Terminal branch of radial artery in hand

**Ulnar Artery**
- On transverse carpal ligament (TCL) into Guyon’s canal, divides into deep and superficial palmar branches
- Palmar carpal branch
- Dorsal carpal branch
- Deep palmar branch
- Superficial palmar arch
- Deep to flexor tendons
- Deep to extensor tendons
- Anastomoses with deep palmar arch
- Terminal branch of the ulnar artery

---

**Allen test**: Occlude both radial and ulnar arteries at the wrist. Patient squeezes fist to exsanguinate the hand. Release one artery and check for hand perfusion. Repeat with the other artery. Test confirms patency of arches/vessels.
### Triangular Fibrocartilage Complex (TFCC) Tear

**DESCRIPTION**

- Can be traumatic (class 1) or degenerative (class 2)
- Only periphery is vascular (i.e., peripheral tear can be repaired)

**Hx & PE**

- **Hx:** Ulnar wrist pain, +/- popping/grinding
- **PE:** TFCC is TTP, + TFCC, grind, +/- piano key

**WORKUP/FINDINGS**

- **XR:** Usually normal; tears assoc. w/styloid base fx
  - **MRA:** Study of choice for diagnosis of tears

**TREATMENT**

1. Class 1: repair or debride tear (fix styloid fracture if needed)
2. Class 2: NSAIDs, splint; ulnar shortening procedure

### De Quervain’s Tenosynovitis

**DESCRIPTION**

- Inflammation of first dorsal compartment (APL/EPB tendons)
- Middle age women #1.
- Assoc. w/tendon abnormality

**Hx:** Radial pain/swelling

**PE:** Tenderness at 1st dorsal compartment, + Finkelstein’s test

**XR:** Usually normal

**MR:** No indication

**TREATMENT**

1. Splint and NSAIDs
2. Corticosteroid injection into sheath
3. Surgical release

### Ganglion Cyst

**DESCRIPTION**

- Synovial fluid–filled cyst arising from a wrist joint
- Most common mass in wrist
- Dorsal wrist most common site (usually from SL joint)

**Hx:** Mass, +/- pain

**PE:** Palpable, mobile mass, +/- tenderness, + transillumination

**XR:** Wrist series usually normal

**MR:** Will show cyst well, needed only if diagnosis is uncertain

**TREATMENT**

1. Observation if asymptomatic
2. Aspiration (recurrence 20%)
3. Excision (including stalk of cyst; recurrence <10%)
**MEDIAN NERVE COMPRESSION**

**Pronator Syndrome**
- Proximal median nerve compression
- Sites: 1. Ligament of Struthers, 2. Pronator teres, 3. Lacertus fibrosus, 4. FDS aponeurosis/arch
- Hx: Numbness, tingling, +/- weakness
- PE: Decreased palm sensation, +/- pronator or FDS sign
- XR: Look for supracondylar process off humerus
- EMG/NCS: Can confirm dx (can also be normal)
- Treatment:
  1. Activity modification/rest
  2. Splinting, NSAIDs
  3. Surgical decompression of all proximal compression sites

**AIN Syndrome**
- Rare nerve compression
- Same sites at pronator syndrome
- Motor symptoms only
- Hx: Weakness, +/- pain
- PE: Weak thumb (FPL) and IF (FDP) pinch
- XR: Usually normal
- EMG/NCS: Will confirm diagnosis if unclear
- Treatment:
  1. Activity modification
  2. Splinting, NSAIDs
  3. Surgical decompression

**Carpal Tunnel Syndrome**
- Compression in carpal tunnel
- Most common neuropathy
- Associated with metabolic diseases (thyroid, diabetes), pregnancy
- Hx: Numbness, +/- pain
- PE: +/- thenar atrophy, Durkin’s, +/- Phalen’s & Tinel’s tests
- XR: Usually normal
- EMG/NCS: Will confirm diagnosis if unclear (increased latency, decreased velocity)
- Treatment:
  1. Activity modification
  2. Night splints, NSAIDs
  3. Corticosteroid injection
  4. Carpal tunnel release
### Radial Nerve Compression

**Pin Syndrome**
- **Hx & PE**: Hand & wrist weakness, +/- elbow pain
- **MR**: Evaluate for masses
- **EMG/NCS**: Confirms diagnosis & localizes lesion

- **TREATMENT**
  1. Activity modification
  2. Splint, NSAIDs
  3. Surgical decompression (complete release)

### Radial Tunnel Syndrome
- **Hx & PE**: Lat. elbow pain
- **PE**: Radial tunnel TTP, no weakness

- **TREATMENT**
  1. Activity modification
  2. Splint, NSAIDs
  3. Surgical decompression

### Wartenberg’s Syndrome
- **Hx**: Numbness/pain
- **PE**: Decr. sensation, IF/thumb. + Tinel’s, sx w/pronation

- **TREATMENT**
  1. Activity modification
  2. Wrist splint, NSAIDs

### Ulnar Nerve Compression
- **Ulnar Tunnel (Guyon’s Canal) Syndrome**
- **Hx**: Numbness, weakness in hand
- **PE**: Decr. sensation, +/- atrophy, clawing, weakness

- **TREATMENT**
  1. Activity modification
  2. Splint, NSAIDs
  3. Surgical decompression (address underlying cause of compression)
## Carpal Instability

### Carpal Instability, Dissociative (CID)

- Instability within a carpal row; two main types:
  1. Dorsal intercalated segment instability (DISI)
     - Due to scapholunate (SL) ligament disruption or scaphoid fracture/nonunion
     - Deformity: scaphoid flexes, lunate extends
     - May lead to STT arthritis or SLAC wrist
  2. Volar intercalated segment instability (VISI)
     - Due to lunotriquetral ligament disrupted (also requires dorsal radiocarpal lig. injury)

### Evaluation

- **Hx:** Trauma, pain +/- popping
- **PE:** +/- decreased ROM, +/- snuffbox or SL/LT interval tenderness, + Watson test (DISI) or Regan test (VISI)
- **XR:** Wrist & clenched fist views
  - DISI: SL gap >3mm, SL angle >70°, "ring sign"
  - VISI: disrupted carpal arches
- **MRA:** Can confirm ligament inj.

### Treatment

- **Acute/early treatment:**
  1. Fx: ORIF of scaphoid
  2. Ligament: SL or LT ligament repair or reconstruction with pin fixation
  3. Capsulodesis
- **Chronic/late treatment:**
  1. Limited fusion (e.g., STT fusion for DISI)

### Carpal Instability, Nondissociative (CIND)

- Instability between carpal rows
- Midcarpal or radiocarpal variations
- Associated with generalized hyperlaxity or trauma to ligaments (e.g., ulnar translation at RCJ) or to bones (e.g., distal radius fracture)

### Evaluation

- **Hx:** Fall/trauma or ligament hyperlaxity; popping/clunking
- **PE:** Tenderness, instability
- **XR:** Evaluate for fx & static carpal translation
- **Fluoro:** Dynamic carpal transl.

### Treatment

- **1. Nonoperative:** splint/cast (esp. midcarpal)
- **2. Arthrodesis (fusion):**
  - Midcarpal
  - Radiocarpal

### Carpal Instability, Combined (CIC)

- Instability both within a row & between rows
- Perilunate dislocation most common
- Greater arc injury = transosseous injury
- Lesser arc injury = ligamentous injury

### Evaluation

- **Hx:** Fall/trauma, pain
- **PE:** Tenderness, instability
- **XR:** Disruption of carpal arches, lunate abnormality (angle &/or position)

### Treatment

- **1. ORIF of bones with primary repair of ligaments**
- **2. Late: arthrodesis**
### Degenerative/Arthritic Conditions

- **Primary osteoarthritis in the wrist** is uncommon. It is usually posttraumatic (distal radius/scaphoid fx or lig. injury).

#### Scapholunate Advanced Collapse (SLAC)

- **Wrist arthritis due to posttraumatic scaphoid flexion deformity (SL ligament injury or scaphoid fracture [SNAC])**
- **Arthritis progresses over four stages (I-IV)**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP/Findings</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary osteoarthritis in the wrist</strong> is uncommon. It is usually posttraumatic (distal radius/scaphoid fx or lig. injury).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Scapholunate Advanced Collapse (SLAC)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist arthritis due to posttraumatic scaphoid flexion deformity (SL ligament injury or scaphoid fracture [SNAC])</td>
<td>Hx: Prior trauma/fall (often untreated), pain</td>
<td>XR: 4 stages. DJD at: I. Rad. styloid &amp; scaphoid II. Radioscaphoid joint III. Capitolunate joint IV. Captate migration (radiolunate joint is spared)</td>
<td>I. Styloidectomy &amp; STT fusion II. Proximal row carpectomy or scaphoidectomy &amp; 4 corner (lun., tri., cap., ham.) fusion III. 4 corner fusion IV. Wrist arthrodesis (fusion)</td>
</tr>
<tr>
<td>Arthritis progresses over four stages (I-IV)</td>
<td>PE: +/- decreased ROM with pain, tenderness to palpation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Rheumatoid Arthritis

- **Inflammatory disorder attacks synovium and destroys joint**
- **Radiocarpal (supination & ulnar volar translation) & DRUJ (ulna subluxates dorsally) affected**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP/Findings</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiocarpal (supination &amp; ulnar volar translation) &amp; DRUJ (ulna subluxates dorsally) affected</strong></td>
<td>PE: Swelling, deformity (volar, ulnar translation of the carpus)</td>
<td>LABS: RF, ANA, ESR</td>
<td></td>
</tr>
</tbody>
</table>

#### Kienböck’s Disease

- **Osteonecrosis of the lunate**
- **Etiology: traumatic or repetitive microtrauma to lunate**
- **4 radiographic stages**
- **Associated with ulnar negative variance of wrist**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP/Findings</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Osteonecrosis of the lunate</strong></td>
<td>Hx: Pain, stiffness, and disability of wrist</td>
<td>XR: Stage I: Normal x-ray; II: Lunate sclerosis IIIA: Lunate fragmented IIIB: IIIA + scaphoid flexed IV. DJD of adjacent joints</td>
<td>Stage: I. Immobilization I-III: Radial shortening II: STT fusion or proximal row carpectomy (PRC) IV. Wrist fusion or PRC</td>
</tr>
<tr>
<td><strong>Etiology: traumatic or repetitive microtrauma to lunate</strong></td>
<td>PE: Lunate/proximal row tenderness, decreased ROM, decreased grip strength</td>
<td>MR: Needed to dx stage I</td>
<td></td>
</tr>
<tr>
<td><strong>4 radiographic stages</strong></td>
<td>Associated with ulnar negative variance of wrist</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Madelung’s Deformity

- **Description:**
  - Deformity of the distal radius
  - Volar ulnar physis disrupted causes increased volar tilt & radial inclination
  - Ages 6-12; females > males

- **Evaluation:**
  - **Hx:** Pain in wrists & deformity
  - **PE:** Deformity & prominent ulna head
  - **XR:** Distal radius deformity (incr. tilt & inclination) & dorsal ulna subluxation

- **Treatment:**
  - Asymptomatic: observation and/or activity modification
  - Symptomatic: radial osteotomy +/- ulna recession

---

### Radial Club Hand (Radial Hemimelia)

- **Description:**
  - Failure of formation (partial or complete: stages I-IV) of the radius
  - Associated with syndromes (TAR, VATER)

- **Evaluation:**
  - **Hx/PE:** Bowing of forearm, radial deviation of hand
  - **XR:** Radius short or absent, bowed ulna

- **Treatment:**
  1. Elbow ROM (no surgery if stiff)
  2. Hand centralization (age 1)

---

#### Netter’s Concise Orthopaedic Anatomy 179
<table>
<thead>
<tr>
<th>USES</th>
<th>INTERNERVOUS PLANE</th>
<th>DANGERS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOREARM: ANTERIOR APPROACH (HENRY)</td>
<td>Proximal</td>
<td>Radial artery</td>
<td>Most commonly only a portion of the incision is needed/used</td>
</tr>
<tr>
<td>• ORIF of fractures</td>
<td>Brachioradialis (radial)</td>
<td>Superficial radial nerve</td>
<td>Proximally, must ligate the radial recurrent artery</td>
</tr>
<tr>
<td>• Osteotomy</td>
<td>Pronator teres (median)</td>
<td>Posterior interosseous nerve (PIN)</td>
<td>Distally, must detach pronator quadratus to get to distal radius</td>
</tr>
<tr>
<td>• Biopsy &amp; bone tumors</td>
<td>Brachioradialis (radial)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal</td>
<td>Brachioradialis (radial)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FCR (median)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Superficial branch of radial nerve</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Superficial radial nerve</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

WRIST: DORSAL APPROACH

<table>
<thead>
<tr>
<th>USES</th>
<th>INTERNERVOUS PLANE</th>
<th>DANGERS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRIST: VOLAR APPROACH</td>
<td>Proximal (same as Henry)</td>
<td>Median nerve</td>
<td>Incise transverse carpal ligament to access volar wrist capsule/bones</td>
</tr>
<tr>
<td>• ORIF (e.g., distal radius, scaphoid)</td>
<td>Brachioradialis (radial)</td>
<td>Palmar cutaneous br.</td>
<td></td>
</tr>
<tr>
<td>• Carpal tunnel release</td>
<td>FCR (median)</td>
<td>Motor recurrent branch</td>
<td></td>
</tr>
<tr>
<td>• Tendon repair</td>
<td>Distal (over wrist &amp; palm)</td>
<td>Superficial palmar arch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>None</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The wrist is approached dorsally with no internervous plane as the muscles are all innervated by the radial nerve (PIN). If needed, a compartment other than the 4th can be opened. The capsular sensory branch of the PIN is in the 4th compartment.
Dorsal Approach to Wrist Joint

Volar Approach to Wrist Joint
### WRIST ARTHROSCOPY PORTALS

- **Uses:** Diagnostic, TFCC tears, synovectomy, assist in fracture fixation, loose body removal, chondral lesions
- **Portals are named for relation to the dorsal extensor wrist compartments (R & U indicate radial or ulnar side of tendon).**

<table>
<thead>
<tr>
<th>PORTAL</th>
<th>LOCATION</th>
<th>DANGERS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Between APL &amp; ECRL tendons. Distal to radial styloid</td>
<td>1. Deep branch of radial art. 2. Superficial radial n. brs. 3. Lat. antebrachial cut. brs.</td>
<td>• <strong>Use is limited</strong> b/c of close proximity to &amp; risk of neurovascular injury • Shows distal scaphoid &amp; radial styloid</td>
</tr>
<tr>
<td>3-4</td>
<td>Between EPL &amp; EDC tendons, 1cm distal to Lister’s tubercle</td>
<td>None (PIN capsular br. in 4th comp)</td>
<td>• The <strong>“workhorse”</strong> portal of arthroscopy • Shows SL interosseous lig., ligament of Testut (RSL), distal radius fossae</td>
</tr>
<tr>
<td>4-5</td>
<td>Between EDC &amp; EDQ tendons</td>
<td>None</td>
<td>• Shows radial TFCC attachment, LT interosseous ligament</td>
</tr>
<tr>
<td>6R</td>
<td>Radial side of ECU tendon (b/w EDQ &amp; ECU)</td>
<td>Dorsal cutaneous br. ulnar n.</td>
<td>• Shows ulnar insertion of TFCC, UT, &amp; UL ligaments, pre styloid recess</td>
</tr>
<tr>
<td>6U</td>
<td>Ulnar side of ECU tendon</td>
<td>Dorsal cutaneous br. ulnar n.</td>
<td>• Similar to 6R. Used less due to risk of nerve injury. Can be used for outflow.</td>
</tr>
<tr>
<td>Midcarpal radial</td>
<td>1cm distal to 3-4 portal, along radial border of 3rd MC</td>
<td>None</td>
<td>• Distal scaphoid, proximal capitate, SL ligament, STT articulation</td>
</tr>
<tr>
<td>Midcarpal ulnar</td>
<td>1cm distal to 4-5 portal, in line with 4th MC</td>
<td>None</td>
<td>• Lunotriquetral joint, LT ligament, triquetrohamate articulation</td>
</tr>
</tbody>
</table>

Other portals: Midcarpal: STT and triquetrohamate. Distal radioulnar: proximal and distal to ulnar head.

### FASCIOTOMIES

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<td>Disorders</td>
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<td>Surgical Approaches</td>
<td>218</td>
</tr>
</tbody>
</table>
Common names of digits
1 Thumb
2 Index
3 Middle
4 Ring
5 Little

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palmaris longus tendon</td>
<td>Not present in all people. Can be used for tendon grafts.</td>
</tr>
<tr>
<td>Anatomic snuffbox</td>
<td>Site of scaphoid. Tenderness can indicate a scaphoid fracture.</td>
</tr>
<tr>
<td>Thumb carpometacarpal joint</td>
<td>Common site of arthritis and source of radial hand pain.</td>
</tr>
<tr>
<td>Thenar eminence</td>
<td>Atrophy can indicate median nerve compression (e.g., carpal tunnel syndrome).</td>
</tr>
<tr>
<td>Hypothenar eminence</td>
<td>Atrophy can indicate ulnar nerve compression (e.g., ulnar or cubital tunnel syndrome).</td>
</tr>
<tr>
<td>Proximal palmar crease</td>
<td>Approximate location of the superficial palmar arch of the palm.</td>
</tr>
<tr>
<td>Distal palmar crease</td>
<td>Site of metacarpophalangeal joints on volar side of hand.</td>
</tr>
<tr>
<td>CHARACTERISTICS</td>
<td>OSSIFY</td>
</tr>
<tr>
<td>----------------</td>
<td>--------</td>
</tr>
<tr>
<td><strong>METACARPALS</strong></td>
<td></td>
</tr>
<tr>
<td>• Triangular in cross section: gives 2 volar muscular attachment sites</td>
<td><strong>Primary:</strong> body 9wk (fetal)</td>
</tr>
<tr>
<td>• Thumb MC has saddle-shaped base: increases it mobility</td>
<td><strong>Secondary</strong> epiphysis 2yr</td>
</tr>
<tr>
<td><strong>PHALANGES</strong></td>
<td></td>
</tr>
<tr>
<td>• Volar surface is almost flat</td>
<td><strong>Primary</strong> body 8wk (fetal)</td>
</tr>
<tr>
<td>• Tubercles and ridges are sites for attachment</td>
<td><strong>Secondary</strong> epiphysis 2-3yr</td>
</tr>
<tr>
<td>• Nomenclature for digits: thumb, index finger (IF), middle finger (MF), ring finger (RF), small/little finger (SF or LF), proximal phalanx (P1), middle phalanx (P2), distal phalanx (P3)</td>
<td></td>
</tr>
</tbody>
</table>
### Radiograph Technique, Findings, and Clinical Application

<table>
<thead>
<tr>
<th>Technique</th>
<th>Findings</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP (anteroposterior)</td>
<td>Palm down on plate, beam perpendicular to plate</td>
<td>Metacarpals, phalanges, CMC, MCP, and IP joints</td>
</tr>
<tr>
<td>Lateral</td>
<td>Ulnar wrist and hand on plate, stagger finger flexion</td>
<td>Alignment of bones, joints</td>
</tr>
<tr>
<td>Oblique</td>
<td>Lateral with 40° rotation</td>
<td>Alignment and position of bones</td>
</tr>
<tr>
<td>Thumb stress view</td>
<td>Abduct thumb at 0° &amp; 30° of flexion, beam at MCPJ</td>
<td>Thumb MCPJ under stress</td>
</tr>
</tbody>
</table>

### Other Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Technique</th>
<th>Findings</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>Axial, coronal, and sagittal</td>
<td>Articular congruity, bone healing, bone alignment</td>
<td>Fractures (esp. scaphoid, hook of hamate), nonunions</td>
</tr>
<tr>
<td>MRI</td>
<td>Sequence protocols vary</td>
<td>Soft tissues (ligaments, tendons), bones</td>
<td>Occult fractures (e.g., scaphoid), ligament/tendon injuries</td>
</tr>
<tr>
<td>Bone scan</td>
<td>All bones evaluated</td>
<td>Infection, stress fx, tumors</td>
<td></td>
</tr>
</tbody>
</table>
Metacarpal Fractures

Transverse fractures of metacarpal shaft usually angulated dorsally by pull of interosseous muscles.

In fractures of metacarpal neck, volar cortex often comminuted, resulting in marked instability after reduction, which often necessitates pinning.

Oblique fractures tend to shorten and rotate metacarpal, particularly in index and little fingers because metacarpals of middle and ring fingers are stabilized by deep transverse metacarpal ligaments.

Fracture of Base of Metacarpals of Thumb

Type I (Bennett fracture). Intraarticular fracture with proximal and radial dislocation of 1st metacarpal. Triangular bone fragment sheared off.

Type II (Rolando fracture). Intraarticular fracture with Y-shaped configuration.

Fracture of Proximal Phalanx

Reduction of fractures of phalanges or metacarpals requires correct rotational as well as longitudinal alignment. In normal hand, tips of flexed fingers point toward tuberosity of scaphoid, as in hand at left.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>METACARPAL FRACTURES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Common in adults, usually a fall or punching mechanism.</td>
<td>Hx: Trauma, pain, swelling, +/- deformity</td>
<td>By location:</td>
<td>• Nondisplaced: cast</td>
</tr>
<tr>
<td>• 5th MC most common (boxer fx).</td>
<td>PE: Swelling, tenderness. Check for rotational deformity. Check neurovascular integrity.</td>
<td>• Head</td>
<td>• Displaced: reduce</td>
</tr>
<tr>
<td>• Thumb MC base fractures: displaced, intraarticular fractures problematic.</td>
<td>XR: Hand. Evaluate for angulation &amp; shortening</td>
<td>• Neck (most common)</td>
<td>◦ Stable: cast</td>
</tr>
<tr>
<td>◦ Bennett’s fx: APL deforms fx</td>
<td>CT: Useful to evaluate for nonunion of fracture</td>
<td>• Shaft (transverse, spiral)</td>
<td>◦ Unstable: CR-PCP vs. ORIF</td>
</tr>
<tr>
<td>◦ Rolando’s fx: can lead to DJD</td>
<td></td>
<td>• Base</td>
<td>◦ Shortened: ORIF</td>
</tr>
<tr>
<td>• 4th &amp; 5th MCs can tolerate some angulation, 2nd &amp; 3rd cannot</td>
<td></td>
<td>◦ Thumb MC</td>
<td>• Intraarticular</td>
</tr>
<tr>
<td></td>
<td></td>
<td>◦ Bennett: volar lip fx</td>
<td>◦ Head: ORIF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>◦ Rolando: comminuted</td>
<td>◦ Thumb base:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>◦ Small finger MC: “Baby Bennett”</td>
<td>◦ Bennett:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>◦ CR-PCP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>◦ Rolando: ORIF</td>
</tr>
</tbody>
</table>

**Phalangeal Fractures**

- **Common injury**
- **Mechanism:** jamming, crush, or twisting
- **Distal phalanx most common**
- **Stiffness** is common problem; early motion and occupational therapy needed for best results
- **Intraarticular fractures can lead to early osteoarthritis**
- **Nail bed injury common w/tuft (distal phalanx) fx**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHALANGEAL FRATURES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Common injury</td>
<td>• Hx: Trauma, pain, swelling, +/- deformity</td>
<td>• Description:</td>
<td>• Extraarticular:</td>
</tr>
<tr>
<td>• Mechanism: jamming, crush, or twisting</td>
<td>• PE: Swelling, tenderness. Check for rotational deformity. Check neurovascular integrity.</td>
<td>• Intra- vs extraarticular</td>
<td>◦ Stable: buddy tape/splint</td>
</tr>
<tr>
<td>• Distal phalanx most common</td>
<td>• XR: Hand. Evaluate for angulation &amp; shortening</td>
<td>• Displaced/nondisplaced</td>
<td>◦ Unstable: CR-PCP vs ORIF</td>
</tr>
<tr>
<td>• Stiffness is common problem; early motion and occupational therapy needed for best results</td>
<td>• CT: Useful to evaluate for nonunion of fracture</td>
<td>• Transverse, spiral, oblique</td>
<td>• Intraarticular: ORIF</td>
</tr>
<tr>
<td>• Intraarticular fractures can lead to early osteoarthritis</td>
<td></td>
<td>• Location:</td>
<td>• Middle phalanx volar base fx:</td>
</tr>
<tr>
<td>• Nail bed injury common w/tuft (distal phalanx) fx</td>
<td></td>
<td>• Condyle</td>
<td>◦ Stable: extension block splint</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Neck</td>
<td>◦ Unstable: ORIF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Shaft/diaphysis</td>
<td>• Tuft fx: irrigate wound, repair nail bed as needed, splint fx/digit</td>
</tr>
</tbody>
</table>

**COMPLICATIONS:** Stiffness/loss of range of motion (esp. intraarticular fractures), nonunion/malunion, osteoarthritis
### Mallet Finger—Extensor Digitorum Avulsion

- **Rupture of extensor tendon from distal phalanx**
- **Soft tissue or bony form**
- **Mech: jamming finger**

**Hx:** "Jammed" finger; pain, DIPJ deformity
**PE:** Extensor lag at DIPJ; inability to actively extend DIPJ

**XR:** Hand series. Look for bony avulsion (EDC) fx from dorsal base of P3 in bony form of injury

**TREATMENT**

1. DIPJ extension splint, 6wk for most injuries
2. Bony mallet with DIPJ subluxation: consider PCP vs ORIF

### Jersey Finger—Flexor Digitorum Profundus Avulsion

- **FDP tendon rupture from P3**
- **Mech: forced extension against a flexed finger**
- **Tendon retracts variably**

**Hx:** Forced DIPJ extension, injury; pain
**PE:** Inability to flex DIPJ (−profundus test)

**XR:** Hand series. Look for avulsion fracture from volar base of P3. May be retracted to finger/palm.

**Leddy classification: Type:**

1: to palm. Early repair
2: to PIPJ. Repair < 6wk
3: to A4: ORIF

### Gamekeeper’s Thumb

- **Thumb MCP joint proper ulnar collateral ligament injury**
- **Mech: forced radial deviation**
- **Often a ski pole injury**

**Hx:** Pain, decreased grip
**PE:** Pain & laxity of MCPJ at 30° of flexion, +/- palpable mass (Stenor lesion)

**XR:** Hand; t/o avulsion fx
**Stress Fluoro:** Can compare side to side asym.
**MR:** If diagnosis is unclear

**TREATMENT**

- **Incomplete tear (sprain) or no Stenor lesion:** splint 4-6wk
- **Complete tear or Stenor lesion:** primary repair

**Stenor lesion:** when adductor aponeurosis falls under torn ulnar collateral ligament, producing a palpable mass/bump

**Stress testing of the thumb MCP in extension tests the accessory collateral ligament and volar plate integrity**
### Flexor Tendon Zones

<table>
<thead>
<tr>
<th>ZONE</th>
<th>BOUNDARIES</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Distal to FDS insertion</td>
<td>Single tendon (FDP) injury. Primary repair. DIPJ contracture results if tendon shortened &gt;1 cm. Quadriga effect can also result.</td>
</tr>
<tr>
<td>II</td>
<td>Finger flexor retinaculum</td>
<td>“No man’s land.” Both tendons (FDS, FDP) require early repair (within 7 days) and mobilization. Lacerations may be at different locations on each tendon and away from skin laceration. Preserve A2 &amp; A4 pulleys during repair.</td>
</tr>
<tr>
<td>III</td>
<td>Palm</td>
<td>Primary repair. Articular arch &amp; median nerve injuries common.</td>
</tr>
<tr>
<td>IV</td>
<td>Carpal tunnel</td>
<td>Must release &amp; repair the transverse carpal ligament during tendon repair.</td>
</tr>
<tr>
<td>V</td>
<td>Wrist &amp; forearm</td>
<td>Primary repair (+ any neurovascular injury). Results are usually favorable.</td>
</tr>
<tr>
<td>Thumb I</td>
<td>Distal to FPL insertion</td>
<td>Primary tendon repair. Rerupture rate is high.</td>
</tr>
<tr>
<td>Thumb II</td>
<td>Thumb flexor retinaculum</td>
<td>Primary tendon repair. Preserve either A1 or oblique pulley.</td>
</tr>
<tr>
<td>Thumb III</td>
<td>Thenar eminence</td>
<td>Do not operate in this zone. Recurrent motor branch is at risk of injury.</td>
</tr>
</tbody>
</table>

### Extensor Tendon Zones

<table>
<thead>
<tr>
<th>ZONE</th>
<th>BOUNDARIES</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>DIP joint</td>
<td>“Mallet finger.” Splint in extension for 6 wk continuously.</td>
</tr>
<tr>
<td>II</td>
<td>Middle phalanx</td>
<td>Complete lacerations: primary repair and extension splint.</td>
</tr>
<tr>
<td>III</td>
<td>PIP joint</td>
<td>Central slip injury. Splint in extension for 6 wk. If triangular ligament is also disrupted, lateral bands migrate volarly, resulting in “boutonniere finger.”</td>
</tr>
<tr>
<td>IV</td>
<td>Proximal phalanx</td>
<td>Primary repair of tendon (and lateral bands if needed), then extension splint.</td>
</tr>
<tr>
<td>V</td>
<td>MCP joint</td>
<td>Often from “fight bite.” Repair tendon and sagittal bands as needed.</td>
</tr>
<tr>
<td>VI</td>
<td>Metacarpal</td>
<td>Primary repair and early mobilization/dynamic splinting.</td>
</tr>
<tr>
<td>VII</td>
<td>Wrist</td>
<td>Retinaculum likely injured. Primary tendon repair, early mobilization.</td>
</tr>
<tr>
<td>VIII</td>
<td>Distal forearm</td>
<td>At musculotendinous jxn. Primary repair of tendinous tissue &amp; immobilize.</td>
</tr>
</tbody>
</table>
**STRUCTURE** | **DESCRIPTION** | **COMMENT**
--- | --- | ---
Flexor tendon sheath | Fibroosseous tunnel lined with tenosynovium. Protects, lubricates, and nourishes the tendon. | Site of possible infection; check for Kanavel signs (see Disorders table). A2 & A4 (over P1 & P2) most important; must be intact to prevent “bowstringing” of tendons. Tight A1 can cause a trigger finger. A3 covers PIP volar plate: incise to access.

Pulleys | Thickening of sheath to stabilize tendons 5 annular (A1|MCPJ, A3|PIPJ, A5|DIPJ) over joints; A2, A4 over phalanges 3 or 4 cruciate pulleys. | 

Vincula | Within sheath, give vascular supply to tendons: 2 vincula (longa and brevia). | Vincula torn in type 1 FDP rupture (dysvascular), preserved in types 2 & 3 rupture.

Volar plate (palmar ligament) | Thickening of volar capsule of interphalangeal joints. | FDS & FDP tendons insert here to flex the PIP & DIP joints, respectively. Prevent hyperextension.
### LIGAMENT ATTACHMENTS COMMENTS

#### CARPOMETACARPAL

<table>
<thead>
<tr>
<th>LIGAMENT</th>
<th>ATTACHMENTS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thumb</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capsule</td>
<td>Base of metacarpal to trapezium</td>
<td>Surrounds joint and is a secondary stabilizer</td>
</tr>
<tr>
<td><strong>Anterior (volar) oblique</strong></td>
<td>Ulnar side of 1st metacarpal base to tubercle of trapezium</td>
<td>“Beak” ligament. Holds fragment in Bennett’s fx. Primary restraint to subluxation. Injury can lead to osteoarthritis.</td>
</tr>
<tr>
<td><strong>Dorsal radial</strong></td>
<td>Dorsal trapezium to dorsal MC base</td>
<td>Strongest. Dorsal and radial support. Torn in dorsal dislocation.</td>
</tr>
<tr>
<td>1st intermetacarpal</td>
<td>Ulnar 1st MC base to radial 2nd MC base</td>
<td>Prevents 1st metacarpal from translating radially</td>
</tr>
<tr>
<td><strong>Posterior oblique</strong></td>
<td>Trapezium to dorsal ulnar MC base</td>
<td>Secondary stabilizer</td>
</tr>
<tr>
<td>Ulnar collateral</td>
<td>Volar ulnar trapezium to ulnar MC base</td>
<td>Limits abduction and extension</td>
</tr>
<tr>
<td><strong>Radial lateral</strong></td>
<td>Radially on trapezium and MC base</td>
<td>Under the APL tendon/insertion</td>
</tr>
</tbody>
</table>

#### Finger

<table>
<thead>
<tr>
<th>LIGAMENT</th>
<th>ATTACHMENTS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capsule</td>
<td>Base of metacarpal to carpus</td>
<td>Adds stability</td>
</tr>
<tr>
<td>CMC ligaments</td>
<td>Base of metacarpal to carpus</td>
<td>Dorsal (strongest), volar, interosseous ligaments</td>
</tr>
<tr>
<td>Intermetacarpal</td>
<td>Between adjacent metacarpal bases</td>
<td>Adds ulnar and radial stability to CMC joint</td>
</tr>
</tbody>
</table>

- Saddle joint. Highly mobile, has both inherent bony and ligamentous stability. Prone to develop osteoarthritis.
- Primary movements: flexion, extension, adduction, abduction.
- Complex (combined) movements: opposition, retropulsion, palmar abduction, radial abduction/adduction.

- Gliding joints. 2nd & 3rd CMC have little motion, so minimal metacarpal fx angulation is acceptable b/c of immobility. 4th & 5th CMC have more anteroposterior motion, so more metacarpal fx angulation is acceptable b/c of mobility.
### Metacarpophalangeal Joint

**Thumb**

- **Type:** Diarthrodial joint. Motion: primary = flexion & extension; secondary = rotation, adduction, abduction
- **Capsule:** Surrounds joint. Secondary stabilizer dorsally. Taut in flexion.
- **Proper collateral ligament:** Center of metacarpal head to palmar proximal phalanx. Primary stabilizer. Taut in flexion, test in 30° flexion. Ulnar collateral ligament injured in “gamekeeper’s/skier’s” thumb.
- **Accessory collateral ligament:** Palmar to proper collateral lig. Taut in extension. Test integrity in extension.
- **Volar (palmar) plate:** Palmar metacarpal head to palmar proximal phalanx base. Primary stabilizer in extension. Laxity in extension indicates injury to volar plate (+/- accessory collateral lig.)

**Finger**

- **Type:** Diarthrodial joint. Motion: primary = flexion & extension (ROM 0-90°); secondary = radial & ulnar deviation
- **Asymmetry of metacarpal head & collateral ligament origin result in “cam effect” (tight in flexion, loose in extension)
- **Capsule:** Surrounds joint. Secondary stabilizer; synovial reflections volar & dorsal
- **Proper collateral ligament:** Dorsal MC head to palmar P1 base. Primary stabilizer; tight in flexion, loose in extension.
- **Accessory collateral ligament:** Palmar MC head to volar plate. Palmar to proper collaterals; stabilizes the volar plate.
- **Volar (palmar) plate:** Palmar MC head to palmar P1 base. Limits extension; volar support.
- **Deep transverse (inter) metacarpal ligament:** Between adjacent metacarpal bases and MCPJ volar plates. Interconnects the volar plates, MCPJs, and metacarpals. Can prevent shortening of isolated metacarpal fractures.
**LIGAMENT ATTACHMENTS COMMENTS**

**PROXIMAL INTERPHALANGEAL**

- Hinge joints: Primary motion = flexion & extension (PIPJ: ROM 0-110°, DIPJ: ROM 0-60°). Minimal rotation or deviation motion. No “cam effect” in this joint. PIPJ is prone to stiffness/contracture after injury and/or immobilization.

<table>
<thead>
<tr>
<th>LIGAMENT</th>
<th>ATTACHMENTS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capsule</td>
<td>Surrounds joint</td>
<td>Weak stabilizer esp. dorsally (central slip adds most support)</td>
</tr>
<tr>
<td>Proper collateral</td>
<td>Center of P1 head to volar P2</td>
<td>Primary stabilizer to deviation. Constant tension through ROM</td>
</tr>
<tr>
<td>Accessory collateral</td>
<td>Volar proximal phalanx head to volar plate (not bone)</td>
<td>Origin volar to axis of rotation: tight in ext., loose in flexion. This can result in a contracture (do not immobilize in flexion)</td>
</tr>
<tr>
<td>Volar (palmar) plate</td>
<td>Volar middle phalanx to volar proximal phalanx (via check-rein ligaments)</td>
<td>Primary restraint to hyperextension. Firm distal attachment, looser proximal attachment (more prone to injury). Checkrein ligaments often contract after injury: contracture</td>
</tr>
</tbody>
</table>

**OTHER INTERPHALANGEAL**

- Thumb interphalangeal (IPJ) and finger distal interphalangeal joints (DIPJ)

<table>
<thead>
<tr>
<th>LIGAMENT</th>
<th>ATTACHMENTS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capsule</td>
<td>Surrounds joints</td>
<td>Weak stabilizer</td>
</tr>
<tr>
<td>Proper collateral</td>
<td>B/w adjacent phalanges</td>
<td>Similar to PIPJ, constant tension, no “cam effect”</td>
</tr>
<tr>
<td>Accessory collateral</td>
<td>Volar to collateral ligaments</td>
<td>Similar to PIPJ, less prone to contracture than PIPJ</td>
</tr>
<tr>
<td>Volar (palmar) plate</td>
<td>Volarly b/w phalanges</td>
<td>Primary restraint to hyperextension; can be injured</td>
</tr>
</tbody>
</table>

**OTHER STRUCTURES**

- Grayson’s ligament | From flexor sheath to skin; volar to neurovascular bundle | Stabilizes skin & neurovascular bundle | Involved in Dupuytren’s disease/nodules |
<p>| Cleland’s ligament | From periosteum to skin | Stabilizes skin during flexion/extension; dorsal to NV bundle |</p>
<table>
<thead>
<tr>
<th>JOINT MOTION</th>
<th>STRUCTURE</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metacarpophalangeal Joint</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>Interosseous muscles</td>
<td>Insert on proximal phalanx and lateral band (volar to rotation axis)</td>
</tr>
<tr>
<td></td>
<td>Lumbricals</td>
<td>Inserts on radial lateral band (volar to axis of rotation of MCPJ)</td>
</tr>
<tr>
<td>Extension</td>
<td>EDC via sagittal bands</td>
<td>Sagittal bands insert on volar plate, creating a “lasso” around proximal phalanx base and extend joint through the lasso. EDC has minimal attachment to P1 (which does not extend the joint) but extends joints via the sagittal bands.</td>
</tr>
<tr>
<td><strong>Proximal Interphalangeal Joint</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>Flexor digitorum superficialis (FDS)</td>
<td>Primary PIPJ flexor via insertion on middle phalanx volar base</td>
</tr>
<tr>
<td></td>
<td>Flexor digitorum profundus (FPD)</td>
<td>Secondary PIPJ flexor</td>
</tr>
<tr>
<td>Extension</td>
<td>EDC via the central slip (band)</td>
<td>Central slip of EDC inserts on dorsal P2 base to extend PIPJ</td>
</tr>
<tr>
<td></td>
<td>Lumbricals via lateral bands</td>
<td>Has attachment to radial lateral band (dorsal to rotation axis)</td>
</tr>
<tr>
<td><strong>Distal Interphalangeal Joint</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>Flexor digitorum profundus (FPD)</td>
<td>Tendon attaches at P3 volar base, pulls through tendon sheath</td>
</tr>
<tr>
<td>Extension</td>
<td>EDC via terminal extensor tendon</td>
<td>Lateral bands converge at terminal insertion on dorsal P3 base</td>
</tr>
<tr>
<td></td>
<td>Oblique retinacular ligament (ORL)</td>
<td>Links PIPJ &amp; DIPJ extension; extends DIPJ as PIPJ is extended</td>
</tr>
</tbody>
</table>

Note: Black arrows indicate pull of long extensor tendon; red arrows indicate pull of interosseous and lumbrical muscles; dots indicate axis of rotation of joints.
### INTRINSIC APPARATUS

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>DESCRIPTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagittal band</td>
<td>Inserts on volar plate (P1); extensor tendon (EDC) glides under it</td>
<td>Extends MCPJ via “lasso” around P1 base; radial sagittal bands are weaker, may rupture</td>
</tr>
<tr>
<td>Oblique fibers</td>
<td>Covers MCPJ and base of proximal phalanx</td>
<td>Holds EDC centered over MCPJ</td>
</tr>
<tr>
<td>Lateral bands</td>
<td>Lateral hood fibers join tendinous portion of interossei/lumbricals to form lateral bands</td>
<td>Volar to MCPJ axis: flexes MCPJ Dorsal to PIPJ axis: extends PIPJ</td>
</tr>
</tbody>
</table>

### Extrinsic Extensor Tendon (EDC) glides under the dorsal hood (to extend MCP) before trifurcating at prox. phalanx

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>DESCRIPTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral slip</td>
<td>EDC trifurcates over P1 giving two lateral slips</td>
<td>These slips conjoin with lateral bands</td>
</tr>
<tr>
<td>Central slip</td>
<td>Central slip of trifurcation; inserts base of P2</td>
<td>Extends PIPJ; torn in boutonniere injury</td>
</tr>
<tr>
<td>Terminal extensor tendon</td>
<td>Confluence of two conjoined lateral bands on dorsal base of distal phalanx (P3)</td>
<td>Extends DIPJ via insertion on dorsal base of P3; avulsed in mallet finger injury</td>
</tr>
<tr>
<td>Conjoined lateral band</td>
<td>Confluence of EDC lateral slips and lateral bands from extensor aponeurosis</td>
<td>Both join distally to make terminal extensor tendon</td>
</tr>
</tbody>
</table>

### OTHER STRUCTURES

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>DESCRIPTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junctura tendinae</td>
<td>Tendinous connections between ECD tendons to adjacent fingers proximal to MCPJ</td>
<td>Prevents full extension of finger when adjacent digit is flexed (see page 155)</td>
</tr>
</tbody>
</table>
**HAND SPACES**

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>CHARACTERISTICS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thenar space</td>
<td>Between flexor tendons and adductor pollicis</td>
<td>Potential space: site of possible infection</td>
</tr>
<tr>
<td>Midpalmar space</td>
<td>Between flexor tendons and metacarpals</td>
<td>Potential space: site of possible infection</td>
</tr>
<tr>
<td>Parona’s space</td>
<td>Between flexor tendons and pronator quadratus</td>
<td>Potential space: “horseshoe” abscess can occur here as infection tracks proximally</td>
</tr>
<tr>
<td>Radial bursa</td>
<td>Proximal extension of FPL sheath</td>
<td>Infection can track proximally</td>
</tr>
<tr>
<td>Ulnar bursa</td>
<td>Communicates with SF FDS/FDP flexor tendon sheath</td>
<td>Flexor sheath infection can track proximally into bursa</td>
</tr>
</tbody>
</table>

**OTHER STRUCTURES**

- Hand

---

**Image Description:**
- **Thenar space:** Between flexor tendons and adductor pollicis. Potential space: site of possible infection.
- **Midpalmar space:** Between flexor tendons and metacarpals. Potential space: site of possible infection.
- **Parona’s space:** Between flexor tendons and pronator quadratus. Thumb and SF flexor sheaths communicate here. Potential space: “horseshoe” abscess can occur here as infection tracks proximally.
- **Radial bursa:** Proximal extension of FPL sheath. Infection can track proximally.
- **Ulnar bursa:** Communicates with SF FDS/FDP flexor tendon sheath. Flexor sheath infection can track proximally into bursa.

**Names:**
- **Fascia of adductor pollicis muscle**
- **Thenar space**: (deep to flexor tendon and 1st lumbrical muscle)
- **Lumbral muscles in fascial sheaths**
- **Holythenar muscles**
- **Fibrous and synovial (tendon) sheaths of finger**
- **Septum between midpalmar and thenar spaces**
- **Common palmar digital artery and nerve**
- **Common flexor sheath (ulnar bursa)**
- **Fibrous and synovial (tendon) sheaths of finger**
- **Midpalmar space**: (deep to flexor tendons and ulnar bursa)
- **Lumbral muscles in fascial sheaths**
- **Dorsal interosseous muscles**
- **Extensor tendons**
- **Septum between midpalmar and thenar spaces**
- **Common flexor sheath (ulnar bursa)**
- **Lumbral muscles in fascial sheaths**
- **Dorsal interosseous muscles**
- **Extensor tendons**

**Diagrams:**
- **Flexor digitorum superficialis tendon (FDS)**
- **Flexor digitorum profundus tendon (FPS)**
- **Flexor pollicis longus tendon in tendon sheath (radial bursa)**
- **Adductor pollicis muscle**
- **Palmar interosseous fascia**
- **Palmar interosseous muscles**
- **Dorsal interosseous muscles**
- **Adductor pollicis muscle**
- **Hypotenar muscles**
- **Hypothenar muscles**
- **Thenar space**
- **Midpalmar space**
- **Lumbral muscles in fascial sheaths**
- **Fascia of adductor pollicis muscle**
- **Flexor tendons to 5th digit in common flexor sheath (ulnar bursa)**
- **Profundus and superficialis flexor tendons to 3rd digit**
- **Common flexor sheath (ulnar bursa)**
- **Flexor digitorum profundus tendon (FPS)**
- **Flexor digitorum superficialis tendon (FDS)**
- **Common palmar digital artery and nerve**
- **Common palmar digital artery and nerve**
- **Fibrous and synovial (tendon) sheaths of finger**
- **Septum between midpalmar and thenar spaces**
- **Common palmar digital artery and nerve**
- **Common palmar digital artery and nerve**
- **Fibrous and synovial (tendon) sheaths of finger**
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<tr>
<th>STRUCTURE</th>
<th>CHARACTERISTICS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FINGERTIP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nail</td>
<td>Cornified epithelium</td>
<td>If completely avulsed, consider replacing to prevent eponychium and matrix adhesions</td>
</tr>
<tr>
<td>Nail bed/matrix</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germinal</td>
<td>Under eponychium and nail to edge of lunula</td>
<td>Where nail grows (1mm a week), must be intact (repaired) for normal nail growth Adheres to nail. Repair may prevent nail deformity.</td>
</tr>
<tr>
<td>Sterile</td>
<td>Under nail, distal to lunula</td>
<td></td>
</tr>
<tr>
<td>Pulp</td>
<td>Multiple septa, nerves, arteries</td>
<td>Felon is an infection of the pulp</td>
</tr>
<tr>
<td>Paronychia</td>
<td>Radial and ulnar nail folds</td>
<td>Common site of infection</td>
</tr>
<tr>
<td>Eponychia</td>
<td>Proximal nail fold</td>
<td>Common site of infection</td>
</tr>
</tbody>
</table>

- The digital artery is superficial/volar to the nerve proximally but runs dorsal to the nerve in the finger.
- Volar neurovascular bundle supplies the distal finger and fingertip.
### STEPS

#### INJECTION OF THUMB CMC JOINT

1. Ask patient about allergies
2. Palpate thumb CMC joint on volar radial aspect
3. Prepare skin over CMC joint (iodine/antiseptic soap)
4. Anesthetize skin locally (quarter size spot)
5. Palpate base of thumb MC, pull axial distraction on thumb with slight flexion to open joint. Use 22 gauge or smaller needle, and insert into joint (if available use an image intensifier to confirm needle is in joint). Aspirate to ensure needle is not in a vessel. Inject 1-2 ml of 1:1 local (without epinephrine)/corticosteroid preparation into CMC joint. (The fluid should flow easily if needle is in joint)
6. Dress injection site

#### FLEXOR TENDON SHEATH BLOCK

1. Ask patient about allergies
2. Palpate the flexor tendon at the distal palmar crease over metacarpal head/A1 pulley.
3. Prepare skin over palm (iodine/antiseptic soap)
4. Insert 25 gauge needle into flexor tendon at the level of the distal palmar crease. Withdraw needle very slightly so that it is just outside tendon, but inside sheath. Inject 2-3 ml of local anesthetic without epinephrine. (Add corticosteroid if injecting for trigger finger).
5. Dress injection site

#### DIGITAL/METACARPAL BLOCK

1. Prepare skin over dorsal proximal finger web space (iodine/antiseptic soap)
2. Insert 25 gauge needle between metacarpal necks (metacarpal block) or on either side of proximal phalanx (digital block) in digital web space. Aspirate to ensure that needle is not in a vessel. Inject 1-2 ml of local anesthetic (without epinephrine) on both sides of the bones. Consider injecting local anesthetic dorsally over the bone as well.
3. Care should be taken not to inject too much fluid into the closed space of the proximal digit.
4. Dress injection site
### Fractures and dislocations of thumb

Injury to proximal phalanx or metacarpophalangeal joint of thumb caused by fall with outstretched hand on ski pole.

### Boxer fracture

Fractures of metacarpal neck commonly result from end-on blow of fist. Often called street-fighter or boxer fractures.

### Fight bite

Penetration of metacarpophalangeal joint by tooth in fist fight.

### Mallet finger

Usually caused by direct blow on extended distal phalanx, as in baseball, volleyball.

### Table: Hand History

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hand dominance</td>
<td>Right or left</td>
<td>Dominant hand injured more often</td>
</tr>
<tr>
<td>2. Age</td>
<td>Young</td>
<td>Trauma, infection</td>
</tr>
<tr>
<td></td>
<td>Middle age-elderly</td>
<td>Arthritis, nerve entrapments</td>
</tr>
<tr>
<td>3. Pain</td>
<td>Acute</td>
<td>Trauma, infection</td>
</tr>
<tr>
<td>a. Onset</td>
<td>Chronic</td>
<td>Arthritis</td>
</tr>
<tr>
<td>b. Location</td>
<td>CMC (thumb)</td>
<td>Arthritis (OA) especially in women</td>
</tr>
<tr>
<td></td>
<td>Joints (MCPs, IPs)</td>
<td>Arthritis (osteoarthritis, rheumatoid)</td>
</tr>
<tr>
<td></td>
<td>Volar (fingers)</td>
<td>Purulent tenosynovitis (± Kanavel signs)</td>
</tr>
<tr>
<td>4. Stiffness</td>
<td>In AM, “catching”</td>
<td>Rheumatoid arthritis</td>
</tr>
<tr>
<td></td>
<td>Catching/clicking</td>
<td>Trigger finger</td>
</tr>
<tr>
<td>5. Swelling</td>
<td>After trauma</td>
<td>Infection (e.g., purulent tenosynovitis, felon, paronychia)</td>
</tr>
<tr>
<td></td>
<td>No trauma</td>
<td>Trigger finger, arthritides, gout, tendinitis</td>
</tr>
<tr>
<td>6. Mass</td>
<td></td>
<td>Ganglion, Dupuytren’s contracture, giant cell tumor</td>
</tr>
<tr>
<td>7. Trauma</td>
<td>Fall, sports injury</td>
<td>Fracture, dislocation, tendon avulsion, ligament injury</td>
</tr>
<tr>
<td></td>
<td>Open wound</td>
<td>Infection</td>
</tr>
<tr>
<td>8. Activity</td>
<td>Sports, mechanical</td>
<td>Trauma (e.g., fracture, dislocation, tendon or ligament injury)</td>
</tr>
<tr>
<td>9. Neurologic symptoms</td>
<td>Pain, numbness, tingling</td>
<td>Nerve entrapment (e.g., carpal tunnel), thoracic outlet syndrome, radiculopathy (cervical)</td>
</tr>
<tr>
<td></td>
<td>Weakness</td>
<td>Nerve entrapment (usually in wrist or more proximal)</td>
</tr>
<tr>
<td>10. History of arthritides</td>
<td>Multiple joints involved</td>
<td>Rheumatoid arthritis, Reiter’s syndrome, etc.</td>
</tr>
<tr>
<td>EXAMINATION</td>
<td>TECHNIQUE</td>
<td>CLINICAL APPLICATION</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Inspection</td>
<td></td>
<td><strong>Rheumatoid arthritis</strong> Ulnar drift/swan neck, boutonniere finger with swan-neck deformity of other fingers.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Osteoarthritis</strong> Heberden’s nodes seen in index and middle finger distal interphalangeal joints. Bouchard’s nodes seen in proximal interphalangeal joints of the ring and small finger.</td>
</tr>
<tr>
<td>Finger position</td>
<td>Flexion</td>
<td>Dupuytren’s contracture, purulent tenosynovitis Fracture (acute), fracture malunion.</td>
</tr>
<tr>
<td>Skin, hair, nail changes</td>
<td>Cool, hairless, spoon, etc</td>
<td>Neurovascular disorders: Raynaud’s, diabetes, nerve injury.</td>
</tr>
<tr>
<td>Swelling</td>
<td>DIPs, PIPs, MCPs, Fusiform shape finger</td>
<td>Osteoarthritis: Heberden’s nodes (at DIPs: #1), Bouchard’s nodes (at PIPs) Rheumatoid arthritis Purulent tenosynovitis</td>
</tr>
<tr>
<td>Muscle wasting</td>
<td>Thenar eminence, Hypotenar eminence/intrinsics</td>
<td>Median nerve injury, CTS, C8/T1 pathology Ulnar nerve injury (e.g., cubital tunnel syndrome)</td>
</tr>
</tbody>
</table>
### EXAMINATION

#### TECHNIQUE

<table>
<thead>
<tr>
<th>EXAMINATION</th>
<th>SKIN</th>
<th>METACARPSALS</th>
<th>PHAL ANGS &amp; JOINTS</th>
<th>SOFT TISSUES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warm, red</td>
<td>Each along its length</td>
<td>Each separately</td>
<td>Thenar, hypothenar, palm (palmar fascia)</td>
</tr>
<tr>
<td></td>
<td>Cool, dry</td>
<td></td>
<td></td>
<td>Flexor tendons: along volar finger</td>
</tr>
</tbody>
</table>

#### CLINICAL APPLICATION

|                      | Infection | Neurovascular compromise | Tenderness may indicate fracture | Tenderness: fracture, arthritis | Wasting indicates median nerve injury | Wasting indicates ulnar nerve injury | Nodules: Dupuytren’s contracture; snapping | Tenderness suggests purulent tenosynovitis | Tenderness: paronychia or felon |

---

**Stenosing tenosynovitis (trigger finger)**

Patient unable to extend affected finger. It can be extended passively, and extension occurs with distinct and painful snapping action. Circle indicates point of tenderness where nodular enlargement of tendons and sheath is usually palpable.

**Dupuytren’s contracture**

Flexion contracture of 4th and 5th fingers (most common). Dimpling and puckering of skin. Palpable fascial nodules near flexion crease of palm at base of involved fingers with cordlike formations extending to proximal palm.

**Infections of the fingers**

- **Paronychia**
- **Felon**

**Purulent tenosynovitis. Four cardinal signs of Kanavel**

1. Pain on extension
2. Fusiform swelling
3. Slight flexion
4. Tenderness along tendon sheath

*Ch06_X9781416059875_183-218.indd2 202 8/5/09 10:00:20 AM*
## Range of Motion

### Finger

<table>
<thead>
<tr>
<th>Joint</th>
<th>Motion</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP joint</td>
<td>Flex 90°, extend 0°, adduct/abduct 0-20°</td>
<td>Decreased flexion if casted in extension (collateral ligaments shorten)</td>
</tr>
<tr>
<td>PIP joint</td>
<td>Flex 110°, extend 0°</td>
<td>Hyperextension leads to swan neck</td>
</tr>
<tr>
<td>DIP joint</td>
<td>Flex 80°, extend 10°</td>
<td>All fingers should point to scaphoid at full flexion</td>
</tr>
</tbody>
</table>

### Thumb

<table>
<thead>
<tr>
<th>Joint</th>
<th>Motion</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMC joint</td>
<td>Radial abduction: flex 50°, extend 50°</td>
<td>Motion is in plane of palm</td>
</tr>
<tr>
<td>MCP joint</td>
<td>Palmar abduction: abduct 70, adduct 0°</td>
<td>Motion is perpendicular to plane of the palm</td>
</tr>
<tr>
<td>IP joint</td>
<td>In plane of palm: flex 50°, extend 0°</td>
<td></td>
</tr>
<tr>
<td>Opposition</td>
<td>In plane of palm: flex 75°, extend 10°</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Touch thumb to small finger base</td>
<td>Motion is mostly at CMC joint</td>
</tr>
</tbody>
</table>

Normal finger flexion is composite of flexion of MP, PIP, and DIP joints and allows fingertip to touch distal palmar crease. Normal thumb opposition is composite of movements of CMC, MP, and IP joints. Normal range is to base of little finger.
### Neurovascular

#### Sensory

<table>
<thead>
<tr>
<th>Examination</th>
<th>Technique</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial nerve (C6)</td>
<td>Dorsal thumb, web space</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Median nerve (C6-7)</td>
<td>Radial border, index finger</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Ulnar nerve (C8)</td>
<td>Ulnar border, small finger</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
</tbody>
</table>

#### Motor

<table>
<thead>
<tr>
<th>Examination</th>
<th>Technique</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial nerve/PIN (C7)</td>
<td>Finger MCP extension</td>
<td>Weakness = Extensor digitorum or nerve lesion</td>
</tr>
<tr>
<td></td>
<td>Thumb abduction/extension</td>
<td>Weakness = APL/EPL or nerve/root lesion</td>
</tr>
<tr>
<td>Median nerve (C8)</td>
<td>Finger PIP flexion</td>
<td>Weakness = FDS or corresponding nerve/root lesion</td>
</tr>
<tr>
<td>AIN</td>
<td>Index finger DIP flexion</td>
<td>Weakness = FDP or AIN nerve lesion</td>
</tr>
<tr>
<td>Motor recurrent branch</td>
<td>Thumb IP flexion</td>
<td>Weakness = FPL or corresponding nerve/root lesion</td>
</tr>
<tr>
<td></td>
<td>Thumb opposition</td>
<td>Weakness = APB, OP, 1/2 FPB or nerve/root lesion; (CTS)</td>
</tr>
<tr>
<td>Ulnar nerve (deep branch) (T1)</td>
<td>Finger abduction</td>
<td>Weakness = Dorsal/volar interosseous or nerve lesion</td>
</tr>
<tr>
<td></td>
<td>Thumb adduction</td>
<td>Weakness = Adductor pollicis or nerve/root lesion</td>
</tr>
</tbody>
</table>

#### Reflex

<table>
<thead>
<tr>
<th>Examination</th>
<th>Technique</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoffman’s</td>
<td>Flick MF DIP/J into flexion</td>
<td>Pathologic if thumb IPJ flexes: myelopathy</td>
</tr>
</tbody>
</table>

#### Vascular

<table>
<thead>
<tr>
<th>Examination</th>
<th>Technique</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capillary refill</td>
<td>Squeeze finger tip</td>
<td>Color (blood) should return in less than 2 seconds</td>
</tr>
<tr>
<td>Allen’s test</td>
<td>Occlude both radial &amp; ulnar arteries, then release one Arches, digital borders</td>
<td>Hand should “pink up” if artery that was released AND arches are patent. Failure to “pink up” = arterial injury</td>
</tr>
<tr>
<td>Doppler</td>
<td>Arches, digital borders</td>
<td>Use if presence of pulses/patent vessels is in question</td>
</tr>
</tbody>
</table>
**Profundus test**
Stabilize PIPJ in extension, flex DIPJ only
Inability to flex DIPJ alone indicates FDP pathology

**Sublimus test**
Extend all fingers, flex a single finger at PIPJ
Inability to flex PIP of isolated finger indicates FDS pathology

**Froment’s sign**
Hold paper with thumb and index finger, pull
If thumb IP flexion is positive, suggest adductor pollicis weakness and/or ulnar nerve palsy

**CMC grind test**
Axial compress and rotate CMC joint
Pain indicates arthritis at CMC joint of thumb

**Finger instability test**
Stabilize proximal joint, apply varus and valgus stress
Laxity indicates collateral ligament injury

**Thumb instability test**
Stabilize MCP, apply valgus stress in extension and 30° of flexion
Laxity at 30°: ulnar collateral ligament injury
Laxity in extension: accessory collateral ligament and/or volar plate injury

**Bunnell-Littler test**
Extend MCPJ, passively flex PIPJ
Tight or inability to flex PIPJ, improved with MCPJ flexion indicates tight intrinsic muscles

**Elson test**
Flex PIPJ 90° over table edge, resist P2 extension
DIPJ rigidly extending (via lateral bands) indicates central slip injury (boutonnière)
### ORIGINS AND INSERTIONS

<table>
<thead>
<tr>
<th>CARPUS</th>
<th>METACARPAL</th>
<th>PHALANGES—DORSAL</th>
<th>PHALANGES—PLANTAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezium</td>
<td>Dorsal interosseous</td>
<td>Proximal phalanx</td>
<td>Proximal phalanx</td>
</tr>
<tr>
<td>Abductor pollicis brevis</td>
<td>Palmar interosseous</td>
<td>Ext. pollicis brevis (thumb)</td>
<td>Abductor pollicis brevis (thumb)</td>
</tr>
<tr>
<td>Flexor pollicis brevis</td>
<td>Adductor pollicis</td>
<td>Dorsal interossei</td>
<td>Flexor pollicis brevis (thumb)</td>
</tr>
<tr>
<td>Opponens pollicis</td>
<td>Abd. pollicis longus</td>
<td>Abductor digit minimi</td>
<td>Adductor pollicis</td>
</tr>
<tr>
<td>Capitate</td>
<td>Opponens pollicis</td>
<td>Flexor digit minimi brevis</td>
<td>Flexor digit minimi brevis</td>
</tr>
<tr>
<td>Adductor pollicis</td>
<td>Opp. digit minimi</td>
<td>Extensor digitorum communis (central slip)</td>
<td>Palmar interossei</td>
</tr>
<tr>
<td>Hamate</td>
<td>Flex. digit minimi brevis</td>
<td>Extensor digitorum communis (terminal tendon)</td>
<td>Flexor digit minimi brevis</td>
</tr>
<tr>
<td>Flex. digit minimi brevis</td>
<td>Abd. pollicis longus</td>
<td></td>
<td>Adductor digit minimi</td>
</tr>
<tr>
<td>Opponens digit minimi</td>
<td>Flexor pollicis radialis</td>
<td></td>
<td>Flexor digit minimi brevis</td>
</tr>
<tr>
<td>Pisiform</td>
<td>Extensor digitorum communis (terminal tendon)</td>
<td></td>
<td>Abductor digit minimi</td>
</tr>
<tr>
<td>Abductor digit minimi</td>
<td>Extensor pollicis</td>
<td></td>
<td>Flexor pollicis longus (thumb)</td>
</tr>
<tr>
<td>Opponens digit minimi</td>
<td>Flexor pollicis longus</td>
<td></td>
<td>Flexor pollicis longus (thumb)</td>
</tr>
<tr>
<td></td>
<td>Extensor digitorum communis (central slip)</td>
<td></td>
<td>Flexor pollicis lowrus (thumb)</td>
</tr>
</tbody>
</table>

**Lumbricals** originate on flexor digitorum profundus (FDP) tendon and insert on the radial lateral bands.
### Muscles of the Hand

#### Anterior (palmar) view

- **Pronator quadratus muscle**
- **Ulnar nerve**
- **Ulnar artery and palmar carpal branch**
- **Flexor carpi ulnaris tendon**
- **Palmar carpal arterial arch**
- **Pisiform**
- **Median nerve**
- **Abductor digiti minimi muscle (cut)**
- **Flexor digiti minimi brevis muscle (cut)**
- **Opponens digiti minimi muscle**
- **Deep transverse metacarpal ligaments**

---

#### Muscles of the Hand

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve</th>
<th>Action</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thenar Compartment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abductor pollicis brevis (APB)</td>
<td>Scaphoid, trapezium</td>
<td>Lateral prox. phalanx (thumb)</td>
<td>Median</td>
<td>Palmar pronation</td>
<td>Primary muscle in opposition</td>
</tr>
<tr>
<td>Flexor pollicis brevis</td>
<td>1. Superficial head 2. Deep head</td>
<td>Trans. carpal lig. Trapezium</td>
<td>Base of thumb Proximal phalanx</td>
<td>Median</td>
<td>Thumb MCP flexion</td>
</tr>
<tr>
<td>Opponens pollicis</td>
<td>Trapezium</td>
<td>Lateral thumb MC</td>
<td>Median</td>
<td>Oppose (flex/abduct) thumb</td>
<td>Pronates/stabilizes thumb MC</td>
</tr>
<tr>
<td><strong>Adductor Compartment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adductor pollicis</td>
<td>1. Oblique head 2. Transverse head</td>
<td>1. Capitate, 2nd and 3rd MC 2. 3rd metacarpal</td>
<td>Ulnar base of proximal phalanx of thumb</td>
<td>Ulnar</td>
<td>Thumb adduction and thumb MCP flexion</td>
</tr>
<tr>
<td><strong>Hypotthenar Compartment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palmaris brevis [PB]</td>
<td>Transverse carpal ligament [TCL]</td>
<td>Skin on medial palm</td>
<td>Ulnar</td>
<td>Wrinkles skin</td>
<td>Protects ulnar nerve</td>
</tr>
<tr>
<td>Abductor digiti minimi [ADQ]</td>
<td>Pisiform (FCU tendon)</td>
<td>Ulnar base of prox. phalanx</td>
<td>Ulnar</td>
<td>SF abduction</td>
<td>Ulnar nerve and artery under it</td>
</tr>
<tr>
<td>Flexor digiti minimi brevis [FDMB]</td>
<td>Hamate, TCL</td>
<td>Base of proximal phalanx of SF</td>
<td>Ulnar</td>
<td>SF MCP flexion</td>
<td>Deep to ADQ and nerve</td>
</tr>
<tr>
<td>Opponens digiti minimi [ODQ]</td>
<td>Hamate, TCL</td>
<td>Ulnar side 5th metacarpal</td>
<td>Ulnar</td>
<td>Oppose (flex and supinate) SF</td>
<td>Deep to other muscles</td>
</tr>
</tbody>
</table>

- Abductor muscles are superficial; opponens muscles are deep
- Motor recurrent branch of median innervates thenar muscle and radial 2 lumbricals
- Deep branch at ulnar nerve innervates hypotenar, adductor pollicis, interossei, and ulnar 2 lumbricals
## Intrinsic Muscles

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumbricals 1 &amp; 2</td>
<td>FDP tendons (radial 2)</td>
<td>Radial lateral bands</td>
<td>Median</td>
<td>Extend PIP, flex MCP</td>
<td>Only muscles in body to insert on their own antagonist (FDP). Palmar to deep transverse MC ligaments.</td>
</tr>
<tr>
<td>Lumbricals 3 &amp; 4</td>
<td>FDP tendons (medial 3)</td>
<td>Radial lateral bands</td>
<td>Ulnar</td>
<td>Extend PIP, flex MCP</td>
<td></td>
</tr>
<tr>
<td>Interosseous: dorsal (DIO)</td>
<td>Adjacent metacarpals</td>
<td>Proximal phalanx and extensor expansion (lateral bands)</td>
<td>Ulnar</td>
<td>Digit abduction MCP flexion</td>
<td>DAB: Dorsal ABduct Bipennate: each belly has separate insertion</td>
</tr>
<tr>
<td>Interosseous: palmar (PIO)</td>
<td>Adjacent metacarpals</td>
<td>Extensor expansion (lateral bands)</td>
<td>Ulnar</td>
<td>Digit adduction</td>
<td>PAD: Palmar ADduct Unipennate</td>
</tr>
</tbody>
</table>
Thenar compartment
Adductor compartment
Dorsal interosseous compartments
Palmar interosseous compartments
Hypothenar compartment

Carpal tunnel release
Transverse carpal ligament

<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>COMPARTMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COMPARTMENTS (10)</td>
</tr>
<tr>
<td>Thenar</td>
<td>Abductor pollicis brevis, flexor pollicis brevis, opponens pollicis</td>
</tr>
<tr>
<td>Hypothenar</td>
<td>Abductor digiti minimi, flexor digiti minimi brevis, opponens digiti minimi</td>
</tr>
<tr>
<td>Adductor</td>
<td>Adductor pollicis</td>
</tr>
<tr>
<td>Palmar interosseous (3)</td>
<td>Palmar interosseous muscles</td>
</tr>
<tr>
<td>Dorsal interosseous (4)</td>
<td>Dorsal interosseous muscles</td>
</tr>
</tbody>
</table>

FASCIOTOMIES

- Incisions: 3 incisions (2 dorsal and 1 carpal tunnel release) can release all compartments.
- Dorsal (1): Over 2nd metacarpal, dissect on both sides: release radial 2 interosseous (2 dorsal, 1 palmar)
- Dorsal (2): Over 4th metacarpal, dissect on both sides: release ulnar 4 interosseous (2 dorsal, 2 palmar)
- Medial: Release transverse carpal ligament, then thenar, hypothenar, & adductor compartments
BRACHIAL PLEXUS

Medial Cord

**Ulnar** (C7-T1): Runs in forearm under FCU, on FDP. **Dorsal cutaneous branch** divides 5cm proximal to wrist. This nerve continues into the dorsal aspect of the ulnar digits as **dorsal digital nerves**. Ulnar nerve enters Guyon's canal, then divides into **superficial** (sensory) and **deep** (motor) branches. The deep branch bends around the hook of the hamate and runs with the **deep arterial arch**. The superficial branch continues into the palmar aspect of the fingers as the **palmar digital nerves**.

**Sensory:**
- Dorsal ulnar hand: via **dorsal cutaneous branch**
- Dorsal small & ring fingers: via **dorsal digital branches**
- Ulnar proximal palm: via **palmar cutaneous branch**
- Ulnar distal palm: via **common palmar digital branches**
- Palmar small & ring fingers: via **proper palmar digital branches**

**Motor:**
- **Superficial (sensory) branch**
  - Palmaris brevis—only muscle innervated by this branch
- **Deep (motor) branch:** travels with deep arterial arch
  - **Hypotenar compartment**
    - Abductor digiti minimi (ADM)
    - Flexor digiti minimi brevis (FDMB)
    - Opponens digiti minimi (ODM)
  - **Adductor compartment**
    - Adductor pollicis
  - **Intrinsic muscles**
    - Lumbricals (ulnar two [3,4])
    - Dorsal interossei (DIO)
    - Palmar (volar) interossei (VIO)
  - **Thenar compartment**
    - Flexor pollicis brevis (FPB)—**deep head only**
**NERVES • Hand**

**BRACHIAL PLEXUS**

**Medial and Lateral Cords**

**Median** (C5[6]-T1): Runs in forearm on FDP. **Palmar cutaneous branch** branches proximal to the carpal tunnel. The median nerve enters the carpal tunnel. The **motor recurrent branch** exits distal to transverse carpal ligament (TCL) and supplies the thenar muscles. Anatomic variants include exit through (at risk in carpal tunnel release) or under the TCL. The remainder of the nerve is sensory and supplies the palmar radial 3½ digits.

- **Sensory:** Palm of hand: via **palmar cutaneous branch**
  - Volar thumb, IF, MF, radial RF: via **palmar digital branches**
  - Dorsal distal thumb, IF, MF, radial RF: via **proper palmar digital branch**
- **Motor:** **Motor (recurrent) branch**
  - Thenar compartment
    - Abductor pollicis brevis (APB)
    - Opponens pollicis
    - Flexor pollicis brevis (FPB)—superficial head only
  - Intrinsic muscles
    - Lumbricals (radial two [1,2])

**Posterior Cord**

**Radial** (C5-T1): Superficial branch runs under brachioradialis to wrist, then bifurcates in medial & lateral branches that supply the dorsal hand & thumb web space. They continue as **dorsal digital branches** to the dorsal fingers.

- **Sensory:** Dorsal radial hand: via **superficial branch**
  - Dorsal proximal thumb, IF, MF, radial RF: via **dorsal digital branches**
- **Motor:** None (in hand)
• **Radial artery:** divides at wrist into **superficial branch**, which anastomoses with the superficial palmar arch. The **deep branch** runs thru the bellies of the 1st dorsal interosseous muscle & terminates as the **deep palmar arch**.

• **Ulnar artery:** divides at wrist into a **deep branch**, which anastomoses with the deep palmar arch. The **superficial branch** terminates as the **superficial palmar arch**.

### DEEP PALMAR ARCH

- **Princeps pollicis**
- **Radialis indicis**
- **Deep palmar (arterial) arch**
- **Continuation of deep branch of radial artery**
- **Supplies radial IF; may branch from deep arch**
- **Two terminal branches of bifurcated princeps pollicis**
- **Anastomoses with common digital arteries**

### SUPERFICIAL PALMAR ARCH

- **Proper palmar digital artery to SF**
- **Common palmar digital (3)**
- **First branch off arch; supplies ulnar small finger**
- **In 2nd-4th web spaces, each bifurcates**
- **Runs on radial & ulnar borders of digits**

**Comment/Supply**

- **Superficial arch supplies most of the hand/fingers. It is dominant ⅔ of the time. This arch is complete 80% of the time.**
- **Deep arch supplies the thumb (& radial IF). It is usually the nondominant arch. This arch is complete 98% of the time.**
- **The arches are codominant ⅔ of the time. Allen’s test determines if arch is complete (but not which is dominant).**
- **Arteries are volar to the nerves in the palm, but cross to become dorsal to the nerves in the fingers.**
<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP/FINDINGS</th>
<th>TREATMENT</th>
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<tr>
<td><strong>OSTEOARTHRITIS</strong></td>
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<tr>
<td>• Loss of articular cartilage</td>
<td>Hx: Elderly or hx of injury</td>
<td>XR: OA findings: joint space loss, osteophytes, sclerosis, subchondral cysts</td>
<td>1. NSAIDs 2. Steroid injection 3. Arthrodesis/fusion 4. Arthroplasty</td>
</tr>
<tr>
<td>• Due to wear or posttraumatic</td>
<td>Pain: worse w/activity</td>
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<tr>
<td>• DIPJ #1 (Heberden’s nodes)</td>
<td>PE: Nodule/deformity, tenderness, decreased ROM</td>
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<tr>
<td>• PIPJ #2 (Bouchard’s nodes)</td>
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<tr>
<td><strong>MUCOUS CYST</strong></td>
<td>Hx: Mass near a joint</td>
<td>XR: Joint arthritis</td>
<td>1. Excision of cyst and associated osteophyte</td>
</tr>
<tr>
<td>• Ganglion cyst from arthritic joint (DIPJ #1)</td>
<td>PE: Mass, +/- tenderness</td>
<td></td>
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</tr>
<tr>
<td>• Autoimmune disease attacks synovium and destroys joints</td>
<td>PE: Deformities (ulnar drift, swan neck, boutonniere)</td>
<td></td>
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<tr>
<td>• MCPJ #1</td>
<td></td>
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<tr>
<td>• Multiple deformities develop</td>
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<tr>
<td><strong>SWAN NECK DEFORMITY</strong></td>
<td>Hx: Injury or RA</td>
<td>XR: Shows bony deformity</td>
<td>1. Early: splint 2. Late: surgical release and reconstruction 3. Arthrodesis</td>
</tr>
<tr>
<td>• FDS insertion/volar plate injury</td>
<td>PE: Deformity: flexed DIPJ, injury hyperextended PIPJ</td>
<td></td>
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<tr>
<td>• Traumatic or assoc. with RA</td>
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<tr>
<td>• Lateral bands subluxate dorsally, hyperextends PIPJ</td>
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<tr>
<td>• Central slip (EDC) and triangular ligament injury</td>
<td>PE: Deformity: flexed PIPJ, + Elson’s test (inability to extend the flexed PIPJ)</td>
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</tr>
<tr>
<td>• Traumatic or assoc. with RA</td>
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<tr>
<td>• Lateral bands subluxate volarly, hyperflexes PIPJ</td>
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</tbody>
</table>

**Hand**

**Osteoarthrosis**

Section through distal interphalangeal joint shows irregular, hyperplastic bony nodules (Heberden’s nodes) at articular margins of distal phalanx. Cartilage eroded and joint space narrowed.

**Rheumatoid arthritis**

Radiograph of distal interphalangeal joint reveals late-stage degenerative changes. Cartilage destruction and marginal osteophytes (Heberden’s nodes).

**Boutonniere deformity of index finger with swan-neck deformity of other fingers**

**Late-stage degenerative changes in carpometacarpal articulation of thumb**

**Radiograph shows cartilage thinning at proximal interphalangeal joints, erosion of carpus and wrist joint, osteoporosis, and finger deformities**

**Section through distal interphalangeal joint shows irregular, hyperplastic bony nodules (Heberden’s nodes) at articular margins of distal phalanx. Cartilage eroded and joint space narrowed.**
### Purulent Flexor Tenosynovitis

- **DESCRIPTION**: Tendon sheath infection
  - Usu. from puncture/bite
  - May spread proximally into deep spaces or Parona’s space (horse-shoe abscess)

- **Hx & PE WORKUP/FINDINGS**
  - **Kanaval signs (4):**
    1. Flexed position
    2. Fusiform swelling
    3. Pain w/passive extension
    4. Flexor sheath tenderness

- **TREATMENT**
  1. Diagnosis
     - 48hr: IV antibiotics, close observation (I&D if no improvement)
  2. Diagnosis
     - 48hr: Irrigation and debridement of sheath
     - IV antibiotics

### Felon

- **DESCRIPTION**: Deep infection/abscess in pulp of finger
  - Staph. aureus #1

- **Hx & PE**
  - **Pointing abscess, edema, erythema, drainage**

- **XR**
  - Usually not needed

- **TREATMENT**
  1. Incise and drain (must release septum in pulp)
  2. Antibiotics (IV vs oral)

### Paronychia / Epionychia

- **DESCRIPTION**: Infection of nail fold
  - #1 hand infection
  - Etiology: nail biting, hang nails

- **Hx & PE**
  - **Erythema, tenderness, +/− drainage**

- **XR**
  - Usually not needed

- **TREATMENT**
  1. Early: warm soaks
  2. I&D and oral antibiotics
  3. Partial nail excision

### Deep Space Infections

- **DESCRIPTION**: Infection in deep spaces or tissues (e.g., thenar, hypothenar, Parona’s [horse-shoe])

- **Hx & PE**
  - **Edema, erythema, tenderness, fluctuance, +/− drainage**

- **XR**
  - Usually normal

- **TREATMENT**
  1. Incise & drain, IV abx
  2. Wound care/dressing changes as needed

### Sporotrichosis

- **DESCRIPTION**: Fungal (Sporothrix s.) infection from plants/roses
  - Spreads via lymphatics

- **Hx & PE**
  - Rash/discoloration
  - Early: single nodule
  - Late: multiple nodules/rash

- **XR**
  - Usually not needed

- **TREATMENT**
  - Potassium iodine solution
### Bites: Human/Animal

- **Hx:** Bite, pain & swelling
- **PE:** Puncture wound or laceration, edema, +/- drainage, erythema (local or tracking proximally)
- **XR:** Hand series: rule out foreign body (e.g., tooth) or air in tissues/joint
- **LABS:** CBC, ESR, CRP

1. Td & rabies prophylaxis if indicated
2. I&D, wound care
3. IV antibiotics (ampicillin/sulbactam)

### STENOSING TENOSYNOVITIS (Trigger Finger)

- **Hx:** 40+, pain, snapping or locking (esp. in AM)
- **PE:** Tender flexor sheath, snapping with flex./ext.
- **XR:** Usually normal
- **MR:** Not needed, PE is diagnostic

1. Splint, occupational rx
2. Corticosteroid injection into tendon sheath
3. A1 pulley release

### Dupuytren’s Disease

- **Hx:** Usually male, 40+, c/o hand mass
- **PE:** Nodule in palm, +/- contracture of MCPJ or PIPJ
- **XR:** Usually normal
- **MR:** Not needed if diagnosis is clear. May be useful if etiology of mass is unclear.

1. Early (mass, no contracture): reassurance
2. Late (contracture): surgical excision of cords

### Retinacular Cyst

- **Hx:** Small volar mass
- **PE:** Firm, “pea”-size nodule, does not move w/tendon
- **XR:** Usually normal
- **MR:** Not needed

1. Aspiration/puncture
2. Surgical excision if recurrent
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<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>TREATMENT</th>
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</table>
| **SYNDACTYLY** | • Failure of differentiation of finger tissue  
• Most common congenital hand anomaly  
• Complete (to finger tip) vs incomplete  
• Simple (soft tissue) vs complex (bone) | Hx: Fingers are connected  
PE: Fingers are connected either to tip or incompletely down the finger  
XR: Will determine if bones are fused (complex) | 1. Should wait approximately 1yr, then surgically separate fingers  
2. Careful incision planning and skin grafts improve results |
| **CAMPTODACTYLY** | • Congenital finger flexion anomaly  
• Usually PIPJ of small finger  
• Type 1 (infants), type 2 (adolescents)  
• Etiology: abnormal lumbrical or FDS insertion | Hx: Finger flexed. Noticed at birth or during adolescent growth  
PE: Inability to fully extend joint  
XR: Shows flexion, bones typically normal | 1. Nonoperative: stretching, splint  
2. Functionally debilitating contraction: surgical release/tendon transfer |
| **CLINODACTYLY** | • Deviation of finger in coronal plane  
• Radial deviation of small finger #1  
• Eti: delta-shaped middle phalanx | Hx/PE: Deviation of finger, cosmetic and functional complaints  
XR: Shows delta-shaped middle phalanx | 1. Mild: no treatment  
2. Functional deficit: surgical correction/realignment osteotomy |
<table>
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<th>DESCRIPTION</th>
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<tr>
<td><strong>DUPLICATE THUMB (PREAXIAL POLYDACTYLY)</strong>&lt;br&gt;• An extra thumb or portion thereof&lt;br&gt;• Wassel classification (7 types): Type 4 is most common&lt;br&gt;• Autosomal dominant or sporadic&lt;br&gt;• Associated with some syndromes</td>
<td>Hx/PE: Extra thumb or portion of thumb&lt;br&gt;XR: Will show bifid or extra phalanges depending on which type of duplication</td>
<td>1. Surgical reconstruction to obtain stable thumb. Generally, retain ulnar thumb/structures &amp; reconstruct radial side (e.g., type 4)</td>
</tr>
<tr>
<td><strong>THUMB HYPOPLASIA</strong>&lt;br&gt;• Partial or complete absence of thumb&lt;br&gt;• Blauth classification: Types I–V&lt;br&gt;• Treatment based on presence of CMC joint&lt;br&gt;• Associated with some syndromes</td>
<td>Hx/PE: Small to completely absent thumb&lt;br&gt;XR: Range of small, shortened, or absent bones (phalanges, metacarpal, trapezium). Evaluate for presence of the CMC joint</td>
<td>1. Type I: Small thumb: no treatment&lt;br&gt;2. Types II–IIIA: Reconstruction&lt;br&gt;3. Types IIIB–V (no CMCJ): amputation &amp; pollicization</td>
</tr>
<tr>
<td><strong>CONSTRICION BAND SYNDROME</strong>&lt;br&gt;• Constrictive bands lead to digit necrosis or diminished growth/development.&lt;br&gt;• Nonhereditary</td>
<td>Hx/PE: Short/truncated fingers with bands at level of diminished growth&lt;br&gt;XR: Small, shortened, or absent phalanges</td>
<td>1. Complete amputations if needed&lt;br&gt;2. Release/excise bands, Z-plasty as needed for skin coverage</td>
</tr>
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USES

FINGER: VOLAR APPROACH
- Flexor tendons (repair/explore)
- Digital nerves
- Soft tissue releases
- Infection drainage

FINGER: MID-LATERAL APPROACH
- Phalangeal fractures

INTERNERVIOUS PLANE

FINGER: VOLAR APPROACH
No planes

FINGER: MID-LATERAL APPROACH
No planes

DANGERS

FINGER: VOLAR APPROACH
- Digital artery
- Digital nerve
- Flexor tendon

FINGER: MID-LATERAL APPROACH
- Digital nerve
- Digital artery

COMMENT

FINGER: VOLAR APPROACH
- Make a “zigzag” incision connecting finger creases
- Neurovascular bundle is lateral to the tendon sheath.

FINGER: MID-LATERAL APPROACH
- Soft tissues are thin; capsule can be incised if care is not taken.
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### STRUCTURE

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<th>Structure</th>
<th>Clinical Application</th>
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<td>Iliac crest</td>
<td>Site for contusion of iliac crest (&quot;hip pointers&quot;) Common site for autologous bone graft harvest</td>
</tr>
<tr>
<td>Anterior superior iliac spine</td>
<td>Origin of sartorius muscle. An avulsion fracture can occur here. Lateral femoral cutaneous nerve (LFCN) courses here and can be entrapped. Landmark used for measuring the “Q” angle of the knee</td>
</tr>
<tr>
<td>Symphysis pubis</td>
<td>Site of osteitis pubis; uncommon cause of anterior pelvic pain</td>
</tr>
<tr>
<td>Inguinal ligament</td>
<td>External iliac artery becomes femoral artery here; femoral pulse can be palpated just inferior to the ligament in the femoral triangle.</td>
</tr>
<tr>
<td>Greater trochanter</td>
<td>Tenderness can indicate trochanteric bursitis.</td>
</tr>
<tr>
<td>Erector spinae muscles</td>
<td>Overuse and spasm are common causes of lower back pain (LBP).</td>
</tr>
<tr>
<td>Posterior superior iliac spine</td>
<td>Site of bone graft harvest in posterior spinal procedures.</td>
</tr>
<tr>
<td>Sacroiliac joint</td>
<td>Degeneration of joint can cause lower back pain (LBP).</td>
</tr>
<tr>
<td>Ischial tuberosity</td>
<td>Avulsion fracture (hamstring muscles) or bursitis can occur here.</td>
</tr>
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**Rectus abdominis muscle**

**Pubic symphysis**

**Superficial circumflex iliac vein**

**Superficial epigastric veins**

**Pubic symphysis**

**Erector spinae muscle**

**Posterior superior iliac spine**

**Sacroiliac joint**

**Intergluteal (natal) cleft**

**Ischial tuberosity**

**Gluteus maximus muscle**

**Gluteal fold**

**Linea alba**

**Semilunar line**

**Umbilicus**

**Hip joint**

**Pubic tubercle**

**Greater trochanter of femur**

**Gluteus medius muscle**

**Sacrum**

**Greater trochanter of femur**

**Gluteus maximus muscle**
**Pelvis**

- Combination of 3 bones (two innominate bones & sacrum) and 3 joints (two sacroiliac joints & symphysis pubis)
- The pelvis has no inherent stability. It requires ligamentous support for its stability.
- Two portions of pelvis divided by pelvic brim/iliopectineal line
  - False (greater) pelvis—above the brim, bordered by the sacral ala and iliac wings
  - True (lesser) pelvis—below the brim, bordered by the ischium and pubis

**Sacrum**

- 5 vertebra are fused
- 4 pairs of foramina (left and right)
- Ala (wing) expands laterally
- Sacral canal opens to hiatus distally
- Kyphotic (approx. 25°), the apex is at S3
- Transmits weight from spine to pelvis
- Nerves exit through the sacral foramina (anterior & posterior)
- Ala is common site for sacral fractures
- Sacral canal narrows distally before opening to sacral hiatus
- Segments fuse to each other at puberty

**Coccyx**

- 4 vertebra are fused
- Lack features of typical vertebrae
- Is attached to gluteus maximus and coccygeal m.
- Common site for “tailbone” fracture
**CHARACTERISTICS**

- 3 bones (ilium, ischium, pubis) fuse to become one bone at triradiate cartilage in acetabulum
- Ilium: body, ala (wing)
- Pubis: inferior & superior rami
- Ischium: body & tuberosity
- Acetabulum: “socket” of hip joint, has 2 walls (anterior & posterior) & notch/condyloid fossa inferiorly. Articular cartilage is horseshoe shaped

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<th>OSSIFY</th>
<th>FUSE</th>
<th>COMMENTS</th>
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<tr>
<td><strong>INNOMINATE BONE</strong></td>
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<tr>
<td>Primary (one in each body)</td>
<td>2-6mo to acetabulum 15yr</td>
<td></td>
<td>- Iliac crest is common site for both tricortical and cancellous bone graft harvest</td>
</tr>
<tr>
<td>Secondary</td>
<td>15yr All fuse 20yr</td>
<td></td>
<td>- Contusion to iliac crest known as “hip pointer”</td>
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<tr>
<td>Iliac crest</td>
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<tr>
<td>Triradiate</td>
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<td></td>
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<tr>
<td>Ischial tuberosity</td>
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<td></td>
</tr>
<tr>
<td>Pubis</td>
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<tr>
<td>Acetabulum: 45° oblique orientation, 15° anteverted</td>
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</tbody>
</table>

- Ilium: body, ala (wing)
- Pubis: inferior & superior rami
- Ischium: body & tuberosity
- Acetabulum: “socket” of hip joint, has 2 walls (anterior & posterior) & notch/condyloid fossa inferiorly. Articular cartilage is horseshoe shaped.

**INNOMINATE BONE**

- 3 bones (ilium, ischium, pubis) fuse to become one bone at triradiate cartilage in acetabulum
- Ilium: body, ala (wing)
- Pubis: inferior & superior rami
- Ischium: body & tuberosity
- Acetabulum: “socket” of hip joint, has 2 walls (anterior & posterior) & notch/condyloid fossa inferiorly. Articular cartilage is horseshoe shaped.
OSTEOLOGY • Pelvis

**STRUCTURE** | **ATTACHMENTS/RELATED STRUCTURES** | **COMMENT**
--- | --- | ---
Anterior superior iliac spine (ASIS) | Sartorius, Inguinal ligament, Transverse & int. oblique abdominal m. | • LFCN crosses the ASIS & can be compressed there  
• Sartorius can avulse from it (avulsion fx)  
• Landmark to measure Q angle of the knee

Anterior inferior iliac spine (AIIS) | Rectus femoris, Tensor fasciae latae, Iliofemoral ligament (hip capsule) | • Rectus femoris can avulse from it (avulsion fx)

Posterior superior iliac spine (PSIS) | Posterior SI ligaments, Marked by skin dimple | • Excellent bone graft site

Arcuate line | Pectineus | • Aka pectineal line. Strong, weight-bearing region

Gluteal lines | 3 lines: anterior, inferior, posterior | • Separate origins of gluteal muscles

Gtr. trochanter | SEE ORIGINS/INSERTIONS | • Tendon with trochanteric bursitis

Lesser trochanter | Iliacus/psoas muscle | • Tendon can snap over trochanter (“snapping hip”)

Ischial tuberosity | SEE ORIGINS/INSERTIONS, Sacrotuberous ligaments | • Excessive friction = bursitis (weaver’s bottom)  
• Hamstrings can avulse (avulsion fx)

Ischial spine | Coccygeus & levator ani attach, Sacrospinous ligaments |  

Lesser sciatic foramen | Short external rotators exit: Obturator externus, Obturator internus | • Obturator internus is landmark to posterior column  
• Obt. externus not seen in posterior approach

Greater sciatic foramen | Structures that exit:  
1. Superior gluteal nerve  
2. Superior gluteal artery  
3. Piriformis muscle  
4. Pudendal nerve  
5. Inferior pudendal artery  
6. Nerve to the Obturator internus  
7. Posterior Cutaneous nerve of thigh  
8. Sciatic nerve  
9. Inferior gluteal nerve  
10. Inferior gluteal artery  
11. Nerve to Quadratus femoris | • Piriformis muscle is the reference point  
• Superior gluteal nerve and artery exit superior to the piriformis  
• POP’S IQ is mnemon for the nerves (structures) that exit inferior to the piriformis (medial to lateral) (see page 243)  
• Sciatic nerve (especially peroneal division) may exit pelvis above or through the piriformis as an anatomic variation
**STRUCTURE** | **RELATED STRUCTURES** | **COMMENT**
---|---|---
**ACETABULAR COLUMNS**
Anterior (iliopubic) | 1. Superior pubic ramus  
2. Anterior acetabular wall  
3. Anterior iliac wing  
4. Pelvic brim | Involved in several different fracture patterns
Posterior (ilioischial) | 1. Ischial tuberosity  
2. Posterior acetabular wall  
3. Greater & lesser sciatic notches | Involved in several different fracture patterns

**ACETABULAR ZONES**
Zones defined by 2 lines: 1. ASIS to center of acetabulum, 2. perpendicular to line 1  
Structures can be injured when screws are placed in these zones (e.g., acetabular cups)
Anterior superior | External iliac artery & vein | Do not put screws in this zone
Anterior inferior | Obturator nerve, artery, vein | Do not put screws in this zone
Posterior superior | Sciatic nerve  
Superior gluteal nerve, artery, vein | This is the **safe zone**
Posterior inferior | Sciatic nerve  
Inferior gluteal nerve, artery, vein  
Internal pudendal nerve, artery, vein | This is a secondary safe zone. Safe screw placement can be achieved with care if necessary.
**RADIOGRAPH TECHNIQUE FINDINGS CLINICAL APPLICATION**

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<th>CLINICAL APPLICATION</th>
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<td>AP (anteroposterior)</td>
<td>AP, IR feet 15°, beam directed at midpelvis</td>
<td>6 radiographic lines: 1. Iliopectineal (ant. column) 2. Ilioischial (post. column) 3. Radiographic “teardrop” 4. Acetabular roof (“dome”) 5. Ant. acetabulum rim/wall 6. Post. acetabulum rim/wall</td>
<td>Screening for fractures (sacral, pelvic acetabular, proximal femur), use ATLS protocol; dysplasia, degenerative joint disease/arthritis</td>
</tr>
<tr>
<td>Pelvic inlet view</td>
<td>AP, beam 45° caudal</td>
<td>Sacroiliac joints, pelvic brim/pubic rami, sacrum</td>
<td>Pelvic ring fractures: shows posterior displacement or symphysis widening</td>
</tr>
<tr>
<td>Pelvic outlet view</td>
<td>AP, beam 45° cephalad</td>
<td>Iliac crest, symphysis pubis, sacral foramina</td>
<td>Pelvic ring fractures: shows superior displacement of hemipelvis</td>
</tr>
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<td>Oblique/Judet views</td>
<td>Beam at affected hip: Elevate affected hip 45°</td>
<td>Obturator foramen</td>
<td>Acetabulum fx: anterior column, posterior wall</td>
</tr>
<tr>
<td>Oblique/Judet views</td>
<td>Elevate unafflicted hip 45°</td>
<td>Iliac crest, sciatic notches</td>
<td>Acetabulum fx: posterior column, anterior wall</td>
</tr>
<tr>
<td>OTHER STUDIES</td>
<td></td>
<td></td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>CT</td>
<td>Axial, coronal, &amp; sagittal</td>
<td>Articular congruity, fx fragments</td>
<td>Fractures, especially sacrum &amp; acetabulum</td>
</tr>
<tr>
<td>MRI</td>
<td>Sequence protocols</td>
<td>Soft tissues: muscles, cartilage</td>
<td>Labral tears, tumors, stress fx</td>
</tr>
<tr>
<td>Bone scan</td>
<td>All bones evaluated</td>
<td>All bones evaluated</td>
<td>Tumors, infection</td>
</tr>
</tbody>
</table>

**Radiograph, AP pelvis**

- Sacroiliac joint
- Ilioischial line (posterior column)
- Iliopectineal line (anterior column)
- Teardrop
- Roof (of acetabulum)
- Posterior wall (of acetabulum)
- Anterior wall (of acetabulum)
- Pubic symphysis
SACRAL FRACTURE

- **Mechanism:**
  - Elderly—fall; young—high energy (e.g., MVA)
  - Isolated injuries rare, usually assoc. w/pelvis or spine fx
  - **Nerve root injury** very common

- **Plain XR:** identifies 50% of fractures

- **Hx:** Trauma (fall or accident), pain +/- neurologic sx
  - **PE:** Palpate spine & sacrum. Complete neuro exam including rectal exam.

- **XR:** AP pelvis, lateral sacrum
  - **CT:** Necessary for diagnosis & preop planning

- **By direction of fracture**
  - Vertical, Denis:
    - Zone 1: lateral to foramina
    - Zone 2: through foramina
    - Zone 3: medial to foramina
  - II. Transverse
  - III. Oblique
  - Complex: "U" or "H" shape

- **Treatment**
  - Minimally displaced/stable:
    - Nonoperative
  - Displaced/unstable:
    - Closed reduction and percutaneous fixation
    - Open reduction, internal fixation
  - **Nerve injury:** decompression

**COMPLICATIONS:** Nerve root injury & cauda equina syndrome, esp. zone 3 fractures; nonunion/malunion, chronic pain
### Classification of Pelvic Fractures (Young and Burgess)

#### Anteroposterior Compression Type I (APC-I)
- Young & Burgess: AP Compression (APC)
  - I. <2.5cm pubic diastasis + 1 or 2 pubic rami fractures
  - II. >2.5cm diastasis + anterior SI injury, but vertically stable
  - III. Complete ant. (symphysis) & post. (SIJ) disruption. Unstable

#### Anteroposterior Compression Type II (APC-II)
- Young & Burgess: AP Compression (APC)
  - I. <2.5cm pubic diastasis + 1 or 2 pubic rami fractures
  - II. >2.5cm diastasis + anterior SI injury, but vertically stable
  - III. Complete ant. (symphysis) & post. (SIJ) disruption. Unstable

#### Anteroposterior Compression Type III (APC-III)
- Young & Burgess: AP Compression (APC)
  - I. <2.5cm pubic diastasis + 1 or 2 pubic rami fractures
  - II. >2.5cm diastasis + anterior SI injury, but vertically stable
  - III. Complete ant. (symphysis) & post. (SIJ) disruption. Unstable

### Pelvic Ring Fracture

- **Mechanism**: High-energy blunt trauma (e.g., MVA)
- **Associated Injuries**: GI, GU, extremity fxs, neurologic, vascular, head (LC)
- **High Morbidity**: Usually due to uncontrolled hemorrhage (venous > arterial bleeding) esp. w/ APC3 (“open book”) fxs
- **Open Fracture**: Higher morbidity and complication rate.
- **Stability of fx based on ligament disruption (esp. ST, SS, posterior SI)**
- **Avulsion of iliolumbar ligament/L5 transverse process**: Suggests unstable fx
- **Lateral Compression (LC)**
  - I. Sacral compression + ipsilateral rami fracture
  - II. LC1 + iliac wing fx or post. SIJ injury. Vertically stable
  - III. LC2 with contralateral APC3 (“windswept” pelvis)

### Evaluation
- **Hx**: High-energy trauma, pain +/- neurologic sx
- **PE**: Inspect perineum for open injury. LE may be malrotated. Pelvic “rock.” Rectal & vaginal exams for associated injuries. Complete neuro exam incl. rectal tone & bulbocavernosus reflexes.

### Treatment
- **ATLS Protocol**: Treat life-threatening injuries
- **Pelvic Hemorrhage**: Pelvis compression (e.g., sheet) or external fixation to reduce pelvic volume
- **Diverting Colostomy**: For open injury or any communication w/open bowel
- **Operative for LC2 & 3; APC 2 & 3, vertical stress**
  - Anterior: ORIF of symphysis
  - Post: 1. ORIF of iliac wing and sacral fractures; 2. SI screws for dislocated SIJ

### Complications
- **Hemorrhage** (venous > arterial [internal pudendal a. > superior gluteal a.]), neurologic injuries (L5 root at risk w/SI screws), malunion/nonunion, chronic pain (esp. at SIJ) and functional disability, infection, thromboembolism
PELVIC FRACTURE—OTHER

**Mechanism:** Low-energy trauma (fall, sports injury, etc)

**Stable isolated fractures,** pelvic ring not disrupted

Can occur in osteopenic bone

**Hx:** Pain, esp. with WB

**PE:** TTP at bony site

**XR:** AP, inlet/outlet views

**CT:** Often not needed, can determine displacement

**Isolated fxs:** Inferior or superior pubic rami, iliac wing/crest

**Avulsions:** ASIS (sartorius), AIIS (rectus femoris), ischial tuberosity (hamstrings)

**TREATMENT**

- Isolated fxs: treat with limited rest, WBAT
- Avulsion fx: most treated nonoperatively. Reattach if widely displaced.

**COMPLICATIONS:** Malunion/nonunion, chronic pain/disability, thromboembolism
## Acetabulum—Elementary Fractures

- **Description**: Mechanism: high-energy blunt trauma (e.g., MVA); fem. head into acetabulum. Fracture pattern determined by force vector & position of femoral head at impact. Multiple associated injuries: GI, GU, extremity fractures. Surgical approaches: Kocher-Langenbeck: posterior fxs (PW, PC, transverse, T type); Ilioinguinal: anterior fxs (AW, AC/HT, both columns).

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hx: High-energy trauma, pain, inability to WB</td>
<td>Letournel &amp; Judet:</td>
<td><strong>ACETABULAR FRACTURE</strong></td>
<td>Reduce hip if dislocated (traction if necessary to maintain reduction)</td>
</tr>
<tr>
<td>PE: LE may be malrotated. Inspect skin for Morel-Lavalle lesion. Neuro exam.</td>
<td>- Elementary fractures</td>
<td>Nonoperative: NWB for 12wk</td>
<td></td>
</tr>
<tr>
<td>XR: AP pelvis, obturator &amp; iliac obliques (Judit views) are essential. Roof arc angle: center of head to fx (≤45° is WB)</td>
<td>- Associated fractures</td>
<td>- Roof arc angle &gt;45°</td>
<td></td>
</tr>
<tr>
<td>CT: Essential to accurately define fx (size, impaction, articular involvement, LB) &amp; do preop planning</td>
<td>- Posterior wall</td>
<td>- Posterior wall fx ≤20-30%</td>
<td></td>
</tr>
<tr>
<td>- Posterior column</td>
<td>- Anterior column</td>
<td>- Irreducible fx/dx</td>
<td></td>
</tr>
<tr>
<td>- Anterior column</td>
<td>- Transverse</td>
<td>- Marginal impaction</td>
<td></td>
</tr>
<tr>
<td>- Transverse &amp; post. wall</td>
<td>- T type</td>
<td>- Loose bodies in hip joint</td>
<td></td>
</tr>
<tr>
<td>- Ant. column and post. hemitransverse</td>
<td>- Both columns</td>
<td>- XRT for HO prophylaxis</td>
<td></td>
</tr>
</tbody>
</table>

**Complications**: Posttraumatic arthritis, nerve injury (sciatic nerve), postsurgical (heterotopic ossification [HO], sciatic nerve injury, bleeding), malunion/nonunion, infection (assoc. with Morel-Lavalle lesion), thromboembolism.
Acetabulum—Associated Fractures

- Posterior column/posterior wall
- Transverse/posterior wall
- T-shaped fracture
- Anterior column/posterior hemi transverse
- Both columns

Open reduction internal fixation acetabular fracture

- Posterior column fracture. Repair with plate and lag screw
- Anterior column fracture. Repair with plate and long screws
- Transverse fracture. Repair with plate and lag screw
**LIGAMENTS**

**ATTACHMENTS**

**COMMENTS**

**SACROILIAC**

- This is a gliding joint. It has minimal rotational motion during gait. There should be no vertical motion in the normal joint.
- Vertical stability is essential; the body weight is transmitted through this joint.
- Articular surface (located inferiorly in articulation) covered with: sacrum (articular cartilage), ilium (fibrocartilage)

<table>
<thead>
<tr>
<th>LIGAMENT</th>
<th>ATTACHMENT</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior sacroiliac</td>
<td>Posterolateral sacrum to posteromedial ilium</td>
<td>Strongest in pelvis: key to vertical stability</td>
</tr>
<tr>
<td></td>
<td>Oblique orientation: sacrum to PSIS &amp; PIIS</td>
<td>Resists rotational forces</td>
</tr>
<tr>
<td></td>
<td>Vertical orientation: sacrum to PSIS</td>
<td>Resists vertical forces, blends with sacrotuberous ligament</td>
</tr>
<tr>
<td>Anterior sacroiliac</td>
<td>Anterior sacrum to anterior ilium</td>
<td>Weaker than posterior; resists rotational forces</td>
</tr>
<tr>
<td>Intersosseous</td>
<td>Sacrum to ilium</td>
<td>Adds support to anterior &amp; posterior ligaments</td>
</tr>
</tbody>
</table>

**PELVIC STABILITY**

- Rotational stability: Tranverse/horizontal orientation
  - Short posterior SI, anterior SI, sacrospinous, iliolumbar ligaments
- Vertical stability: Longitudinal/vertical orientation
  - Long posterior SI, sacrotuberous, lumbosacral ligaments
JOINTS • Pelvis

**Median (sagittal) section**
- Body of L5 vertebra
- False pelvis
- Lumbosacral (L5—S1) intervertebral disc
- Sacral promontory
- Greater sciatic foramen
- True pelvis
- Ischial spine
- Sacrospinous ligament
- Lesser sciatic foramen
- Sacrotuberous ligament
- Coccyx
- Ischial tuberosity

**Lateral view**
- Wing (ala) of ilium (gluteal surface)
- Body of ilium
- Anterior superior iliac spine
- Anterior inferior iliac spine
- Acetabulum
- Greater sciatic foramen
- Sacrospinous ligament
- Acetabular labrum
- Lunate (articular) surface
- Sacrotuberous ligament
- Transverse acetabular ligament
- Sacrospinous ligament
- Acetabular notch
- Posterior superior iliac spine
- Posterior inferior iliac spine

**LIGAMENTS**

<table>
<thead>
<tr>
<th>LIGAMENTS</th>
<th>ATTACHMENTS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUBIC SYMPHYSIS</td>
<td>• Anterior articulation of two hemipelvess. Articulating surfaces are covered with hyaline cartilage. • Fibrocartilage disc between two pubic bones in the joint</td>
<td>Strongest supporting ligament Music attachments also support inferiorly</td>
</tr>
<tr>
<td>Superior pubic</td>
<td>Both pubic bones superiorly (&amp; anteriorly)</td>
<td></td>
</tr>
<tr>
<td>Arcuate pubic</td>
<td>Both pubic bones inferiorly</td>
<td></td>
</tr>
</tbody>
</table>

**OTHER LIGAMENTS**

<table>
<thead>
<tr>
<th>LIGAMENTS</th>
<th>ATTACHMENTS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacrospinous</td>
<td>Anterolateral sacrum to spinous process</td>
<td>Resists rotation, divides sciatic notches</td>
</tr>
<tr>
<td>Sacrotuberous</td>
<td>Posterolateral sacrum to ischial tuberosity</td>
<td>Resists vertical forces, provides vertical stability</td>
</tr>
<tr>
<td>Iliolumbar</td>
<td>L4 &amp; L5 transverse process to posterior iliac crest</td>
<td>Avulsion fracture sign of unstable pelvic ring injury</td>
</tr>
<tr>
<td>Lumbosacral</td>
<td>L5 transverse process to sacral ala</td>
<td>Anterior support, assists in providing vertical stability</td>
</tr>
</tbody>
</table>
### QUESTION ANSWER CLINICAL APPLICATION

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>Young</td>
<td>Ankylosing spondylitis</td>
</tr>
<tr>
<td></td>
<td>Middle aged–elderly</td>
<td>Sacroiliitis, decreased mobility</td>
</tr>
<tr>
<td>2. Pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Onset</td>
<td>Acute</td>
<td>Trauma: fracture, dislocation, contusion</td>
</tr>
<tr>
<td></td>
<td>Chronic</td>
<td>Systemic inflammatory, degenerative disorder</td>
</tr>
<tr>
<td>b. Character</td>
<td>Deep, non-specific</td>
<td>Sacroiliac etiology, infection, tumor</td>
</tr>
<tr>
<td></td>
<td>Radiating</td>
<td>To thigh or buttock, SI joint, L-spine</td>
</tr>
<tr>
<td>c. Occurrence</td>
<td>In/out of bed, on stairs</td>
<td>Sacroiliac etiology</td>
</tr>
<tr>
<td></td>
<td>Adducting legs</td>
<td>Symphysis pubis etiology</td>
</tr>
<tr>
<td>3. PMHx</td>
<td>Pregnancy</td>
<td>Laxity of ligament in SI joint causes pain</td>
</tr>
<tr>
<td>4. Trauma</td>
<td>Fall on buttock, twist injury</td>
<td>Sacroiliac joint injury</td>
</tr>
<tr>
<td></td>
<td>High velocity: MVA, fall</td>
<td>Fracture, pelvic ring disruption</td>
</tr>
<tr>
<td>5. Activity/work</td>
<td>Twisting, stand on one-leg</td>
<td>Sacroiliac etiology</td>
</tr>
<tr>
<td>6. Neurologic symptoms</td>
<td>Pain, numbness, tingling</td>
<td>Spine etiology, sacroiliac etiology</td>
</tr>
<tr>
<td>7. History of arthritides</td>
<td>Multiple joints involved</td>
<td>SI involvement of RA, Reiter’s syndrome, ankylosing spondylitis, etc</td>
</tr>
</tbody>
</table>

**Anteroposterior compression pelvic fracture of pelvis (open book fracture)**

Forceful frontal impact causes anteroposterior compression of pelvis

**Lateral compression injury pelvic (overlapping pelvis)**

Caused by forceful blow to side of pelvis

Anteroposterior compression pelvic fracture of pelvis (open book fracture)

Forceful frontal impact causes anteroposterior compression of pelvis

Lateral compression injury pelvic (overlapping pelvis)

Caused by forceful blow to side of pelvis
<table>
<thead>
<tr>
<th>EXAM/OBSERVATION</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INSPECTION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin</td>
<td>Discoloration, wounds</td>
<td>Recent trauma</td>
</tr>
<tr>
<td>ASIS’s/iliac crests</td>
<td>Both level (same plane)</td>
<td>If on different plane: leg length discrepancy, sacral torsion</td>
</tr>
<tr>
<td>Lumbar curvature</td>
<td>Increased lordosis</td>
<td>Flexion contracture</td>
</tr>
<tr>
<td></td>
<td>Decreased lordosis</td>
<td>Paraspinal muscle spasm</td>
</tr>
<tr>
<td><strong>PALPATION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bony structures</td>
<td>Standing: ASIS, pubic &amp; iliac tubercles, PSIS</td>
<td>Unequal side to side = pelvic obliquity: leg length discrepancy</td>
</tr>
</tbody>
</table>
|                       | Lying: iliac crest, ischial tuberosity | “Hip pointer”/contusion, fractures
|                       |                                  | Ischial bursitis (“weaver’s bottom”), avulsion fx                                    |
| Soft tissues           | Sacroiliac joint                 | Sacroiliitis                                                                            |
|                       | Inguinal ligament                | Protruding mass: hemia                                                                  |
|                       | Femoral pulse & nodes            | Diminished pulse: vascular injury; palpable nodes: infection                           |
|                       | Muscle groups                    | Each group should be symmetric bilaterally                                              |
| **RANGE OF MOTION**    |                                  |                                                                                        |
| Forward flexion        | Standing: bend forward           | PSISs should elevate slightly (equally)                                                |
| Extension              | Standing: lean backward          | PSISs should depress (equally)                                                         |
| Hip flexion            | Standing: knee to chest          | PSIS should drop but will elevate in hypomobile SI joint
|                       |                                  | Ischial tuberosity should move laterally; will elevate in hypomobile SI joint         |
### Exam/Observation Technique Clinical Application

#### Neurovascular

<table>
<thead>
<tr>
<th>Sensory</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Iliohypogastric nerve (L1)</td>
<td>Suprapubic, lat butt/thigh</td>
</tr>
<tr>
<td>Ilioinguinal nerve (L1)</td>
<td>Inguinal region</td>
</tr>
<tr>
<td>Genitofemoral nerve</td>
<td>Scrotum or mons</td>
</tr>
<tr>
<td>Lateral femoral cutaneous nerve (L2-3)</td>
<td>Lateral hip/thigh</td>
</tr>
<tr>
<td>Pudendal nerve (S2-4)</td>
<td>Perineum</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Motor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral (L2-4)</td>
<td>Hip flexion</td>
</tr>
<tr>
<td>Inferior gluteal nerve</td>
<td>External rotation</td>
</tr>
<tr>
<td>N. to quad. femoris</td>
<td>External rotation</td>
</tr>
<tr>
<td>Superior gluteal nerve</td>
<td>Abduction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflex</td>
<td>Bulbocavernosus</td>
</tr>
<tr>
<td>Pulses</td>
<td>Femoral pulse</td>
</tr>
</tbody>
</table>

#### Special Tests

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelvic rock</td>
<td>Push both iliac crests</td>
</tr>
<tr>
<td>SI stress test</td>
<td>Press ASIS &amp; iliac crests</td>
</tr>
<tr>
<td>Trendelenburg sign</td>
<td>Standing: lift one leg (flex hip)</td>
</tr>
<tr>
<td>Patrick (FABER)</td>
<td>Flex, Abduct, ER hip, then abduct more</td>
</tr>
<tr>
<td>Meralgia</td>
<td>Pressure medial to ASIS</td>
</tr>
<tr>
<td>Rectal and vaginal</td>
<td>Especially after trauma</td>
</tr>
</tbody>
</table>
### ORIGINS AND INSERTIONS

#### Pelvis

**PUBIC RAMI**
- Pectineus
- Adductor longus
- Adductor brevis
- Adductor magnus*
- Gracilis
- Obturator internus
- Obturator externus

**GREATER TROCHANTER**
- Origin of psoas major muscle from sides of vertebral bodies, intervertebral discs and transverse processes (T12-L4)
- Piriformis muscle
- Pectineus muscle
- Adductor longus muscle
- Adductor brevis muscle

**ISCHIAL TUBEROSITY**
- Semimembranosus
- Semitendinosus
- Biceps femoris (LH)
- Adductor magnus*

**LINEA ASPERA**
- Vastus lateralis
- Vastus medialis
- Vastus intermedius

**ORIGINS**

<table>
<thead>
<tr>
<th>PUBIC RAMI</th>
<th>GREATER TROCHANTER</th>
<th>ISCHIAL TUBEROSITY</th>
<th>LINEA ASPERA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORIGINS</td>
<td>INSERTIONS</td>
<td>INSERTIONS</td>
<td>INSERTIONS</td>
</tr>
<tr>
<td>Pectineus</td>
<td>Gluteus medius (posterior)</td>
<td>Gluteus maximus</td>
<td>Gluteus maximus</td>
</tr>
<tr>
<td>Adductor longus</td>
<td>Gluteus minimus (anterior)</td>
<td>Adductor magnus*</td>
<td>Adductor magnus</td>
</tr>
<tr>
<td>Adductor brevis</td>
<td>Quadratus femoris</td>
<td>Semimembranosus</td>
<td>Adductor magnus</td>
</tr>
<tr>
<td>Adductor magnus*</td>
<td>Biceps femoris (LH)</td>
<td>Semitendinosus</td>
<td>Adductor brevis</td>
</tr>
<tr>
<td>Gracilis</td>
<td>Obturator internus</td>
<td>Adductor longus</td>
<td>Adductor magnus</td>
</tr>
<tr>
<td>Obturator externus</td>
<td>Obturator externus</td>
<td>Obturator externus</td>
<td>Pectineus</td>
</tr>
</tbody>
</table>

**INSERTIONS**

- **SHORT EXTERNAL ROTATORS**
  - Piriformis
  - Superior gemellus
  - Obturator internus
  - Obturator externus

*Has two origins*
# HIP FLEXORS

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psoas major</td>
<td>T12-L5 vertebrae</td>
<td>Lesser trochanter</td>
<td>Femoral</td>
<td>Flex hip</td>
<td>Covers lumbar plexus</td>
</tr>
<tr>
<td>Psoas minor</td>
<td>T12-L1 vertebrae</td>
<td>Iliopubic eminence</td>
<td>L1-ventral ramus</td>
<td>Assists in hip flexion</td>
<td>Weak—present in 50% of people</td>
</tr>
<tr>
<td>Iliacus</td>
<td>Iliac fossa/sacral ala</td>
<td>Lesser trochanter</td>
<td>Femoral</td>
<td>Flex hip</td>
<td>Covers ant. ilium</td>
</tr>
</tbody>
</table>

Also see muscles of the thigh/hip in Chapter 8.
<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HIP ABDUCTORS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensor fasciae latae</td>
<td>Iliac crest, ASIS</td>
<td>Iliotibial band/ proximal tibia</td>
<td>Superior gluteal</td>
<td>Abducts, flex, IR thigh</td>
<td>A plane in anterior approach to hip</td>
</tr>
<tr>
<td>Gluteus medius</td>
<td>Ilium b/w ant. and post. gluteal lines</td>
<td>Greater trochanter (posterior)</td>
<td>Superior gluteal</td>
<td>Abducts, IR thigh</td>
<td>Trendelenburg gait if muscle is out</td>
</tr>
<tr>
<td>Gluteus minimus</td>
<td>Ilium b/w ant. and inf. gluteal lines</td>
<td>Greater trochanter (anterior)</td>
<td>Superior gluteal</td>
<td>Abducts, IR thigh</td>
<td>Works in conjunction with medius</td>
</tr>
<tr>
<td><strong>HIP EXTENSORS AND EXTERNAL ROTATORS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gluteus maximus</td>
<td>Ilium, dorsal sacrum</td>
<td>ITB, gluteal tuberosity (femur)</td>
<td>Inferior gluteal</td>
<td>Extend, ER thigh</td>
<td>Must be split in posterior approach to hip</td>
</tr>
<tr>
<td>Obturator externus</td>
<td>Ischiopubic rami, obturator membrane</td>
<td>Trochanteric fossa</td>
<td>Obturator</td>
<td>ER thigh</td>
<td>Inserts at start point for IM nail</td>
</tr>
<tr>
<td><strong>Short External Rotators</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piriformis</td>
<td>Anterior sacrum</td>
<td>Superior greater trochanter</td>
<td>N. to piriformis</td>
<td>ER thigh</td>
<td>Used as landmark for sciatic nerve</td>
</tr>
<tr>
<td>Superior gemellus</td>
<td>Ischial spine</td>
<td>Medial greater trochanter</td>
<td>N. to obturator internus</td>
<td>ER thigh</td>
<td>Detached in posterior approach to hip</td>
</tr>
<tr>
<td>Obturator internus</td>
<td>Ischiopubic rami, obturator mem.</td>
<td>Medial greater trochanter</td>
<td>N. to obturator internus</td>
<td>ER, abduct thigh</td>
<td>Exits through lesser sciatic foramen</td>
</tr>
<tr>
<td>Inferior gemellus</td>
<td>Ischial tuberosity</td>
<td>Medial greater trochanter</td>
<td>N. to quadratus femoris</td>
<td>ER thigh</td>
<td>Detached in posterior approach to hip</td>
</tr>
<tr>
<td>Quadratus femoris</td>
<td>Ischial tuberosity</td>
<td>Intertrochanteric crest</td>
<td>N. to quadratus femoris</td>
<td>ER thigh</td>
<td>Ascending br. medial circumflex artery under muscle</td>
</tr>
</tbody>
</table>
### Lumbar Plexus

Lumbar plexus comprises the ventral rami of L1-L4. Two divisions: anterior (innervates flexors), posterior (extensors). Plexus formed within the psoas muscle.

#### Anterior Division

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Location</th>
<th>Sensory</th>
<th>Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcostal (T12): Inferior to 12th rib</td>
<td>Subxiphoid region</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Iliohypogastric (L1): Under psoas, pierces abdominal muscles</td>
<td>Above pubis, posterolateral buttocks</td>
<td>Above pubis, posterolateral buttocks</td>
<td>Transversus abdominis, internal oblique</td>
</tr>
<tr>
<td>Ilioinguinal (L1): Under psoas, pierces abdominal muscles</td>
<td>Inguinal region, anterosuperior thigh</td>
<td>Scrotum or labia majora</td>
<td>Cremaster</td>
</tr>
</tbody>
</table>

#### Posterior Division

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Location</th>
<th>Sensory</th>
<th>Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obturator (L2-4): Exits via obturator canal, splits into ant. &amp; post. division (can be injured by retractors placed behind the transverse acetabular ligament (TAL))</td>
<td>Inferomedial thigh via cut. br. of obturator n.</td>
<td>None</td>
<td>Obturator externus (posterior division)</td>
</tr>
<tr>
<td>Accessory Obturator (L2-4): Inconsistent</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Femoral (L2-4): Lies between psoas major and iliacus</td>
<td>None (in pelvis)</td>
<td>Psoas, iliacus, pectineus</td>
<td>Psoas, iliacus, pectineus</td>
</tr>
</tbody>
</table>

### Lateral Femoral Cutaneous (FFCN) (L2-3): runs on iliacus, crosses inferior to ASIS (can be compressed there: meralgia paresthetica)

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Location</th>
<th>Sensory</th>
<th>Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral cutaneous nerve of thigh</td>
<td>None (in pelvis)</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

---

**Diagram:**

- Subcostal nerve (T12)
- Iliohypogastric nerve
- Ilioinguinal nerve
- Genitofemoral nerve
- Lateral cutaneous nerve of thigh
- Femoral nerve
- Obturator nerve

**Schema:**

- T12 (Subcostal nerve)
- L1 (Iliohypogastric nerve)
- L2 (Ilioinguinal nerve)
- L3 (Genitofemoral nerve)
- L4 (Lateral femoral cutaneous nerve)
- L5 (Gray rami communicantes)
- Femoral nerve
- Accessory obturator nerve
- Obturator externus (posterior division)
- Obturator externus (posterior division)
- Femoral nerve
- Lumbosacral trunk

**Key:**

- White and gray rami communicantes
- Muscular branches to psoas and iliacus muscles
- Femoral nerve
- Accessory obturator nerve
- Obturator externus (posterior division)
- Femoral nerve
- Lumbosacral trunk

---

**Netter's Concise Orthopaedic Anatomy**
**LUMBOSACRAL PLEXUS**

Lumbosacral plexus comprises the ventral rami of L4-S3(4). Two divisions: Anterior (innervates flexors), posterior (extensors). Plexus lies on anterior piriformis muscle.

### Anterior Division

<table>
<thead>
<tr>
<th>Nerve to quadratus femoris (L4-S1)</th>
<th>Sensory: None</th>
<th>Motor: Quadratus femoris, Inferior gemelli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nerve to obturator internus (L5-S2)</td>
<td>Sensory: None</td>
<td>Motor: Obturator internus, Superior gemelli</td>
</tr>
</tbody>
</table>

### Posterior Division

<table>
<thead>
<tr>
<th>Nerve to piriformis</th>
<th>Sensory: None</th>
<th>Motor: Piriformis muscle, Coccygeus, Levator ani</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nerve to quadratus femoris (and inferior gemellus)</td>
<td>Sensory: None</td>
<td>Motor: Quadratus femoris, Inferior gemelli</td>
</tr>
<tr>
<td>Nerve to obturator internus (and superior gemellus)</td>
<td>Sensory: None</td>
<td>Motor: Obturator internus, Superior gemelli</td>
</tr>
</tbody>
</table>

### Pudendal (S2-4)

<table>
<thead>
<tr>
<th>Sensory: Perineum</th>
<th>Motor: Bulbospongiosus, Ischiocavernosus, Urethral sphincter, Urogenital diaphragm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory: Perineal nerve (scrotal/labial br.)</td>
<td>Motor: Perineal nerve</td>
</tr>
<tr>
<td>Sensory: Inferior rectal nerve</td>
<td>Motor: Perineal nerve, Urogenital diaphragm</td>
</tr>
<tr>
<td>Sensory: Dorsal nerve to penis/clitoris</td>
<td>Motor: Perineal nerve</td>
</tr>
</tbody>
</table>

### Nerve to coccygeus (S3-4)

| Sensory: None | Motor: Coccygeus, Levator ani |

---

**Topography:** medial and slightly anterior view of hemisected pelvis
### NERVES • Pelvis

**Superior Gluteal (L4-S1):** Exits greater sciatic foramen above the piriformis
- **Sensory:** None
- **Motor:** Gluteus medius, Gluteus minimus, Tensor fasciae latae

**Inferior Gluteal (L5-S2):** Exits greater sciatic foramen
- **Sensory:** None
- **Motor:** Gluteus maximus

**Nerve to Piriformis (S2):** Directly innervates muscle
- **Sensory:** None
- **Motor:** Piriformis

**Posterior Femoral Cutaneous (S1-S3):** Exits via greater sciatic foramen, under piriformis, medial to sciatic nerve
- **Sensory:** Inferior buttocks: via inferior cluneal nerves
- **Motor:** None

**Sciatic (L4-S3):** Largest nerve in body. Two components: tibial (ant. division) and peroneal (post. division). Exits greater sciatic foramen under piriformis. Anatomic variants include exiting through or above piriformis. Reflecting short ERs will protect sciatic in posterior approach to hip.
- **Sensory:** None (in pelvis; see Chapters 8-10)
- **Motor:** None (in pelvis; see Chapters 8-10)

### Other Nerves (Nonplexus)

**Superior Cluneal (L1-3):** Branches of dorsal rami.
- **Sensory:** Superior ⅔ of buttocks

**Medial Cluneal (S1-3):** Branches of dorsal rami
- **Sensory:** Sacral and medial buttocks

* Piriformis muscle is the landmark in gluteal region. Most nerves exit inferior to it. **POP'S IQ** is a mnemonic: Pudendal, N. to Obturator internus, Posterior cutaneous, Sciatic, Inferior gluteal, N. to Quadratus femoris.
### Aorta

<table>
<thead>
<tr>
<th>Artery</th>
<th>Course</th>
<th>Comment/Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common iliacs</td>
<td>Branch at L4, run along anterior spine</td>
<td>Blood supply to pelvis &amp; lower extremities</td>
</tr>
<tr>
<td>Median sacral</td>
<td>Descends along anterior spine &amp; sacrum</td>
<td>Anastomoses with lateral sacral arteries</td>
</tr>
</tbody>
</table>

### Common Iliac Artery

<table>
<thead>
<tr>
<th>Artery</th>
<th>Course</th>
<th>Comment/Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal iliac</td>
<td>Under ureter toward sacrum, then divides</td>
<td>Supplies most of pelvis &amp; pelvic organs</td>
</tr>
<tr>
<td>External iliac</td>
<td>On ant. surface of psoas to inguinal ligament</td>
<td>Does not supply much of the pelvis</td>
</tr>
</tbody>
</table>

### Internal Iliac

#### Anterior Division

<table>
<thead>
<tr>
<th>Artery</th>
<th>Course</th>
<th>Comment/Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obturator</td>
<td>Through obturator foramen w/obturator nerve</td>
<td>Fovea artery (ligamentum teres) branches</td>
</tr>
<tr>
<td>Inferior gluteal</td>
<td>Exits greater sciatic foramen under piriformis</td>
<td>Supplies gluteus maximus muscle</td>
</tr>
<tr>
<td>Multiple visceral branches</td>
<td>Umbilical</td>
<td>Supplies bladder (via sup. vesical arteries)</td>
</tr>
<tr>
<td></td>
<td>Uterine/vaginal (females)</td>
<td>Supplies uterus &amp; vagina (via vaginal br.)</td>
</tr>
<tr>
<td></td>
<td>Inferior vesical (males)</td>
<td>Supplies bladder, prostate, ductus deferens</td>
</tr>
<tr>
<td></td>
<td>Middle rectal</td>
<td>Anastomoses w/sup. &amp; inf. rectal arteries</td>
</tr>
<tr>
<td></td>
<td>Internal pudendal</td>
<td>Runs with pudendal nerve</td>
</tr>
</tbody>
</table>

#### Posterior Division

<table>
<thead>
<tr>
<th>Artery</th>
<th>Course</th>
<th>Comment/Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior gluteal</td>
<td>Exits greater sciatic foramen above piriformis</td>
<td>In sciatic notch, can be injured in posterior column fractures or pelvic ring injuries</td>
</tr>
<tr>
<td>Iliolumbar</td>
<td>Runs superiorly toward iliac fossa</td>
<td>Supplies illum, iliacus, &amp; psoas muscles</td>
</tr>
<tr>
<td>Lateral sacral</td>
<td>Run along sacrum, anterior to the sacral roots</td>
<td>Supplies sacrum/sacral muscles/nerves</td>
</tr>
</tbody>
</table>
### Deep dissection

**ARTERY COURSE COMMENT/SUPPLY**

<table>
<thead>
<tr>
<th>ARTERY</th>
<th>COURSE</th>
<th>COMMENT/SUPPLY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXTERNAL ILIAC ARTERY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep circumflex iliac</td>
<td>Runs laterally under internal oblique to iliac crest</td>
<td>Supplies anterolateral abdominal wall muscles</td>
</tr>
<tr>
<td>Inferior epigastric</td>
<td>Runs superiorly in transversalis fascia</td>
<td>Supplies anterior abdominal wall muscles</td>
</tr>
<tr>
<td>Femoral artery</td>
<td>Continuation of EIA under inguinal ligament</td>
<td>Terminal branch of external iliac artery</td>
</tr>
<tr>
<td><strong>FEMORAL ARTERY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superficial circumflex iliac</td>
<td>In subcutaneous tissues toward ASIS</td>
<td>Supplies superficial abdominal tissues</td>
</tr>
<tr>
<td>Superficial epigastric</td>
<td>In subcutaneous tissues toward umbilicus</td>
<td>Supplies superficial abdominal tissues</td>
</tr>
<tr>
<td>Superficial &amp; deep external pudendal</td>
<td>Medially over the adductors &amp; spermatic cord to inguinal and genital regions</td>
<td>Supplies subcutaneous tissues in the public region and the scrotum/labia majus</td>
</tr>
<tr>
<td>Profunda femoris (deep artery of thigh)</td>
<td>Between adductor longus &amp; pectineus/ adductor brevis</td>
<td>Gives off circumflex (2) &amp; perforating branches</td>
</tr>
<tr>
<td>Medial circumflex femoral</td>
<td>B/w pectineus &amp; psoas, then posterior to femoral neck under quadratus femoris</td>
<td>Runs under quadratus femoris; can be injured in posterior approach to hip</td>
</tr>
<tr>
<td>Lateral circumflex femoral</td>
<td>Runs laterally deep to sartorius &amp; rectus</td>
<td>At risk in anterolateral approach to hip</td>
</tr>
</tbody>
</table>
### OSTEITIS PUBIS

- Inflammation or degeneration of pubic symphysis
- Etiology: repetitive microtrauma (sports) or fracture

**Hx:** Anterior pelvic pain, sports or trauma

**PE:** Symphysis pubis is tender to palpation

**XR:** AP pelvis (+/- inlet & outlet views)

**CT/MR:** Not usually necessary for diagnosis

1. Activity modification
2. Rest, NSAIDs
3. Fusion if symptoms are refractory to conservative care

### SACROILIITIS

- Inflammation or degeneration of sacroiliac joint
- Infection can also occur here
- Assoc. w/Reiter’s syndrome

**Hx:** Low back pain

**PE:** SIJ tender to palpation, + FABER test; injection can help diagnosis

**XR/CT:** SI joints, +/- DJD

**Bone Scan:** r/o infection

**LABS:** CBC, ESR, CRP if infection is suspected

1. Rest, NSAIDs
2. Injection can be diagnostic & therapeutic (corticosteroid)
3. Fusion: rarely indicated

### ISCHIAL BURSITIS

- Inflammation of bursa of ischial tuberosity
- Often from prolonged sitting
- Aka “weaver’s bottom”
- Mimics hamstring injury

**Hx:** Buttocks pain, sitting

**PE:** Ischial tuberosity tender to palpation; active hamstrings NOT painful

**XR:** Pelvis, r/o tuberosity avulsion

**MR:** Can evaluate/ r/o hamstring insertion injury

1. Rest
2. NSAIDs
3. Activity modification: decrease sitting or increase cushion

### ILIAC CREST CONTUSION (HIP POINTER)

- Direct trauma to iliac crest
- Common in contact sports (e.g., football, hockey, etc)

**Hx:** Trauma, “hip” pain

**PE:** Iliac crest tender to palpation

**XR:** Pelvis, r/o fracture

**MR/CT:** Usually not necessary for diagnosis

1. Rest, NSAIDs
2. Padding to iliac crest
3. Corticosteroid injection
USES INTERNERVOUS PLANE DANGERS COMMENT

<table>
<thead>
<tr>
<th>USES</th>
<th>INTERNERVOUS PLANE</th>
<th>DANGERS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Open reduction, internal fixation of acetabular fractures involving anterior column of acetabulum</td>
<td>3 windows—interval (access): 1. Lateral to iliopsoas &amp; femoral nerve (anterior, SIJ, iliac fossa, pelvic brim) 2. Between iliopsoas/femoral nerve &amp; external iliac artery (pelvic brim, lateral superior pubic ramus) 3. Medial to external iliac artery &amp; spermatic cord (quadrilateral plate &amp; retropubic space [of Retzius])</td>
<td>• Ext. iliac (EI) vessels  • Corona mortis (vessel from obt. art. to EI art.)  • Femoral nerve  • Lateral femoral cutaneous nerve  • Inferior epigastric artery  • Spermatic cord  • Bladder (use a Foley)</td>
<td>• Good knowledge of abdominal &amp; pelvic anatomy essential to perform this approach  • Must detach pelvic insertion of abdominal muscles &amp; iliacus muscle for exposure  • Use rubber drains around iliopsoas/femoral n. &amp; external iliac vessels to access windows</td>
</tr>
</tbody>
</table>
Kocher-Langenbeck Approach

- Open reduction, internal fixation of acetabular fractures involving posterior column of acetabulum
- No internervous plane
- Gluteus maximus (inf. gluteal n.) fascia is split in line with its fibers; inferior gluteal nerve is limit to the split.
- Tensor fasciae latae also split in line with its fibers

- Sciatic nerve
- Inferior gluteal artery
- Superior gluteal vessels & nerve (esp. w/excessive retraction)
- Heterotopic ossification is common, prophylaxis (e.g., XRT) is often needed.
- Do not take down quadratus femoris due to vascular risk

<table>
<thead>
<tr>
<th>USES</th>
<th>INTERNEUROUS PLANE</th>
<th>DANGERS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open reduction, internal fixation of acetabular fractures involving posterior column of acetabulum</td>
<td>No internervous plane</td>
<td>Sciatic nerve, Inferior gluteal artery, Superior gluteal vessels &amp; nerve (esp. w/excessive retraction)</td>
<td>Heterotopic ossification is common, prophylaxis (e.g., XRT) is often needed. Do not take down quadratus femoris due to vascular risk</td>
</tr>
<tr>
<td>Topic</td>
<td>Page</td>
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<td>Topographic Anatomy</td>
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</table>
**STRUCTURE CLINICAL APPLICATION**

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iliac crest</td>
<td>Site for “hip pointers”/contusion of iliac crest</td>
</tr>
<tr>
<td></td>
<td>Common site for autologous bone graft harvest</td>
</tr>
<tr>
<td>Greater trochanter</td>
<td>Tenderness can indicate trochanteric bursitis.</td>
</tr>
<tr>
<td>Ischial tuberosity</td>
<td>Avulsion fracture (hamstrings) or bursitis can occur here.</td>
</tr>
<tr>
<td>Iliotibial tract (band)</td>
<td>Can snap over greater trochanter of femur, creating “snapping hip” syndrome.</td>
</tr>
<tr>
<td></td>
<td>Tightness can cause lateral knee and/or thigh pain.</td>
</tr>
<tr>
<td>Quadriceps muscle</td>
<td>Atrophy can indicate an injury and/or contribute to knee pain.</td>
</tr>
<tr>
<td>- Vastus lateralis</td>
<td></td>
</tr>
<tr>
<td>- Vastus medialis</td>
<td></td>
</tr>
<tr>
<td>- Rectus femoris</td>
<td></td>
</tr>
<tr>
<td>- Vastus intermedius (not shown)</td>
<td></td>
</tr>
<tr>
<td>Quadriceps tendon</td>
<td>Can rupture with eccentric loading. Defect is felt here.</td>
</tr>
<tr>
<td>Popliteal fossa</td>
<td>Popliteal artery pulse can be palpated here.</td>
</tr>
</tbody>
</table>

**Thigh/Hip • TOPOGRAPHIC ANATOMY**
• Long bone characteristics
  • Proximal femur
    ◦ Head: nearly spherical (½)
    ◦ Neck: antverted from shaft
    ◦ Greater trochanter: lateral
    ◦ Lesser trochanter: posteromedial
  • Shaft: tubular, bows anteriorly
    ◦ Linea aspera posterior: insertion of fascia and muscles
  • Distal femur: 2 condyles
    ◦ Medial: larger, more posterior
    ◦ Lateral: more anterior & proximal
    ◦ Trochlea: anterior articular depression between condyles

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>OSSIFY</th>
<th>FUSE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FEMUR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Primary         | 7-8wk  | 16-18yr | Blood supply
                  (Shaft)  | (fetal) |               |
| Secondary       | Distal physis | birth | 19yr | Head/neck: primarily [medial femoral circumflex] artery (also lateral FCA and of ligamentum teres artery)
                  Head          | 1yr       | 18yr | Shaft: nutrient artery (from profunda fem.)
                  Gtr troch      | 4-5yr     | 16yr | Head vascularity is susceptible to disruption in fracture or dislocation—leads to AVN
                  Lsr troch      | 10yr      | 16yr | Proximal femur bone density decreases with age, making it more susceptible to fracture
|                  |          |      | • Calcar femorale—vertically oriented dense bone in posteromedial aspect of prox. femur
                  |          |      | • Piriformis fossa—posteromedial base of gtr trochanter: starting point for femoral nails
                  |          |      | • Neck/shaft angle: 120-135°
                  |          |      | • Femoral anteverision: 10-15°
                  |          |      | • Distal femur physis: grows approx. 7mm/yr |
**GROUP COMMENT**

### PROXIMAL FEMUR OSTEOLOGY

- Proximal femur comprises several distinct trabecular bone groups that support the head and neck.
- The presence or absence of these groups helps to determine the presence & degree of osteopenia in the prox. femur.
- Malalignment of bone groups determines the fracture type in displaced femoral neck fractures.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary compressive</td>
<td>From superior femoral head to medial neck, strongest cancellous bone, supports body weight</td>
</tr>
<tr>
<td>Primary tensile</td>
<td>From inferior femoral head to lateral cortex</td>
</tr>
<tr>
<td>Secondary compressive</td>
<td>Oriented along lines of stress in proximal femur</td>
</tr>
<tr>
<td>Secondary tensile</td>
<td>Oriented along lines of stress in lateral proximal femur</td>
</tr>
<tr>
<td>Greater trochanteric group</td>
<td>Oriented along lines of stress within the greater trochanter</td>
</tr>
<tr>
<td>Ward’s triangle</td>
<td>Area of relative few trabeculae within the femoral neck</td>
</tr>
</tbody>
</table>

### LOWER EXTREMITY ALIGNMENT

#### Definitions

- **Anatomic axis**: Line drawn along the axis of the femur
- **Mechanical axis**: Line drawn between center of femoral head and intercondylar notch
- **Knee axis**: Line drawn along the inferior aspect of both femoral condyles
- **Vertical axis**: Vertical line, perpendicular to the ground
- **Lateral femoral angle**: Angle formed between the knee axis and the femoral axis

#### Relationships

- **Knee axis**: Parallel to the ground and perpendicular to vertical axis
- **Mechanical axis**: Average of 6° from anatomic axis
- **Lateral femoral angle**: 81° with respect to femoral anatomic axis
  
  87° with respect to femoral mechanical axis
<table>
<thead>
<tr>
<th>RADIOGRAPH</th>
<th>TECHNIQUE</th>
<th>FINDINGS</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP pelvis</td>
<td>Supine, beam at symphysis</td>
<td>Both hips and pelvis</td>
<td>Fractures, dislocations, arthritis</td>
</tr>
<tr>
<td>AP hip</td>
<td>Beam aimed at proximal femur</td>
<td>Femoral head, acetabulum</td>
<td>Fractures, arthritis</td>
</tr>
<tr>
<td>Lateral (frog leg)</td>
<td>Flex, abd. ER hip, beam at hip</td>
<td>Fem. neck, head, acetab. rim</td>
<td>Fractures, arthritis</td>
</tr>
<tr>
<td>Lateral (cross-table)</td>
<td>Flex contralateral hip to remove it; aim beam across table at hip</td>
<td>Femoral neck, head, acetabular rim. Ant &amp; post. cortices seen well on lateral</td>
<td>Often needed for preop fx films Used intraop (fluoro) for ORIF</td>
</tr>
<tr>
<td>AP femur</td>
<td>Supine, beam at mid femur</td>
<td>Femur, soft tissues</td>
<td>Fractures, tumors</td>
</tr>
<tr>
<td>Lateral femur</td>
<td>Beam laterally at mid femur</td>
<td>Femur, soft tissues</td>
<td>Fractures, tumors</td>
</tr>
</tbody>
</table>

See Chapter 7, Pelvis, for views of acetabulum.

### OTHER STUDIES

<table>
<thead>
<tr>
<th>Technique</th>
<th>Articular congruity, fracture fragments</th>
<th>Intraarticular acetabulum or neck fractures</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>Axial, coronal, &amp; sagittal views</td>
<td></td>
</tr>
<tr>
<td>MRI</td>
<td>Sequence protocols vary</td>
<td>Labral tears, AVN, stress fractures</td>
</tr>
<tr>
<td>Bone scan</td>
<td>Radioisotope</td>
<td>All bones evaluated</td>
</tr>
</tbody>
</table>
**DESCRIPTION**
- High-energy trauma (esp. MVA, dashboard injury) or significant fall
- Orthopaedic emergency; risk of femoral head AVN increases with late/delayed reduction
- Multiple associated injuries +/- fractures (e.g., femoral head/neck, acetabulum)
- Posterior most common (85%)  

**EVALUATION**
- Hx: Trauma, severe pain, cannot move thigh/hip
- PE: Thigh position:
  - Post.: adducted, flexed, IR
  - Ant.: abducted, flexed, ER
- Pain (esp. with motion), good neurovascular exam (sciatic n.)
- XR: AP pelvis, frog lateral (femoral head appears of different size), femur and knee series
- CT: Rx/ fx or bony fragments/ loose bodies (postreduction)

**CLASSIFICATION**
- Posterior: Thompson:
  - I: No or minor post. wall fx
  - II: Large posterior wall fx
  - III: Comminuted acetabular fx
  - IV: Acetabular floor fx
  - V: Femoral head fx
- Anterior: Epstein:
  - I (A, B, C): Superior
  - II (A, B, C): Inferior
  - A: No associated fx
  - B: Femoral head fx
  - C: Acetabular fx

**TREATMENT**
- Early reduction essential (<6 hr), then repeat XR & neuro exam
- Posterior: Closed reduction and abduction pillow
  - II-V:
    1. Closed reduction (open if irreducible)
    2. ORIF (fracture or excise fragment/LB)
- Anterior: Closed reduction, ORIF if necessary

**COMPLICATIONS:**
- Posttraumatic osteonecrosis (AVN) (reduced risk with early reduction); sciatic nerve injury (posterior dislocations); femoral artery/nerve injury (anterior dislocations); osteoarthritis; heterotopic ossification
### FEMORAL NECK FRACTURE

#### MECHANISM
- Fall by elderly person most common
- High-energy injury in young adults (e.g., MVA)
- Intracapsular fractures
- Femoral head vascularity at risk in displaced fractures
- Associated with osteoporosis
- High morbidity & complication rates

#### EVALUATION
- Hx: Fall, pain, inability to bear weight/walk
- PE: LE shortened, abducted, externally rotated. Pain w/"rolling"/log roll extremity
- XR: AP pelvis, cross-table lateral
- MR: If symptomatic with negative XR (i.e., rule out occult fracture)

#### CLASSIFICATION
- Garden (4 types):
  - I: Incomplete fracture; valgus impaction
  - II: Complete fracture; nondisplaced
  - III: Complete fracture, partial displacement (varus)
  - IV: Complete fracture, total displacement

#### TREATMENT
- **Young (high-energy)**
  - Urgent reduction (CR vs OR)
  - ORIF (3 parallel screws)
- **Elderly**
  - Early medical evaluation
  - Types I & II: ORIF (3 screws)
  - Types III & IV: hemiarthroplasty
  - Medically unstable, nonoperative

### COMPLICATIONS
- Osteonecrosis (AVN): incidence increases with fx type (displacement) +/- late segmental collapse; nonunion; hardware failure

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
</table>
| Mechanism   | Hx: Fall, pain, inability to bear weight/walk | Garden (4 types):
  - I: Incomplete fracture; valgus impaction
  - II: Complete fracture; nondisplaced
  - III: Complete fracture, partial displacement (varus)
  - IV: Complete fracture, total displacement | Young (high-energy)
  - Urgent reduction (CR vs OR)
  - ORIF (3 parallel screws) |
| Fall by elderly person most common | PE: LE shortened, abducted, externally rotated. Pain w/"rolling"/log roll extremity | | |
| High-energy injury in young adults (e.g., MVA) | XR: AP pelvis, cross-table lateral | | |
| Intracapsular fractures | MR: If symptomatic with negative XR (i.e., rule out occult fracture) | | |
| Femoral head vascularity at risk in displaced fractures | | | |
| Associated with osteoporosis | | | |
| High morbidity & complication rates | | | |

**Type I.** Impacted fracture

**Type II.** Nondisplaced fracture

**Type III.** Partially displaced

**Type IV.** Displaced fracture. Vertical fracture line generally suggests poorer prognosis
### Intertrochanteric Fracture

**DESCRIPTION**
- Fall by an elderly person most common
- Associated with osteoporosis
- Occurs along or below intertrochanteric line
- Extracapsular fractures
- Stable vascularity
- Most heal well with proper fixation

**EVALUATION**
- History (Hx): Fall, pain, inability to bear weight/walk
- Physical examination (PE): LE shortened, ER. Pain with "log rolling" of leg
- X-ray (XR): AP pelvis/hip cross-table
- MRI (MR): If symptomatic with negative XR (rule out occult fracture)

**CLASSIFICATION**
- Evans/Jensen:
  - Type IA: Nondisplaced
  - Type IB: 2 part displaced
  - Type IIA: 3 part, GT fragment
  - Type IIB: 3 part, LT fragment
  - Type III: 4 part reverse obliquity

**TREATMENT**
- Early medical evaluation
- Early (<48 hr) ORIF
- Sliding hip screw/plate
- Cephalomedullary nail
- Reverse obliquity
- Blade plate
- Cephalomedullary nail
- Nonoperative; medically unstable patient

**COMPLICATIONS:** Nonunion/malunion, decreased ambulatory status, hardware failure, mortality (20% in 1st 6 mo)

### Femoral Shaft Fractures

**DESCRIPTION**
- Orthopaedic emergency
- High-energy injury (e.g., MVA, fall)
- Associated injuries (common)
- Potential source of significant blood loss
- Compartment syndrome can occur
- Transport patient in traction

**EVALUATION**
- History (Hx): Trauma, pain, swelling deformity, inability to walk/bear weight
- Physical examination (PE): Deformity, +/− open wound & soft tissue injury; check distal pulses
- X-ray (XR): AP/lateral femur; Knee: trauma series
- Hip: r/o ipsilateral femoral neck fx

**CLASSIFICATION**
- Winquist/Hansen (5 types):
  - Stable
  - Type 0: No comminution
  - Minimal comminution
  - >50% of cortices intact
  - Unstable
  - Type I: Comminuted: <50% of cortices intact
  - Type II: Complete comminution, no intact cortex

**TREATMENT**
- Operative: within 24 hr
- Antegrade, reamed, locked IM nail
- Retrograde nail if needed
- External fixation
- Medically unstable
- High-grade open fx
- Traction—if surgery delayed, medically unstable patient

**COMPLICATIONS:** Neurovascular injury/hemorrhagic shock, nonunion/malunion, hardware failure, knee injury (5%)

---

**Thigh/Hip • TRAUMA**

**Intertrochanteric Fracture of Femur**

[Images showing different types of fractures]

**Femoral Shaft Fractures**

[Images and descriptions]
**SUBTROCHANTERIC FRACTURE**

- Within 5cm of lesser trochanter (LT)
- Mechanism:
  - Low-energy fall: elderly, pathologic fx
  - High-energy: younger (e.g., MVA)
- Vascularity is tenuous, can compromise healing
- Rule out pathologic fx if fracture occurs with minimal/no trauma
- High biomechanical stresses

**DESCRIPTION**

**EVALUATION**

- Hx: Trauma, pain, inability to bear weight
- PE: Shortened, rotated LE. No ROM (pain), check neurovascular status
- XR: AP & lateral of femur. Also, AP pelvis, hip (AP & cross-table lateral), & knee series
- CT: Usually not needed

**CLASSIFICATION**

- Russell-Taylor:
  - Type I: no piriformis fossa extension/involvement
    - A: intact LT
    - B: detached LT
  - Type II: fracture involves piriformis fossa
    - A: intact LT
    - B: detached LT

**TREATMENT**

By type:

- IA: standard IM nail
- IB: cephalomedullary nail
- IIA: cephalomedullary nail with trochanteric start point
- IIB: 95° blade plate or cephalomedullary nail with trochanteric start point

**COMPLICATIONS:** Nonunion, malunion, loss of fixation/implant failure, loss of some ambulatory function (esp. in elderly)

**DISTAL FEMUR FRACTURE**

- Mechanism: direct impact
  - Young: high energy
  - Elderly: low energy (fall)
- Articular congruity needed for normal knee function
- Many associated injuries (e.g., tibia fx, knee ligament injury)
- Vascular injuries possible
- Quads/hamstrings: shorten fx. Gastroc: displace fx posteriorly

**DESCRIPTION**

**EVALUATION**

- Hx: Trauma, pain, inability to bear weight
- PE: Swollen, +/- gross deformity. Careful pulse evaluation (Doppler exam if needed)
- XR: AP & lateral knee, femur, tibia
- CT: Evaluate intraarticular involvement & preop plan

**CLASSIFICATION**

- AO/Muller:
  - A: Extraarticular subtypes 1, 2, 3
  - B: Unicondylar subtypes 1, 2, 3
  - C: Bicondylar subtypes 1, 2, 3

**TREATMENT**

- Nondisplaced/stable:
  - Cast, immobilizer, brace
  - Displaced/unstable:
    - Extraarticular: plate or nail
    - Intraarticular: anatomic reduction of articular surface & locking plate/blade plate
  - External fixation: temporarily in open fx, severely swollen soft tissues, unstable patient

**COMPLICATIONS:** Posttraumatic arthritis, nonunion/malunion, knee stiffness/loss of ROM
The hip is a spheroidal (ball & socket) joint. It has intrinsic stability from osseous, ligamentous, & muscular structures.

**Labrum**
Along acetabular rim except inferiorly
Deepens socket, increases femoral head coverage; can be torn (cause of hip pain)

**Transverse acetabular**
Anteroinferior to posteroinferior acetabulum
Covers cotyloid notch in inferior central acetabulum

**Ligamentum teres**
Fovea (femoral head) to cotyloid notch
Small artery to femoral head within this ligament

**Capsule**
- Iliofemoral (2 bands)
- Pubofemoral
- Ischiofemoral

Acetabulum to femoral neck
Superior: ASIS/ilium to greater trochanter
Inferior: ilium to intertrochanteric line/LT
Anterior: pubic ramus to intertroch. line
Posterior: acetabulum to superior femoral neck
Has some discrete thickenings (ligaments)
Aka “Y ligament of Bigelow”; provides strong anterior support, resists extension
Prevents hyperextension of hip, inferior joint support
Broad, relatively weak ligament (minimal posterior support). Does not provide complete post. joint coverage, so lateral post. neck is extracapsular
**STEPS**

**HIP INJECTION/ASPIRATION**

1. Ask patient about allergies
2. Place patient supine, palpate the greater trochanter
3. Prep skin over insertion site (iodine/antiseptic soap)
4. Anesthetize skin locally (quarter size spot)
5. **Anterior:** Find the point of intersection b/w a vertical line below ASIS and horizontal line from greater trochanter. Insert 20-gauge (3in) spinal needle upward/slightly medial direction at that point.
   **Lateral:** Insert a 20-gauge (3in) spinal needle superior and medial to greater trochanter until it hits the bone (the needle should be within the capsule, which extends down the femoral neck). Can “walk” needle up neck into joint.
6. Inject (or aspirate) local or local/steroid preparation into joint. (The fluid should flow easily if needle is in joint.)
7. Dress injection site

**TROCHANTERIC BURSA INJECTION**

1. Ask patient about allergies
2. Place patient in lateral decubitus position, palpate the greater trochanter
3. Prep skin over lateral thigh (iodine/antiseptic soap)
4. Insert 20-gauge needle (at least 1½ in; 3in in larger patients) into thigh to the bone at the point of most tenderness. Withdraw needle (1-2mm) so it is just off the bone and in the bursa. **Aspirate to ensure needle is not in a vessel.**
5. Inject local or local/corticosteroid preparation into bursa. May redirect needle slightly to inject a septated bursa
6. Dress injection site
### QUESTION ANSWER CLINICAL APPLICATION

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>Young Middle age–elderly</td>
<td>Trauma, developmental disorders Arthritis, fractures</td>
</tr>
<tr>
<td>2. Pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Onset</td>
<td>Acute Chronic</td>
<td>Trauma, (fracture, dislocation), infection Arthritis, labral tear</td>
</tr>
<tr>
<td>b. Location</td>
<td>Lateral hip/thigh Buttocks/posterior thigh Groin/medial thigh Anterior thigh</td>
<td>Bursitis, LFCN entrapment, snapping hip syndrome Consider spine etiology Hip joint or acetabular etiology (likely not from spine) Proximal femur pathology</td>
</tr>
<tr>
<td>c. Occurrence</td>
<td>Ambulation/WB/motion At night</td>
<td>Hip joint etiology (i.e., not pelvis/spine) Tumor, infection</td>
</tr>
<tr>
<td>3. Snapping</td>
<td>With ambulation</td>
<td>Snapping hip syndrome, loose bodies, arthritis</td>
</tr>
<tr>
<td>4. Assisted ambulation</td>
<td>Cane/crutch/walker</td>
<td>Use (and frequency) indicates severity of pain and condition</td>
</tr>
<tr>
<td>5. Activity tolerance</td>
<td>Walk distance and activity cessation</td>
<td>Less distance walked and fewer activities no longer performed = more severe</td>
</tr>
<tr>
<td>6. Trauma</td>
<td>Fall, MVA</td>
<td>Fracture, dislocation, labral tear</td>
</tr>
<tr>
<td>7. Activity/work</td>
<td>Repetitive use</td>
<td>Femoral stress fracture</td>
</tr>
<tr>
<td>8. Neurologic symptoms</td>
<td>Pain, numbness, tingling</td>
<td>LFCN entrapment, spine etiology (e.g., radiculopathy)</td>
</tr>
<tr>
<td>9. History of arthritides</td>
<td>Multiple joints involved</td>
<td>Systemic inflammatory disease</td>
</tr>
</tbody>
</table>

---

**Trauma**

Mechanism of injury often by impact with dashboard, which drives femoral head backward, out of acetabulum

**Osteoarthritis**

Characteristic habitus and gait

**LFCN entrapment**

Numbness and dysesthesias in lateral thigh

---

**Netter’s Concise Orthopaedic Anatomy**

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<th>EXAM/OBSERVATION</th>
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<tr>
<td><strong>INSPECTION</strong></td>
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</tr>
<tr>
<td>Skin</td>
<td>Discoloration, wounds Gross deformity</td>
<td>Trauma Fracture, dislocation</td>
</tr>
<tr>
<td>Position</td>
<td>Shortened, ER Adducted, IR Abducted, ER Flexed</td>
<td>Femoral neck fracture; intertrochanteric fracture Posterior dislocation Anterior dislocation Hip flexion contracture</td>
</tr>
<tr>
<td>Gait</td>
<td>Decreased stance phase Lean laterally (on WB side) Lean posteriorly (keep hip ext)</td>
<td>Knee, ankle, heel (spur), midfoot, toe pain Gluteus medius weakness Gluteus maximus weakness</td>
</tr>
<tr>
<td><strong>PALPATION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bony structures</td>
<td>Greater trochanter/bursa Lesser trochanter</td>
<td>Pain/palpable bursa: infection/bursitis, gluteus medius tendinitis Snapping—IT band may snap over GT Snapping—Psoas tendon may snap over LT</td>
</tr>
</tbody>
</table>
**EXAM/OBSERVATION** | **TECHNIQUE** | **CLINICAL APPLICATION**
--- | --- | ---
**RANGE OF MOTION**
Flexion | Supine: knee to chest Thomas test | Normal: 120-135° Rule out flexion contracture (see Special Tests, p. 263)
Extension | Prone: lift leg off table | Normal: 20-30°
**NEUROVASCULAR**
Sensory
Genitofemoral nerve (L1-2) | Proximal anteromedial thigh | Deficit indicates corresponding nerve/root lesion
Obturator nerve (L2-4) | Inferomedial thigh | Deficit indicates corresponding nerve/root lesion
Lat. femoral cutaneous n. (L2-3) | Lateral thigh | Deficit indicates corresponding nerve/root lesion
Femoral nerve | Anteromedial thigh | Deficit indicates corresponding nerve/root lesion
Post. femoral cutaneous n. (S1-3) | Posterior thigh | Deficit indicates corresponding nerve/root lesion
Motor
Obturator nerve (L2-4) | Thigh/hip adduction | Weakness = adductor muscle group or nerve/root lesion
Superior gluteal nerve (L5) | Thigh abduction | Weakness = gluteus medius or nerve/root lesion
Femoral nerve (L2-4) | Hip flexion Knee extension | Weakness = iliopsoas or nerve/root lesion Weakness = quadriceps or nerve/root lesion
Inferior gluteal nerve (L5-S2) | Hip extension | Weakness = gluteus maximus or nerve/root lesion
Sciatic:
Tibial portion (L4-S3) | Knee flexion | Weakness = biceps long head or nerve/root lesion
Peroneal portion (L4-S2) | Knee flexion | Weakness = biceps short head or nerve/root lesion
Other
Reflex | None | 
Pulses | Femoral |
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>SPECIAL TESTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impingement</td>
<td>Supine: flex, adduct, IR hip</td>
<td>Pain may be indicative of femoroacetabular impingement.</td>
</tr>
<tr>
<td>FABER/Patrick</td>
<td>Flex, ABduct, ER, then abduct more (figure of 4)</td>
<td>Positive if painful. SI joint or hip pathology.</td>
</tr>
<tr>
<td>Log roll</td>
<td>Supine, hip extended: IR/ER</td>
<td>Pain in hip is consistent with arthritis.</td>
</tr>
<tr>
<td>Stinchfield</td>
<td>Resisted straight leg raise</td>
<td>Pain is positive test for hip pathology.</td>
</tr>
<tr>
<td>Thomas sign</td>
<td>Supine; one knee to chest</td>
<td>If opposite thigh elevates off table, flexion contracture.</td>
</tr>
<tr>
<td>Ober</td>
<td>On side: flex and abduct hip</td>
<td>Extend and adduct hip; if stays in abduction, ITB contracture.</td>
</tr>
<tr>
<td>90-90 straight leg</td>
<td>Flex hip &amp; knee 90°, extend knee</td>
<td>&gt;20° of flexion after full knee extension = tight hamstrings.</td>
</tr>
<tr>
<td>Ely's</td>
<td>Prone: passively flex knee</td>
<td>If hip flexes as knee is flexed, tight rectus femoris muscle.</td>
</tr>
<tr>
<td>Leg length</td>
<td>ASIS to medial malleolus</td>
<td>A measured difference of &gt;1cm is positive.</td>
</tr>
<tr>
<td>Meralgia</td>
<td>Pressure medial to ASIS</td>
<td>Reproduction to pain, burning, numbness = LFCN entrapment.</td>
</tr>
</tbody>
</table>

See Chapter 7, Pelvis, for Trendelenburg test.
**Ortolani’s (reduction) test**
With baby relaxed and content on firm surface, hips and knees flexed to 90°. Hips examined one at a time. Examiner grasps baby’s thigh with middle finger over greater trochanter and lifts thigh to bring femoral head from its dislocated posterior position to opposite the acetabulum. Simultaneously, thigh gently abducted, reducing femoral head into acetabulum. In positive finding, examiner senses reduction by palpable, nearly audible “clunk”.

**Barlow’s (dislocation) test**
Reverse of Ortolani’s test. If femoral head is in acetabulum at time of examination, Barlow’s test is performed to discover any hip instability. Baby’s thigh grasped as above and adducted with gentle downward pressure. Dislocation is palpable as femoral head slips out of acetabulum. Diagnosis confirmed with Ortolani’s test.

**Allis’ or Galeazzi’s sign**
With knees and hips flexed, knee on affected side lower because femoral head lies posterior to acetabulum in this position.

**Test for limitation of abduction.** Patient supine and relaxed on table. Legs gently and passively abducted to determine range of motion of each. Seen in Perthes disease.

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<tr>
<td><strong>SPECIAL TESTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ortolani (peds)</td>
<td>Hips at 90°, abduct hips</td>
<td>A clunk indicates the hip(s) was dislocated and now reduced</td>
</tr>
<tr>
<td>Barlow (peds)</td>
<td>Hips at 90°, posterior force</td>
<td>A clunk indicates the hip(s) is now dislocated, should reduce with Ortolani</td>
</tr>
</tbody>
</table>
### ORIGINS AND INSERTIONS • Thigh/Hip

<table>
<thead>
<tr>
<th><strong>PUBIC RAMI (ASPECT)</strong></th>
<th><strong>GREATER TROCHANTER</strong></th>
<th><strong>ISCHIAL TUBEROSITY</strong></th>
<th><strong>LINEA ASPERA/ POSTERIOR FEMUR</strong></th>
</tr>
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<tbody>
<tr>
<td>Pectineus (pectineal line/sup)</td>
<td>Piriformis (anterior)</td>
<td>Inferior gemellus</td>
<td>Adductor magnus*</td>
</tr>
<tr>
<td>Adductor magnus (inferior)</td>
<td>Obturator internus (anterior)</td>
<td>Quadratus femoris</td>
<td>Adductor longus</td>
</tr>
<tr>
<td>Adductor longus (anterior)</td>
<td>Superior gemellus</td>
<td>Semimembranosus</td>
<td>Adductor brevis</td>
</tr>
<tr>
<td>Adductor brevis (inferior)</td>
<td>Gluteus medius (posterior)</td>
<td>Semitendinosus</td>
<td>Biceps femoris (SH)</td>
</tr>
<tr>
<td>Gracilis (inferior)</td>
<td>Gluteus minimus (anterior)</td>
<td>Biceps femoris (LH)</td>
<td>Pectineus</td>
</tr>
<tr>
<td>Psoas minor (superior)</td>
<td></td>
<td>Adductor magnus</td>
<td>Gluteus maximus</td>
</tr>
</tbody>
</table>

Note: Adductor magnus has two origins.

*Adductor magnus has two origins.*
**MUSCLE ORIGIN INSERTION NERVE ACTION COMMENT**

**ANTERIOR**

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articularis genun</td>
<td>Distal anterior femoral shaft</td>
<td>Synovial capsule</td>
<td>Femoral</td>
<td>Pulls capsule superiorly in extension</td>
<td>May join with vastus intermedials</td>
</tr>
<tr>
<td>Sartorius</td>
<td>ASIS</td>
<td>Prox. med. tibia (pes anserinus)</td>
<td>Femoral</td>
<td>Flex, ER hip</td>
<td>Can avulse from ASIS (avulsion fracture)</td>
</tr>
</tbody>
</table>

**Quadriceps**

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
</table>
| Rectus femoris | 1. AIIS  
2. Sup. acetab. rim       | Patella/tibial/tubercle    | Femoral                | Flex thigh, extend leg       | Can avulse from AIIS (avulsion fracture) |
| Vastus lateralis | Gtr. trochanter, lat. linea aspera | Lateral patella/tibia tubercle | Femoral                | Extend leg                    | Oblique fibers can affect Q angle |
| Vastus intermedius | Proximal femoral shaft            | Patella/tibia tubercle    | Femoral                | Extend leg                    | Covers articularis genu |
| Vastus medialis | Intertrochant. line, med. linea aspera | Medial patella/tibia tubercle | Femoral                | Extend leg                    | Weak in many patello-femoral disorders |
### MUSCLE ORIGIN INSERTION NERVE ACTION COMMENT

#### MEDIAL

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obturator externus</td>
<td>Ischiopubic rami, obturator memb</td>
<td>Piniform fossa</td>
<td>Obturator</td>
<td>ER thigh</td>
<td>Insertion at start point of IM nail</td>
</tr>
<tr>
<td><strong>Hip Adductors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adductor longus</td>
<td>Body of pubis (inferior)</td>
<td>Linea aspera (mid 1/3)</td>
<td>Obturator</td>
<td>Adducts thigh</td>
<td>Tendon can ossify</td>
</tr>
<tr>
<td>Adductor brevis</td>
<td>Body and inferior pubic ramus</td>
<td>Pectineal line, linea aspera</td>
<td>Obturator</td>
<td>Adducts thigh</td>
<td>Deep to pectineus</td>
</tr>
<tr>
<td>Adductor magnus</td>
<td>1. Pubic ramus 2. Ischial tub.</td>
<td>Linea aspera, add. tubercle</td>
<td>1. Obturator 2. Sciatic</td>
<td>Adducts &amp; flex/ extend thigh</td>
<td>Muscle has two separate parts</td>
</tr>
<tr>
<td>Gracilis</td>
<td>Body and inferior pubic ramus</td>
<td>Prox. med. tibia (pes anserinus)</td>
<td>Obturator</td>
<td>Adduct thigh, flex/IR leg</td>
<td>Used in ligament reconstruction</td>
</tr>
</tbody>
</table>

#### Hip Flexors

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pectineus</td>
<td>Pectineal line of pubis</td>
<td>Pectineal line of femur</td>
<td>Femoral</td>
<td>Flex and adducts thigh</td>
<td>Part of femoral triangle floor</td>
</tr>
<tr>
<td>MUSCLE</td>
<td>ORIGIN</td>
<td>INSERTION</td>
<td>NERVE</td>
<td>ACTION</td>
<td>COMMENT</td>
</tr>
<tr>
<td>------------------------</td>
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<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>SEMITENDINOSUS</td>
<td>Ischial tuberosity</td>
<td>Proximal medial tibia</td>
<td>Sciatic</td>
<td>Extend thigh, flex leg</td>
<td>Tendon used in ligament reconstructions (ACL)</td>
</tr>
<tr>
<td>SEMIMEMBRANOSUS</td>
<td>Ischial tuberosity</td>
<td>Posterior medial tibia</td>
<td>Sciatic</td>
<td>Extend thigh, flex leg</td>
<td>A border in medial approach</td>
</tr>
<tr>
<td>BICEPS FEMORIS: long head</td>
<td>Ischial tuberosity</td>
<td>Head of fibula</td>
<td>Sciatic</td>
<td>Extend thigh, flex leg</td>
<td>Can avulse front origin (avulsion fx)</td>
</tr>
<tr>
<td>BICEPS FEMORIS: short head</td>
<td>Linea aspera, supracondylar line</td>
<td>Fibula, lateral tibia</td>
<td>Sciatic</td>
<td>Extend thigh, flex leg</td>
<td>Shares tendon insertion with long head</td>
</tr>
</tbody>
</table>
**STRUCTURE**
- Anterior Quadriceps: vastus lateralis, vastus intermedius, vastus medius, rectus femoris
- Posterior Biceps femoris (long head and short head), semitendinosus, semimembranosus, sciatic nerve
- Medial Adductor magnus, adductor longus, adductor brevis, gracilis, femoral artery and vein

**RELATIONSHIP**

**COMPARTMENTS**

- Anterior: Quadriceps; vastus lateralis, vastus intermedius, vastus medius, rectus femoris
- Posterior: Biceps femoris (long head and short head), semitendinosus, semimembranosus, sciatic nerve
- Medial: Adductor magnus, adductor longus, adductor brevis, gracilis, femoral artery and vein

**FASCIOITOMIES**

- Lateral incision: Release the anterior compartment and posterior compartment
- Medial incision: Release the medial compartment
LUMBAR PLEXUS

Anterior Division

Obturator (L2-4): exits via obturator canal, splits into anterior and posterior divisions. Can be injured by retractors placed behind the transverse acetabular ligament.

Sensory: Inferomedial thigh: via cutaneous branch of obturator nerve

Motor:  
- Gracilis (anterior division)
- Adductor longus (anterior division)
- Adductor brevis (anterior/posterior divisions)
- Adductor magnus (posterior division)
**LUMBAR PLEXUS**

### Genitofemoral (L1-2): pierces psoas, lies on anteromedial surface of psoas and divides into two branches

- **Sensory:** Femoral branch: proximal anterior thigh (over femoral triangle)
- **Genital branch:** scrotum/labia
- **Motor:** None (in thigh)

### Posterior Division

#### Lateral femoral cutaneous (LFCN) (L2-3): crosses inferior to ASIS (can be compressed at or near ASIS)

- **Sensory:** Lateral thigh
- **Motor:** None

#### Femoral (L2-4): lies b/w psoas major & iliacus; branches in femoral triangle. Saphenous nerve runs under sartorius.

- **Sensory:** Anteromedial thigh—via anterior/intermediate cutaneous nerves
- **Motor:** Psoas, Pectineus, Sartorius
  - Quadriceps
    - Rectus femoris
    - Vastus lateralis
    - Vastus intermedius
    - Vastus medialis
SACRAL PLEXUS

Sciatic nerve: a single nerve with 2 distinct parts; it divides in the distal thigh into tibial & common peroneal nerves

**Anterior Division**

- **Tibial (L4-S3):** descends (as sciatic) in posterior thigh deep to hamstrings and superficial to adductor magnus muscle
  - **Sensory:** None (in thigh)
  - **Motor:** Biceps femoris (long head)
    - Semitendinosus
    - Semimembranosus

**Posterior Division**

- **Common peroneal (L4-S2):** descends (as sciatic) in posterior thigh deep to hamstrings and superficial to adductor magnus
  - **Sensory:** None (in thigh)
  - **Motor:** Biceps femoris (short head)
- **Posterior femoral cutaneous nerve (PFCN) (S1-3):** through greater sciatic foramen, medial to sciatic nerve
  - **Sensory:** Posterior thigh
  - **Motor:** None
ARTERY: Obturator
BRANCHES: Anterior/posterior branches
COMMENT: Runs through obturator foramen

FEMORAL ARTERY
In femoral triangle, runs in adductor canal (under sartorius, b/w vastus medialis & adductor longus), then passes posterior through the adductor hiatus and becomes the popliteal artery posterior to the distal femur and knee.

Femoral artery (superficial fem. (SFA))
- Superficial circumflex iliac
- Superficial epigastric
- Superficial and deep external pudendal
- Profunda femoris (deep artery)
- Descending genicular artery
- Articular branch
- Saphenous branch
- Supplies superficial abdominal tissues
- Supplies superficial abdominal tissues
- Supplies subcutaneous tissues in pubic region and scrotum/labia majus
- Primary blood supply to thigh. See below
- Anastomosis at knee to supply knee

Profunda femoris (deep artery of thigh)
- Medial femoral circumflex
- Lateral femoral circumflex
- Ascending branch
- Transverse branch
- Descending branch
- Perforators/muscular branch
- Supplies femoral neck, under quad. femoris
- Supplies femoral neck
- Forms anastomosis at femoral neck
- To greater trochanter
- At risk in anteromedial approach to hip
- Supplies femoral shaft and thigh muscles
**ARTERIES OF THE FEMORAL NECK**

### Profunda Femoris
- **Artery**: Medial femoral circumflex (MFCA)
- **Course**: Between pectineus and psoas, then posterior to femoral neck under quadratus femoris
- **Comment/Supply**: Main blood supply to adult femoral head. Major contributor to extracapsular ring/anastomosis

### Lateral Femoral Circumflex Artery
- **Ascending Branches**
  - **Course**: Deep to sartorius & rectus fem.
  - **Comment/Supply**: Less significant blood supply in adult femoral head. Major contributor to extracapsular ring/anastomosis. Gives partial supply to greater trochanter (GT). At risk in anterolateral approach to hip.
- **1st Perforator**: Ascending branch
- **Comment/Supply**: Can contribute to extracapsular ring/anastomosis

### Extracapsular Ring
- **Course**: Formed at the base of the femoral neck primarily from branches of MFCA and LFCA
- **Comment/Supply**: Supply greater trochanter

### Subsynovial Intracapsular Arterial Ring
- **Course**: Formed at the base of the femoral head
- **Comment/Supply**: Will form intraosseous anastomoses. Lat. epiphyseal supplies most of WB femoral head

### Obturator Artery
- **Artery of Ligamentum Teres**
- **Course**: Thru ligamentum teres to fovea interosseous terminal branches
- **Comment/Supply**: Minimal supply to the adult femoral head. Anastomose with lateral epiphyseal arteries

### Other Arteries
- **Superior & inferior gluteal**
- **Comment/Supply**: Can contribute to extracapsular ring/anastomosis

**Pediatric Femoral Head Blood Supply**
- **0-4yr**: MFCA, LFCA, and ligamentum teres artery
- **4-8yr**: Mostly MFCA, minimal LFCA and ligamentum teres artery
- **>8yrs**: MFCA is predominant
<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP/FINDINGS</th>
<th>TREATMENT</th>
</tr>
</thead>
</table>
| **FEMOROACETABULAR IMPINGEMENT** | • Subtle abnormal hip morphology causes bony abutment. 2 types  
  - *Cam:* femoral non-sphericity  
  - *Pincer:* acetabular overcoverage  
  • Causes early DJD | Hx: Insidious onset, groin pain, worse with activity  
  PE: Decreased ROM (esp. IR), + impingement test (flex, add, IR hip) | XR: AP/lateral of hip  
  *Cam:* femoral neck “bump,” +/- herniation pit, decreased offset  
  *Pincer:* increased acetabular coverage  
  MR: Labral tear, chondral injury  
  1. NSAIDs, activity modification  
  2. Surgical dislocation and neck and/or acetabular reshaping  
  3. Osteotomy in selected cases  
  4. THA if advanced DJD |
| **FEMORAL NECK STRESS (FATIGUE) FRACTURE** | • Excessive loading of hip  
  • 2 types: tension (superior neck), compression (inferior neck)  
  • Common in military recruits | Hx: Increased activity with new onset of hip/groin pain  
  PE: +/- pain with and/or diminished ROM | XR: AP, AP in IR, lateral  
  MR: Best study for early detection of fracture  
  BS: Shows fx subacutely  
  • Compression: limited weight-bearing  
  • Tension: urgent percutaneous pinning (prevent displacement) |
| **MERALGIA PARESTHETICA** | • Nerve trapped near ASIS  
  • Due to activity (hip extension), clothing (e.g., belt), or repetitive compression  
  • Common in military recruits | Hx: Pain/burning in lateral thigh  
  PE: Decr. sensation on lateral thigh, + meralgia | XR: AP/lateral of hip: rule out other pathology  
  1. Remove compressive entity (e.g., belt, tight clothing, etc.)  
  2. Surgical release: rare |
| **SNAPPING HIP (COXA SALTANS)** | Snapping in hip. 3 types  
  1. External: ITB over GT  
  2. Internal: psoas over femoral head or iliopsoas tendon  
  3. Intraarticular: usually loose body | Hx: Snapping at hip +/- pain  
  PE: Palpate the tendon (ITB or psoas tendon) then flex & extend hip, feeling for snap. (external over GT; internal over LT) | XR: AP/lateral hip: rule out osseous abnormality (e.g., spur) and hip DJD  
  MR: Loose body, labral tear  
  US/bursography: Psoas tendon  
  External/Internal:  
  1. Activity modification, PT  
  2. Consider injection  
  3. Surgical release: very rare  
  Intraarticular: LB removal |
| **TROCHANTERIC BURSITIS** | • Inflammation of bursa over greater trochanter  
  • F>M, middle age | Hx: Lateral hip pain, cannot sleep on affected side  
  PE: Point tender at trochanter, pain w/adduction | XR: AP pelvis, AP/lateral of hip: rule out spur, OA, calcified tendons  
  1. NSAIDs, PT (ITB stretching)  
  2. Steroid injection  
  3. Surgical excision—rare |
**DESCRIPTION**
- Loss or damage to articular cartilage
- Etiology: Primary—idiopathic; Secondary—posttraumatic, infection, pediatric hip disease

**Hx & PE**
- Hx: Chronic hip or groin pain, increasing over time & with activity
- PE: Decreased ROM (first IR), + log roll, +/- flex contracture/antalgic gait

**WORKUP/FINDINGS**
- XR: AP pelvic/AP/lateral hip
  1. Joint space narrowing
  2. Osteophytes
  3. Subchondral sclerosis
  4. Bony cysts

**TREATMENT**
- 1. NSAIDs/PT
- 2. Injection/activity modification, cane (in opposite hand)
- 3. Osteotomy (young)
- 4. Arthrodesis (young)
- 5. Total hip arthroplasty

---

**OSTEONECROSIS (AVASCULAR NECROSIS/AVN)**
- Necrosis of femoral head due to vascular disruption
- Assoc. w/trauma, steroid or EtOH use, inflammatory disorders.
- M>f, 30-40’s, 50% bilateral
- Greater femoral head involvement, associated w/poor prognosis

**Hx & PE**
- Hx: Groin pain worse with activity
- PE: Limited ROM (esp IR & abd), antalgic gait
- XR: AP/lateral: stage-specific findings (see classification)
- MRI: Most sensitive study, shows early changes in femoral head
- BS: Replaced by MRI

**Classification: Modified Ficat**
- 0: Asymptomatic, nl XR, + MR
- 1: Symptomatic, nl XR, + MR
- 2: XR: sclerosis, no collapse
- 3: XR: + collapse (crescent sign)
- 4: Flat femoral head, nl acetabulum
- 5: Joint narrowing, early DJD
- 6: Advanced DJD incl. acetabulum

**Stage**
- 0-1: Limited WB, observation
- 2: Core decompression
- 3: Consider vascularized fibula or femoral osteotomy
- 4-6: Total hip arthroplasty—appropriate for most patients. Hip fusion: in young laborers
**GENERAL INFORMATION**

- **Goals:** alleviate pain, maintain personal independence, allow performance of activities of daily living (ADLs).
- **Common procedure with high satisfaction rates for primary procedure; revisions are also becoming more common.**
- **Advances in techniques and materials are improving implant survival; this procedure available to younger pts.**

**MATERIALS**

- **Cups (acetabulum) and stems (femur).** Usually made of titanium. Stainless steel or cobalt chrome stems may be too stiff (i.e., modulus mismatch) and cause stress shielding.
- **Bearing surfaces:** Acetabular liners and femoral head implants. Polyethylene (PE) liner and cobalt-chrome (Co-Cr) femoral head currently most common. Ceramic and metal also used.
  - UHMWPE (ultra high molecular weight PE): good surface, but high wear rates and debris lead to aseptic loosening. Direct compression molding is preferred manufacturing technique. Sterilization with irradiation in nonoxygen environment promotes cross-linking. Highly cross-linked PE has much better wear rates.
  - Co-Cr: “supermetal” alloy. Commonly used for femoral bearing surface with PE liner. Metal on metal implants available. Debris particles are much smaller, create less histocytic response. Carcinogenesis is a theoretic concern.
  - Ceramic (alumina): Excellent wear rates, but brittle (could fracture). Can be used with PE liner or ceramic cup.

**TECHNIQUES**

- **Two types of fixation:** 1. Cement, 2. Uncemented/biologic
  - **Cement:** Methylmethacrylate. Most often used in elderly patients. Provides immediate static fixation, no remodelling potential. Cement resists compression better than tension. As such, femoral implants do better than acetabular cups with this fixation. 3rd generation cementing techniques: pressurization, precoat stem, centralizer/restrictor, canal preparation, 2mm mantle
  - **Uncemented/biologic:** Used in younger patients (increasing popularity). Bone ongrowth or ingrowth—bone grows onto/into implant. Has remodelling potential, gives dynamic fixation. Not good a good choice in post-irradiated hip.
  - **Fixation is NOT immediate, needs initial fixation for stability:** 2 techniques.
  - Press fit: Implant 1-2mm larger than bone. Bone hoop stresses provide initial fixation while bone on/ingrows.
  - Line to line: Implant and bone are same size. Screws used to provide initial fixation while bone on/ingrows.
  - **Optimal porous ongrowth pore size:** 50-150 micrometers. Ongrowth surface area varies.
  - **Current gold standard implant:** Uncemented (ingrowth) acetabular cup and cemented femoral steel. Trends are changing, and more uncemented femoral components and alternative bearing surfaces are being used more frequently.
  - **Head size affects stability (larger is more stable) and wear (large head = high volumetric wear).** 28mm is optimal size.

**INDICATIONS**

- **Arthritis of hip**
  - Common etiologies: osteoarthritis, rheumatoid arthritis, osteonecrosis, prior pediatric hip disease
  - Clinical symptoms: groin/hip pain, worse with activity, gradually worsening over time, decreased functional capacity
  - Radiographic findings: appropriate radiographic evidence of hip arthritis should be present

<table>
<thead>
<tr>
<th>Osteoarthritis</th>
<th>Rheumatoid arthritis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Joint space narrowing</td>
<td>1. Joint space narrowing</td>
</tr>
<tr>
<td>2. Sclerosis</td>
<td>2. Periarticular osteoporosis</td>
</tr>
<tr>
<td>4. Osteophyte formation</td>
<td>4. Ankylosis</td>
</tr>
</tbody>
</table>

- Failed conservative treatment: NSAIDs, activity modification, weight loss, PT, cane (contralateral hand), injections
- Other: Fractures (e.g., femoral neck with hip DJD), tumors, developmental disorders (e.g., DDH, etc)
Reduction of hip with prosthesis in place.  

Femoral preparation: 
Rasp in shape of stem of trial prosthesis used to complete channel.  

Trial prosthesis inserted into femoral canal to ensure fit (its collar flush with cut surface of femoral neck) 

TOTAL HIP ARTHROPLASTY—CONTINUED  

Contraindications
- **Absolute**
  - Neuropathic joint
  - Infection
  - Medically unstable patient (e.g., severe cardiopulmonary disease). Patient may not survive the procedure.
- **Relative**
  - Young, active patients. These patients can wear out the prosthesis many times in their lives.

Alternatives
- Considerations: age, activity level, overall medical health
- Osteotomy: femoral or pelvic; usually performed in younger patients
- Arthrodesis/fusion: young laborers with isolated unilateral disease (i.e., normal spine, knee, ankle, contralateral hip)

Procedure
- **Approaches**
  - Posterior, lateral, and anterolateral approaches
  - Minimally invasive, one- and two-incision approaches are becoming more common.
- **Steps**
  - Acetabulum: remove labrum & osteophytes, ream to a cortical rim, implant cup (35-45° coronal tilt, 15-30° anteversion)
  - Femur: dislocate head, cut neck, remove head, find and broach canal (lateralize as needed)—stem cannot be in varus, implant stem, trial head, & neck. Implant the appropriate head/neck and acetabular liner.

Complications
- Infection: Diagnose with labs and aspiration. Prevention is mainstay: perioperative antibiotics, meticulous prep/drape technique, etc. Acute/subacute: irrigation & debridement with PE exchange. Late: one- or two-stage revision.
- Loosening: Patient often complains of “start up” pain. Radiolucent lines seen on plain radiographs. Most often caused by osteolysis. Osteolysis caused from macrophage response to submicron-sized wear particles (usually PE).
- Dislocation: Can be caused from component (either femur or acetabulum) malalignment or soft tissue injury/ dysfunction. Decreased in posterior approach when short external rotators are repaired during closure.
- Neurovascular injury
  - Sciatic nerve: peroneal division (resulting in foot drop) at risk from vigorous retraction in posterior approach
  - Femoral nerve: with vigorous retraction in anterolateral approach
  - Obturator vessels: under the transverse acetabular lig., injured with retractors or anteroinferior quadrant cup screw
  - External iliac vessels: at risk if cup screw placed in anterosuperior quadrant (posterosuperior quadrant is safe)
  - Medial femoral circumflex artery: under quadratus femoris, at risk in posterior approach if muscle is taken down
- Heterotopic ossification: Usually in predisposed patients. Can cause decreased ROM. One dose of XRT can prevent it.
- Medical complications: Deep venous thrombosis (DVT) & pulmonary embolus (PE) known risk of THA. Prophylaxis must be initiated.
- Periprosthetic fracture of femur
  - Stable implant: ORIF (plates, cables, +/- bone graft).
  - Unstable implant: replace with longer stem that passes fx site.
PEDIATRIC DISORDERS • Thigh/Hip

Development dysplasia of hip

**DEVELOPMENTAL DYSPLASIA OF THE HIP (DDH)**

- Abnormal hip development resulting in dislocation, subluxation, or laxity of hip
- Most from capsular laxity & positioning; irreducible teratologic form seen in congenital syndromes or neuromuscular diseases.
- Risk factors: female, breech, first born, family hx, decreased uterine space conditions
- Early diagnosis and treatment essential

**Hx:** Usually unnoticed by parents.
**PE:** Barlow (dislocation), + Ortolani (relocation), +/- Galeazzi test & decreased abduction
**XR:** Useful after 6mo (femoral head begins to ossify). Look for position in acetabulum. Multipl radiographic lines help evaluate hip.
**US:** Useful in neonate. Alpha angle >60 is nl.

**Obtain & maintain concentric reduction:**
- 0-6mo: Pavlik harness
- 6-24mo: Closed reduction, spica cast; open reduction if CR fails
- >2yr: Open reduction with or without femoral osteotomy
- >4yr: Acetabular osteotomy; teratologic hips need open treatment

**COMPLICATIONS:** Osteonecrosis of femoral head: can occur during reduction or from nonanatomic positioning postreduction.

**FEMORAL ANTEVERSION**

- Internal rotation of femur, femoral anteversion does not decrease properly
- #1 cause of intoeing

**Hx:** Usually presents 3-6yr
**PE:** Femur IR (IR >65°), patella points medial, intoeing gait

1. Most spontaneously resolve
2. Derotational osteotomy if it persists past age 10 (mostly cosmetic)
# Thigh/Hip • Pediatric Disorders

## Legg-Calve-Perthes Disease

**DESCRIPTION**
- Idiopathic osteonecrosis of femoral head
- Femoral head must revascularize, can take 2-5 yr to complete
- Prognosis good with onset at 6 yo and minimal lateral pillar involvement

**Catterall & Herring classifications**
- Poor healing results in hip OA as adult

**EVALUATION**
- **Hx:** Boys (4:1), usually 4-8 yo. Limp with hip, thigh, or knee pain. No trauma.
- **PE:** Decreased ROM (esp. IR & abduction)
- **XR:** AP/lateral hip: sclerosis in early stages. “Crescent sign” sign of subchondral collapse/fx
- **MR:** Will show early necrosis when plain x-rays are still normal.

**TREATMENT**
- **Goals:**
  1. Relieve pain symptoms;
  2. Maintain/obtain full ROM;
  3. Contain femoral head
- **Traction, reduced weight-bearing**
- **ROM:** Rest, traction, physical therapy
- **Osteotomy:** Femoral or acetabular usually reserved for older patients

## Slipped Capital Femoral Epiphysis (SCFE)

**DESCRIPTION**
- Displacement (“slip”) of femoral epiphysis through the proximal physis
- Classification: Stable: able to bear weight (WB); Unstable: unable to WB
- Associated with obesity, renal & thyroid disease
- Epiphysis is usually posterior to neck but remains in acetabulum.

**EVALUATION**
- **Hx:** 10-16 yo, obese, limp, hip or knee pain, unable to WB
- **PE:** Decreased ROM (esp. IR), hip ER with flexion, antalgic gait (if able to WB)
- **XR:** AP/lateral: BOTH hips, Klein’s line should intersect epiphysis. Graded on percent of epiphysis that slipped: Gr 1: <33%, Gr 2: 33-50%, Gr 3: >50%
- **MR:** Will show early necrosis when plain x-rays are still normal.

**TREATMENT**
- Percutaneous in situ screw fixation
- One cannulated screw is gold standard
- Progressive slip may still occur
- Forceful reduction NOT recommended
- Prophylactic pinning of contralateral side is common and supported

## Complications: Osteonecrosis (50% in unstable slips), chondrolysis, early osteoarthritis

## Transient Synovitis

**DESCRIPTION**
- Aseptic hip effusion of unknown cause
- May be caused by post viral syndrome or overuse
- Common cause of hip pain & limp
- Diagnosis of exclusion, r/o septic hip

**EVALUATION**
- **Hx:** Ages 2-5 yo, M:F, insidious onset limp
- **PE:** Decreased ROM (esp. abd), antalgic gait
- **XR:** r/o other hip pathology
- **LABS:** CBC, ESR, blood culture
- **US:** Evaluate for effusion (if suspect septic hip)

**TREATMENT**
- Aspirate hip under anesthesia with fluoroscopy if PE & labs indicate infection
- Septic hip requires I&D and antibiotics
- Transient synovitis resolves: 2-10 days
- Observation, rest, +/- NSAIDs
## SURGICAL APPROACHES • Thigh/Hip

### ANTERIOR (SMITH-PETERTSON) APPROACH TO HIP

<table>
<thead>
<tr>
<th>USES</th>
<th>INTERNERVIOUS PLANE</th>
<th>DANGERS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open reduction</td>
<td>Superficial: Sartorius (femoral nerve)</td>
<td>• Lateral femoral cutaneous n.</td>
<td>• Retract LF CN anteriorly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Tensor fasciae latae (SGN)</td>
<td>• Ascending branch of lateral femoral circumflex artery</td>
</tr>
<tr>
<td>Pediatric congenital hip</td>
<td>Deep: Rectus femoris (femoral n.)</td>
<td>• Femoral nerve</td>
<td>• Take down both heads of rectus femoris to expose joint</td>
</tr>
<tr>
<td>dislocation</td>
<td></td>
<td>• Gluteus medius (SGN)</td>
<td>• Vigorous medial retraction can injure femoral nerve</td>
</tr>
<tr>
<td>Adult anterior dislocations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation &amp; debridement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fractures: anterior femoral head (ORIF)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemiarthroplasty</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tumor excision</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### MEDIAL (LUDLOFF) APPROACH TO HIP

<table>
<thead>
<tr>
<th>USES</th>
<th>INTERNERVIOUS PLANE</th>
<th>DANGERS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pediatric hip dislocation</td>
<td>Superficial: Intermuscular plane</td>
<td>• Obturator nerve (ant. division)</td>
<td>• Used most in pediatric cases</td>
</tr>
</tbody>
</table>
| Adductor or psoas release  |                                                           | • Medial femoral circumflex artery                                     | • Good access to transverse acetabular liga-
| Irrigation & debridement  |                                                           | • Obturator nerve (post. division)                                     | ment & psoas tendon, which can block closed hip reduction. Poor ac-
|                           |                                                           | • Adductor brevis (obturator n.)                                       | cess to acetabulum.                                                     |
|                           |                                                           | • Adductor magnus (obturator & sciatic n.)                             |                                                                       |

---

The table above outlines the surgical approaches to the hip, focusing on the anterior and medial routes. Each approach is detailed with specific anatomical considerations and potential dangers to be aware of during the procedure. The diagrams illustrate the anatomical structures and surgical planes, highlighting key nerves and vessels that may be at risk during these approaches.
**USES**

ANTEROLATERAL (WATSON-JONES) APPROACH TO HIP

- Total hip arthroplasty
- Hemiarthroplasty
- ORIF of proximal femur fx

INTERNEUROUS PLANE

- Intermuscular plane
- Tensor fasciae latae (SGN)
- Gluteus medius (SGN)

DANGERS

- Descending branch of LFCA (under rectus femoris)
- Femoral nerve

COMMENT

- Must detach abductors (either osteotomy or extensive release)
- Vigorous medial retraction can injure femoral nerve

LATERAL (HARDINGE) APPROACH TO HIP

- Total hip arthroplasty (not used for revisions)
- Split gluteus medius (superior gluteal n.)
- Split vastus lateralis n. distally (femoral n.)

- Split gluteus medius 1/3 anterior, 2/3 posterior; release minimus

INTERNEUROUS PLANE

- Tensor fasciae latae
- Gluteus medius (split and retracted)
- Greater trochanter
- Fascia lata
- Joint capsule
- Greater trochanter
- Femoral head
- Acetabulum
- Tensor fasciae latae
- Vastus lateralis

DANGERS

- Superior gluteal artery
- Femoral nerve
- Femoral artery & vein
- Superior gluteal nerve

COMMENT

- No osteotomy of greater trochanter required; less dislocation risk
- Split gluteus medius 1/3 anterior, 2/3 posterior; release minimus
USES INTERNERVIOUS PLANE DANGERS COMMENT

POSTERIOR (MOORE/SOUTHERN) APPROACH TO HIP

- Total hip arthroplasty
- Hemiarthroplasty
- Fractures/ORIF
- Posterior hip dislocation

Split gluteus maximus
(inferior gluteal n.)

- Sciatic nerve
- Inferior gluteal artery
- Medial femoral circumflex artery (under quadratus femoris)

- Reflecting piriformis protects sciatic nerve
- IGA injured in proximal extension
- Repair short ERs to prevent dislocation
### Lateral Approach to Thigh (Femur)

- **Vastus lateralis** (split and retracted)
- **Periosteum** (opened)

**Incision may be extended proximally and distally to expose entire femur**

### Hip Arthroscopy Portals

- **Anterior Intersection of vertical line from ASIS and horizontal line from tip of GT**
  - Lateral femoral cutaneous n.
  - Femoral nerve
  - Ascending branch of LFCA

**Second portal. Angle 45° cephalad, 30° to midline. Pierce sartorius & rectus before capsule**

- **Anterolateral**
  - Anterior tip of greater trochanter (GT)
    - Superior gluteal nerve

**Safest portal, establish 1st. Pierce gluteus medius & lateral capsule**

- **Posterolateral**
  - Posterior tip of greater trochanter (GT)
    - Sciatic nerve

**Last portal. Pierce gluteus medius/ minimus**

---

### Table: Lateral Fasciotomies

<table>
<thead>
<tr>
<th>USES</th>
<th>Internervous Plane</th>
<th>Dangers</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>See page 269.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Lateral Approach to Thigh

- **Fractures**
- **Tumors**

- Split vastus lateralis (femoral nerve) or elevate it off intermuscular septum
- Descending branch of lateral femoral circumflex artery
- Perforates from profunda femoris
- Superior lateral geniculate a.

**Incision can be large or small; made along line between greater trochanter and lateral condyle**

**Arteries (at left) encountered or require ligation**

### Hip Arthroscopy Portals

- Arthroscopy used for diagnosis, labral tears, loose body removal, synovectomy, irrigation, and debridement

- Long cannulae, arthroscope, instruments, and traction are needed for hip arthroscopy.
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<th>Page</th>
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<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Iliotibial tract (band)</td>
<td>Tightness can cause lateral knee and/or thigh pain.</td>
</tr>
<tr>
<td>Quadriceps muscle</td>
<td>Atrophy can indicate an injury and/or contribute to knee pain.</td>
</tr>
<tr>
<td>Quadriceps tendon</td>
<td>Can rupture with eccentric loading. Defect is palpated here.</td>
</tr>
<tr>
<td>Patella</td>
<td>Tenderness can indicate fracture; swelling can be prepatellar bursitis.</td>
</tr>
<tr>
<td>Patellar tendon</td>
<td>Can rupture with eccentric loading. Defect is palpated here.</td>
</tr>
<tr>
<td>Patellar retinaculum</td>
<td>Patellar femoral ligaments palpated here. They can be injured in patellar dislocation.</td>
</tr>
<tr>
<td>Joint line</td>
<td>Tenderness here can indicate meniscal pathology.</td>
</tr>
<tr>
<td>Tibial tubercle</td>
<td>Tender in Osgood-Schlatter disease.</td>
</tr>
<tr>
<td>Pes anserinus &amp; bursa</td>
<td>Insertion of medial hamstrings. Bursitis can develop. Site of hamstring tendon harvest.</td>
</tr>
<tr>
<td>Gerdy’s tubercle</td>
<td>Insertion of the iliotibial tract (band).</td>
</tr>
<tr>
<td>Popliteal fossa</td>
<td>Popliteal artery pulse can be palpated here.</td>
</tr>
<tr>
<td>Muscle compartments</td>
<td>Will be firm or tense in compartment syndrome. Anterior most common.</td>
</tr>
</tbody>
</table>
## Distal Femur

- **Characteristics**
  - Distal femur—2 condyles
    - Medial: larger, more posterior
    - Lateral: more ant. & proximal
  - Trochlear groove: a depression between the condyles anteriorly for patella articulation
  - Intercondylar notch: between condyles, site of cruciate origins

- **Ossify**
  - Secondary

- **Fuse**
  - Distal Birth 19yr

- **Comments**
  - Condyles: rounded posteriorly (for flexion) and flat anteriorly (for standing)
  - Epicondyle: origin of collateral ligaments
  - Epicondylar axis and/or post. condylar axis used to determine femur rotation (e.g., in TKA)
  - Sulcus terminale: groove in lateral condyle. Inferior to groove, it is weight-bearing portion of condyle.
  - Adductor tubercle: insertion of adductor magnus
  - Distal femoral physis: grows approx. 7mm/yr

## Patella

- **Characteristics**
  - Ovoid shaped, inf. & sup. poles
  - Triangular in cross section
  - 2 facets (larger lateral & medial) separated by a central ridge
    - Each facet is subdivided into superior, middle, inferior facets
    - Odd facet (7th sub-facet) is far medial on medial facet

- **Ossify**
  - Primary 3yr (single center)

- **Fuse**
  - Primary 11-13yr

- **Comments**
  - Largest sesamoid bone in body
  - Bipartite patella: failure of superolateral portion to fuse. It is often confused with a fracture.
  - Functions: 1. Enhances quadriceps pull (as fulcrum); 2. Protects knee; 3. Enhances knee lubrication
  - Contact point on patella moves proximally w/flexion
  - Odd facet articulates in deep flexion
  - Has thickest articular cartilage (up to 5mm)
**CHARACTERISTICS**

**OSTEOLOGY**

**EXTERNAL VIEW**

**TIBIA**

- **Long bone characteristics**
- **Proximal end**: plateau (canc.)
- **Lateral plateau**: concave
- **7-10° posterior slope**
- **Tubercle**: 3cm below joint line
- **Eminence**: medial & lateral tubercles (spines)
- **Shaft**: triangular cross section
- **Distal end**: pilon (cancellous)
- **Articular surface**: plafond
- **Distal tip**: medial malleolus

**PRIMARY OSSIFY**

- **Shaft**: 7wk (fetal)

**SECONDARY OSSIFY**

1. **Proximal epiphysis**: 9mo
2. **Distal epiphysis**: 1yr
3. **Tibial tuberosity**: 18yr

**FUSE**

- **Lateral plateau fx** more common
- **Osgood-Schlatter**: traction apophysitis at open tibial tubercle apophysis
- **Tubercle**: patellar tendon insertion
- **IM nail insertion point proximal to tibial tubercle**
- **Tibial spine avulsion fx of ACL (peds)**
- **Gerdy’s tubercle on proximal tibia**: insertion site of iliotibial tract (band)
- **Fibularis incisura**: lat. groove for fibula
- **Plafond is roof and medial malleolus is medial wall of ankle mortise**

**FIBULA**

- **Long bone characteristics**
- **Proximal end**: head
- **Shaft**: long, cylindrical
- **Distal end**: lateral malleolus

**PRIMARY OSSIFY**

- **Shaft**: 7wk (fetal)

**SECONDARY OSSIFY**

1. **Proximal epiphysis**: 1-3yr
2. **Distal epiphysis**: 4yr

**FUSE**

- **LCL & biceps femoris insert on head**
- **Neck has groove for peroneal nerve**
- **Nerve can be injured in fibula fx**
- **Shaft used for vascularized BG**
- **Lat. mal. is lat. wall of ankle mortise**
LOWER EXTREMITY ALIGNMENT

### Definitions

<table>
<thead>
<tr>
<th>Anatomic axis of femur</th>
<th>Line drawn along the axis of the femur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatomic axis of tibia</td>
<td>Line drawn along the axis of the tibia</td>
</tr>
<tr>
<td>Mechanical axis of femur</td>
<td>Line drawn between center of femoral head and intercondylar notch</td>
</tr>
<tr>
<td>Mechanical axis of tibia</td>
<td>Line drawn between center of knee and center of ankle mortise</td>
</tr>
<tr>
<td>Knee axis</td>
<td>Line drawn along inferior aspect of both femoral condyles</td>
</tr>
<tr>
<td>Vertical axis</td>
<td>Vertical line, perpendicular to the ground</td>
</tr>
<tr>
<td>Lateral distal femoral angle</td>
<td>Angle formed between knee axis and femoral axis laterally</td>
</tr>
<tr>
<td>Medial tibial angle</td>
<td>Angle formed between knee axis and tibial axis</td>
</tr>
</tbody>
</table>

### Relationships

<table>
<thead>
<tr>
<th>Knee axis</th>
<th>Parallel to the ground and perpendicular to vertical axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical axis of femur</td>
<td>Average of 6° from anatomic axis</td>
</tr>
<tr>
<td>Mechanical axis of tibia</td>
<td>Approximately 3° from vertical axis</td>
</tr>
<tr>
<td>Lateral distal femoral angle</td>
<td>Normally same as anatomic axis of tibia unless tibia has a deformity</td>
</tr>
<tr>
<td>Medial proximal tibial angle</td>
<td>81° from femoral anatomic axis</td>
</tr>
<tr>
<td>Medial proximal tibial angle</td>
<td>87° from femoral mechanical axis</td>
</tr>
<tr>
<td>Medial proximal tibial angle</td>
<td>87° from tibial mechanical axis</td>
</tr>
<tr>
<td>RADIOGRAPH</td>
<td>TECHNIQUE</td>
</tr>
<tr>
<td>------------</td>
<td>-----------</td>
</tr>
<tr>
<td>AP</td>
<td>Supine; beam at 90°</td>
</tr>
<tr>
<td>Lateral</td>
<td>Supine; 30° flexion</td>
</tr>
<tr>
<td>Axial/ sunrise</td>
<td>Prone; knee 115° flex; beam at patella 15° cephalad</td>
</tr>
<tr>
<td>Tunnel/ notch</td>
<td>Prone; knee 45° flex; beam is caudal at knee joint</td>
</tr>
<tr>
<td>Merchant</td>
<td>Supine; legs of table at 45°; beam at PF joint</td>
</tr>
<tr>
<td>Rosenberg</td>
<td>PA (weight-bearing); knees at 45°</td>
</tr>
</tbody>
</table>
**RADIOGRAPH TECHNIQUE FINDINGS CLINICAL APPLICATION**

**LEG**

<table>
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<tr>
<th>Radiograph</th>
<th>Technique</th>
<th>Findings</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP tibia</td>
<td>Supine; beam at mid tibia</td>
<td>Tibia and surrounding soft tissues</td>
<td>Fractures, deformity, infection, etc</td>
</tr>
<tr>
<td>Lateral tibia</td>
<td>Supine; beam laterally mid-tibia</td>
<td>Tibia and surrounding soft tissues</td>
<td>Fractures, deformity, infection, etc</td>
</tr>
</tbody>
</table>

See Foot & Ankle chapter to see views of the ankle.

**OTHER STUDIES**

<table>
<thead>
<tr>
<th>Study</th>
<th>Technique</th>
<th>Findings</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment films</td>
<td>Bilateral full length hip to ankle, WB</td>
<td>Full lower extremity alignment</td>
<td>Determine malalignment/deformity</td>
</tr>
<tr>
<td>Scanogram</td>
<td>Entire bilateral LE with ruler</td>
<td>Measure length of bones</td>
<td>Used for leg length discrepancy</td>
</tr>
<tr>
<td>CT</td>
<td>Axial, coronal, &amp; sagittal views</td>
<td>Articular congruity, fracture fragments</td>
<td>Intraarticular condyle, plateau, pilon fx</td>
</tr>
<tr>
<td>MRI</td>
<td>Sequence protocols vary</td>
<td>Soft tissues: ligaments, meniscus, articular cartilage, bone marrow</td>
<td>Ligament ruptures, meniscal tears, OCD, stress fx, tumor, infection</td>
</tr>
<tr>
<td>Bone scan</td>
<td>Radioisotope</td>
<td>All bones evaluated</td>
<td>Stress fx, infection, tumor</td>
</tr>
</tbody>
</table>
### Patellar Fracture

- **Mechanism:** Direct & indirect: e.g., fall, dashboard, etc.
- **Pull of quadriceps and tendons displace most fx:**
- If intact, retinaculum resists displacement of fragments
- Do not confuse with bipartite patella (unfused superolateral corner)

#### Hx:
Trauma, pain, cannot extend knee, swelling

#### PE:
“Dome” effusion, tenderness, +/- palpable defect, inability to extend knee

#### XR:
Knee trauma series

#### CT:
Not usually needed, will show fx fragments

#### Descriptive/location:
- Nondisplaced
- Transverse
- Vertical
- Stellate
- Inferior/superior pole
- Comminuted

- Nondisplaced or comminuted—knee brace/cast 6-8 wk, ROM
- Displaced (>2-3mm): ORIF (e.g., tension bands) to restore articular surface
- Severely comminuted: may require full or partial patellectomy

#### Complications:
- Osteoarthritis and/or pain, decreased motion and/or strength, osteonecrosis, refracture

### Dislocation of Knee Joint

#### Hx:
Trauma, pain, inability to bear weight

#### PE:
Large effusion, soft tissue swelling, deformity, pain, +/- distal pulses/peroneal nerve function

#### XR:
AP/lateral

#### AGRAM:
Evaluate for arterial injury

#### MR:
Ligament injury, meniscus, articular cartilage injury

#### By position:
- Anterior
- Posterior
- Lateral
- Medial
- Rotatory: anteromedial or anterolateral

#### Treatment:
- Early reduction essential; postreduction neurologic exam and x-rays
- Immobilize (cast) 6-8 wk (if ligaments not torn)
- Surgery if irreducible or vascular injury (revascularize within 6 hr + fasciotomy)
- Early vs. delayed ligament repair/reconstruction

#### Complications:
- Neurovascular: popliteal artery, peroneal nerve injury, knee stiffness (#1), chronic instability

---

**Table: Patellar Fracture**

<table>
<thead>
<tr>
<th>Description</th>
<th>Evaluation</th>
<th>Classification</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanism: direct &amp; indirect: e.g., fall, dashboard, etc.</td>
<td>Hx: Trauma, pain, cannot extend knee, swelling PE: “Dome” effusion, tenderness, +/- palpable defect, inability to extend knee XR: Knee trauma series</td>
<td>Descriptive/location: Nondisplaced Transverse Vertical Stellate Inferior/superior pole Comminuted</td>
<td>Nondisplaced or comminuted—knee brace/cast 6-8 wk, ROM Displaced (&gt;2-3mm): ORIF (e.g., tension bands) to restore articular surface Severely comminuted: may require full or partial patellectomy</td>
</tr>
</tbody>
</table>

**Table: Dislocation of Knee Joint**

<table>
<thead>
<tr>
<th>Description</th>
<th>Evaluation</th>
<th>Classification</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rare: ortho. emergency Usually high-energy injury</td>
<td>Hx: Trauma, pain, inability to bear weight PE: Large effusion, soft tissue swelling, deformity, pain, +/- distal pulses/peroneal nerve function</td>
<td>By position: Anterior Posterior Lateral Medial Rotatory: anteromedial or anterolateral</td>
<td>Early reduction essential; postreduction neurologic exam and x-rays Immobilize (cast) 6-8 wk (if ligaments not torn) Surgery if irreducible or vascular injury (revascularize within 6 hr + fasciotomy) Early vs. delayed ligament repair/reconstruction</td>
</tr>
</tbody>
</table>

**Complications:** Neurovascular: popliteal artery, peroneal nerve injury, knee stiffness (#1), chronic instability
Tibial Plateau Fracture

I. Split fracture of lateral tibial plateau
II. Split fracture of lateral condyle plus depression of tibial plateau
III. Depression of lateral tibial plateau without split fracture
IV. Comminuted split fracture of medial tibial plateau and tibial spine
V. Biocondylar fracture involving both tibial plateaus with widening
VI. Fracture of lateral tibial plateau with separation of metaphyseal-diaphyseal junction

**DESCRIPTION EVALUATION CLASSIFICATION TREATMENT**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Mechanism: axial load AND varus/valgus stress</td>
<td>• Hx: Trauma, pain, swelling, inability to bear weight</td>
<td>Schatzker (6 types):</td>
<td>• Consider joint aspiration</td>
</tr>
<tr>
<td>• Restoration of articular surface/congruity is important</td>
<td>• PE: Effusion, tenderness; do thorough neurovascular exam.</td>
<td>I: Lateral plateau split fx</td>
<td>• Nondisplaced (&lt;3mm step off, &lt;5mm gap): knee brace/cast 6-8wk, NWB 6-12wk</td>
</tr>
<tr>
<td>• Metaphyseal injury: bone will compress, leading to functional bone loss; may need bone graft</td>
<td>• XR: Knee trauma series</td>
<td>II: Lat split/depression fx</td>
<td>• Displaced: ORIF +/- bone graft (plates &amp; screws). Early ROM but NWB 12wk</td>
</tr>
<tr>
<td>• Lateral fracture more common than medial</td>
<td>• CT: To better define fx lines &amp; comminution. Needed for preop planning.</td>
<td>III: Lat. plateau depression</td>
<td>• Avoid both medial &amp; lateral periosteal stripping (incr. nonunion rate)</td>
</tr>
<tr>
<td>• Associated meniscal (50%) and ligament (MCL&gt;ACL) tears</td>
<td>• AGRAM: If decreased pulses. Consider in all type IV fx's</td>
<td>IV: Medial plat. split fx</td>
<td>• Repair torn ligaments/menisci</td>
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<td></td>
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<td>V: Bicondylar plateau fx</td>
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<td>VI: Fx w/metaphyseal-diaphyseal separation</td>
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<td></td>
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<td>Types IV-VI usually result from high-energy trauma</td>
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</table>
**Tibia Shaft Fracture**

- Common long bone fx
- Usually high-E trauma
- Condition of surrounding soft tissues is critically important to success of outcome
- Compartment syndrome: consider in ALL fxs
- Subcutaneous position of tibia predisposes it to open fractures
- May lead to amputation

**Hx:** Trauma, pain, swelling, inability to bear weight

**PE:** Swelling, deformity, +/+ firm/tense compartments

**XR:** AP & lateral of tib./fib. (also knee & ankle series)

**CT:** Not usually needed

**AGRAM:** If decreased pulses

**Complications:** compartment syndrome, nonunion & malunion, knee pain (from IM nail), ankle and/or knee stiffness

---

**Compartment Syndrome**

- **Hx:** Trauma, pain
  - **PE:** 5 P’s: pain (w/passive stretch), paresthesia, pallor, pulseless, paralysis
  - **XR:** Evaluate for fractures

**Angiogram:** If needed to evaluate for vascular inj.

**Compartment Pressures:**
1. Absolute: >30-40mmHg
2. ΔP: <30mmHg of diastolic blood pressure

**Treatment:**
- Nondisplaced: long leg cast 8wk (best for pediatrics, seldom used in adults)
- Displaced/unstable: reamed, locked IM nail
- Open fractures: thorough I&D is critical. External fixation is useful for these fractures.
- Fasciotomies for compartment syndrome

---

**Description** | **Evaluation** | **Classification** | **Treatment**
--- | --- | --- | ---

**Tibia Shaft Fracture**

- Transverse fracture; fibula intact
- Spiral fracture with shortening
- Comminuted fracture with marked shortening
- Segmental fracture with marked shortening

**Incisions for Compartment Syndrome of Leg**

- **Deep posterior compartment**
- Deep flexor muscles
- Flexor digitorum longus
- Tibialis anterior
- Flexor hallucis longus
- Posterior tibial a. and n.
- Tibial n.
- Peroneal a. and n.

- **Deep intermuscular septum**
- Anteromedial incision

- **Superficial posterior compartment**
- Superficial flexor muscles
- Soleus
- Gastrocnemius
- Plantaris tendon

- **Crural (encircling) fascia**

- **Anterolateral incision**

- **Posteromedial incision**

**Description:**
- Location
- Displaced/comminuted

**Type:** transverse, spiral oblique

**Rotation/angulation**

**Complications:** compartment syndrome, nonunion & malunion, knee pain (from IM nail), ankle and/or knee stiffness

**Usually a clinical diagnosis**

**Emergent fasciotomy** (usually two incisions)
Maisonneuve fracture
Complete disruption of tibiobular syndesmosis with diastasis caused by external rotation of talus and transmission of force to proximal fibula, resulting in high fracture of fibula. Interosseous membrane torn longitudinally. Radiograph shows repair with long transverse screw (these fractures easily missed on radiographs).

Pilon fracture
Usual cause is vertical loading of ankle joint, eg, falling from height and landing on heel (usually with ankle dorsiflexed). Fracture and compression of articular surface of tibia plus separation of malleoli and fracture of fibula.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MAISONNEUVE FRACTURE</strong></td>
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<tr>
<td>Complete syndesmosis disruption with diastasis</td>
<td>Hx: Trauma, ankle pain, +/- knee pain</td>
<td>Descriptive: Location Type: Oblique Comminuted</td>
<td>Reduce and stabilize syndesmosis (e.g., with a screw); immobilize while healing</td>
</tr>
<tr>
<td>&amp; proximal fibula fx</td>
<td>PE: Ankle pain, swelling, proximal fibula tenderness</td>
<td></td>
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<tr>
<td>Variant of ankle fracture &amp; deltoid ligament rupture</td>
<td>XR: Leg and ankle series. May need stress views of ankle to see instability</td>
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<tr>
<td>Unstable fracture</td>
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</table>

COMPLICATIONS: ankle instability, ankle arthritis

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<thead>
<tr>
<th>DESCRIPTION</th>
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</thead>
<tbody>
<tr>
<td><strong>PILON (DISTAL TIBIA) FRACTURE</strong></td>
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<tr>
<td>Intraarticular; through distal articular/WW surface</td>
<td>Hx: Trauma, cannot bear weight, pain, swelling</td>
<td>Ruedi/Allgower (3 types):</td>
<td>Nondisplaced: cast &amp; NWB for 6-12wk</td>
</tr>
<tr>
<td>Soft tissue swelling leads to complications with early open treatment</td>
<td>PE: Effusion, tenderness; do good neurovascular exam</td>
<td>I: Non or minimally displaced</td>
<td>Displaced/comminuted: early external fixation and delayed (14 days) ORIF; (plates &amp; screws +/- bone grafting)</td>
</tr>
<tr>
<td>Restoration of articular surface congruity is essential</td>
<td>XR: AP/lateral (obliques)</td>
<td>II: Displaced: articular surface incongruous</td>
<td></td>
</tr>
<tr>
<td>Healing is often slow</td>
<td>CT: Needed to better define fx and preop plan</td>
<td>III: Comminuted articular surface</td>
<td></td>
</tr>
</tbody>
</table>

COMPLICATIONS: posttraumatic DJD, (almost 100% in comminuted fxs), stiffness, malunion, wound complications
KNEE

Structure

- Comprises 3 separate articulations:
  - Medial & lateral femorotibial joints (2)—condyloid (hinge) joints. Femoral condyles articulate with corresponding tibial plateaus.
  - Patellofemoral joint (1)—sellar (gliding) joint. Patella articulates with femoral trochlear groove.
- 3 compartments in the knee: medial, lateral, patellofemoral
- Capsule surrounds entire joint (all three articulations/compartments) and extends proximally into the suprapatellar pouch.
  - The capsule has a synovial lining that also covers the cruciate ligaments (making them intraarticular but extrasynovial)
- Articular (hyaline) cartilage (type II collagen) covers the femoral condyles, tibial plateaus, trochlear groove, and patellar facets.
- Menisci are interposed in the medial & lateral femorotibial joints to: 1. protect the articular cartilage, 2. give support to the knee.
- Knee axis (line drawn between weight-bearing portion of medial & lateral femoral condyles) is parallel to the ground.
  - Mechanical axis of the femur is 3° valgus to the vertical axis, allowing the larger MFC to align with the LFC parallel to the ground.
  - Mechanical axis of the tibia is 3° varus to the vertical axis.

Kinematics

- Inherently unstable joint. Bony morphology adds little stability. Stability primarily provided by surrounding static and dynamic stabilizers. (Dynamic stabilizers may compensate when static stabilizers are injured [e.g., complete or partial ACL rupture].)
  - Medial: Static—superficial and deep medial collateral ligaments (MCL), posterior oblique ligament (POL); Dynamic—semimembranosus, vastus medialis, medial gastrocnemius, PES tendons
  - Lateral: Static—lateral collateral ligament (LCL), iliotibial band (ITB), arcuate ligament.
    - Dynamic—popliteus, biceps femoris, lateral gastrocnemius
- Not a simple hinge joint. The knee has 6 degrees of motion:
  - Extension/flexion, IR/ER, varus/valgus, anterior/posterior translation, medial/lateral translation, compression/distraction
- Flexion & extension are the primary motions in the knee.
  - Flexion is a combination of both “rolling” and “sliding” of the femur on the tibia in varying ratios depending on the degree of flexion.
  - Rolling: equal translation of tibiofemoral contact point & joint axis. Rolling predominates in early flexion.
  - Gliding: translation of tibiofemoral contact point without moving the joint axis. Increased gliding is needed for deep flexion.
  - The cruciate ligaments control the roll/glide function. The PCL alone can maintain this function (e.g., PCL retaining TKA).
  - Normal motion: Extension/flexion: −5 to 140°. 115° needed to get out of a chair; 130° needed for fast running.
    - IR/ER: about 10° total through arc of motion. Tibia IRs in swing, and ERs in stance via “screw home mechanism.”
  - Screw home mechanism: larger MFC ERs tibia in full extension, tightening cruciates and stabilizing the knee in stance.
  - Popliteus IRs the tibia to “unlock” the knee, loosen the cruciates, which allows the knee to initiate flexion.
- Other motions: Medial/lateral translation: minimal in normal knees
  - Anterior/posterior translation: dependent on tissue laxity, usually within 2mm of contralateral side in normal knees
  - Varus/Valgus: approximately 5mm of gapping laterally or medially when stressed in normal knees
**LIGAMENTS ATTACHMENTS FUNCTION/COMMENT**

<table>
<thead>
<tr>
<th>KNEE</th>
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<tbody>
<tr>
<td><strong>Femorotibial Joint—Anterior Structures</strong></td>
</tr>
<tr>
<td><strong>Anterior cruciate ligament (ACL)</strong></td>
</tr>
<tr>
<td><strong>Transverse meniscal ligament</strong></td>
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<tr>
<td><strong>Other Structures</strong></td>
</tr>
<tr>
<td><strong>Ligamentum mucosum (anterior plica)</strong></td>
</tr>
<tr>
<td><strong>Infrapatellar fat pad</strong></td>
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</table>

See Patellofemoral Joint for other anterior structures
**KNEE**

### LIGAMENTS ATTACHMENTS COMMENTS

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<tr>
<th>LIGAMENTS</th>
<th>ATTACHMENTS</th>
<th>COMMENTS</th>
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<tbody>
<tr>
<td><strong>Femorotibial Joint—Posterior Structures</strong></td>
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<tr>
<td><strong>Posterior cruciate ligament (PCL)</strong></td>
<td>Lateral aspect (in notch) of medial femoral condyle to post. proximal tibia (below joint line)</td>
<td>Primary restraint to posterior tibial translation</td>
</tr>
<tr>
<td>Anterolateral bundle</td>
<td>Ant. origin on condyle, lat. on tibia</td>
<td>Secondary restraint to varus, valgus, and ER</td>
</tr>
<tr>
<td>Posteromedial bundle</td>
<td>Post. origin on condyle, med. on tibia</td>
<td>Tight in knee flexion, lax in extension</td>
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<td><strong>Meniscofemoral ligaments</strong></td>
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<tr>
<td>Ligament of Humphrey</td>
<td>Posterior lateral meniscus to MFC and/or PCL, either:</td>
<td>Variably present. Rarely are both present</td>
</tr>
<tr>
<td>Ligament of Wrisberg</td>
<td>Anterior to PCL</td>
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<td></td>
<td>Posterior to PCL</td>
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<tr>
<td><strong>Oblique popliteal ligament (OPL)</strong></td>
<td>Origin on semimembranosus insertion on posterior tibia; inserts on posterior LFC &amp; capsule</td>
<td>Tightens posterior capsule when semimembranousus contracts; considered part of “posteromedial” corner</td>
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**Right knee: posterior view**

- Adductor magnus tendon
- Medial head of gastrocnemius muscle and subtenonoid bursa
- Medial (tibial) collateral ligament
- Semimembranosus tendon
- Semimembranosus bursa deep to tendon (broken line)
- Oblique popliteal ligament (tendinous expansion of semimembranosus muscle)
- Popliteus muscle
- Tibia

**Right knee in extension: posterior view**

- Adductor tubercle on medial epicondyle of femur
- Medial condyle of femur (articular surface)
- Medial meniscus
- Tibial collateral ligament
- Medial condyle of tibia

**Posteromedial compartment**

- Posterior cruciate ligament seen beyond medial meniscus
- Broken lines indicate medial collateral ligament
### Knee Joint: Lateral and Posterolateral Structures

#### First Layer—Superficial

<table>
<thead>
<tr>
<th>Ligament</th>
<th>Attachments</th>
<th>Function/Comment</th>
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<tbody>
<tr>
<td>Iliotibial band (tract) (ITB)</td>
<td>3 insertions: 1. Gerdy’s tubercle, 2. patella and patellar tendon, 3. supracondylar tubercle</td>
<td>Stabilizes lateral knee—“accessory anterolateral ligament.” Post. in flexion (EPs tibia), ant. in extension</td>
</tr>
<tr>
<td>Biceps femoris</td>
<td>2 heads insert on fibular head, lateral to LCL</td>
<td>Lateral stabilizer, also externally rotates tibia</td>
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#### Second Layer—Middle

<table>
<thead>
<tr>
<th>Ligament</th>
<th>Attachments</th>
<th>Function/Comment</th>
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<tbody>
<tr>
<td>Lateral patellofemoral ligament</td>
<td>Lateral femur to lateral edge of patella</td>
<td>May need release if tightened and causing patella tilt and abnormal lateral articular cartilage wear</td>
</tr>
<tr>
<td>Lateral patellar retinaculum</td>
<td>Vastus fascia to tibia &amp; patella</td>
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#### Third Layer—Deep

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<thead>
<tr>
<th>Ligament</th>
<th>Attachments</th>
<th>Function/Comment</th>
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<tbody>
<tr>
<td>Lateral collateral lig. (LCL)</td>
<td>Lateral epicondyle to medial fibular head</td>
<td>Primary restraint to varus stress, also resists ER</td>
</tr>
<tr>
<td>Fabellotibial ligament</td>
<td>Fibula head to fabella, usually with arcuate lig.</td>
<td>Variably present, also called “short collateral”</td>
</tr>
<tr>
<td>Popliteus muscle and tendon</td>
<td>Inserts anterior and distal to LCL origin</td>
<td>Resists tibia ER, varus, and posterior translation</td>
</tr>
<tr>
<td>Popliteofibular ligament (PFL)</td>
<td>Popliteus musculotendinous jux to fibula head</td>
<td>Primary static restraint to external rotation (ER)</td>
</tr>
<tr>
<td>Capsule</td>
<td>Femur to tibia. Extends 15mm below joint line</td>
<td>Reinforced by other structures; resists varus &amp; ER</td>
</tr>
<tr>
<td>Arcuate ligament</td>
<td>Lateral arm: fibular head to posterior femur</td>
<td>Varially present, Y-shaped: two arms. Lateral arm covers popliteus supporting posterolateral knee</td>
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<td>Medial arm: post-lat femur, blends with OPL</td>
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**Other**

- Lateral meniscus: To lateral plateau via coronary ligaments
- Lateral head of gastrocnemius: Origin is on posterior lateral condyle

**Notes:**
- The inferior lateral geniculate artery passes between the superficial and deep lamina of the third layer of the posterolateral corner.
- The LCL, popliteus, and popliteofibular ligament are the most consistent structures and are the focus of surgical reconstruction.
- Most of the posterolateral structures act as stabilizers to varus & ER forces. They also are secondary stabilizers to posterior translation.
- Arcuate “complex” refers to posterolateral stabilizing structures including: LCL, arcuate ligament, popliteus, & lateral gastrocnemius.
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<tr>
<th>LIGAMENTS</th>
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<th>FUNCTION/COMMENT</th>
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<tbody>
<tr>
<td>Femorotibial Joint—Medial Structures</td>
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<tr>
<td><strong>First Layer—Superficial</strong></td>
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<tr>
<td>Sartorius</td>
<td>Becomes fascial layer at insertion at Pes</td>
<td>Covers other tendons at Pes insertion</td>
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<tr>
<td>Fascia</td>
<td>Deep fascia from thigh continues to knee</td>
<td>Blends with retinaculum (ant.) &amp; capsule (post.)</td>
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<tr>
<td><strong>Second Layer—Middle</strong></td>
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<tr>
<td>Superficial medial collateral (MCL)</td>
<td>Medial epicondyle to tibia (deep to Pes)</td>
<td>Primary restraint to valgus force (esp. at 30°)</td>
</tr>
<tr>
<td>Posterior oblique ligament (POL)</td>
<td>Adductor tendon (post. to MCL) to poste-</td>
<td>Secondary stabilizer to anterior translation &amp; IR</td>
</tr>
<tr>
<td>Medial patellofemoral ligament (MPFL)</td>
<td>Medial patella to medial femoral epicondyle</td>
<td>Static stabilizer against valgus. Lax in flexion but tightens dynamically due to semimembr.</td>
</tr>
<tr>
<td>Medial patellar retinaculum</td>
<td>Continuous w/vastus fascia to tibia &amp; patella</td>
<td>Can also be injured in lateral patellar subluxation</td>
</tr>
<tr>
<td>Semimembranosus</td>
<td>Inserts posteromedical on tibia</td>
<td>Gives posteromedical support</td>
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<tr>
<td><strong>Third Layer—Deep</strong></td>
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<tr>
<td>Deep medial collateral (MCL)</td>
<td>Inserts on meniscus &amp; tibia plateau</td>
<td>Stabilizes meniscus. Also known as medial capsular ligament or middle ⅓ capsular ligament</td>
</tr>
<tr>
<td>Meniscofemoral fibers</td>
<td>2 sets of fibers: Femur to meniscus</td>
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<tr>
<td>Meniscotibial fibers</td>
<td>Tibia to meniscus</td>
<td></td>
</tr>
<tr>
<td>Capsule</td>
<td>Femur to tibia, extends 15mm below joint</td>
<td>Reinforced by other posteromedical structures</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
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<tr>
<td>Medial meniscus</td>
<td>Attached firmly to medial tibial plateau via</td>
<td>Posterior horn is secondary stabilizer to ante-</td>
</tr>
<tr>
<td></td>
<td>coronary ligaments</td>
<td>rior translation. Becomes 1° in ACL</td>
</tr>
<tr>
<td>Medial head of gastroc-</td>
<td>Origin on the posteromedical femur</td>
<td>Provides some minor additional dynamic support</td>
</tr>
<tr>
<td>nemius</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Gracilis and semitendinosus tendons are between layers 1 and 2 and act as secondary dynamic medial stabilizers.
- The POL is a confluence of layers 2 and 3 tissues that are indistinct in the posteromedical aspect of the knee.
MENISCUS

Structure

• Fibrocartilage discs interposed in femorotibial joints between femoral condyles and tibial plateaus. Have a triangular cross section—thickest at the periphery, then tapering to a thin central edge.
• Histologically made up of collagen (mostly type 1, also 2, 3, 5, 6), cells (fibrochondrocytes), water, proteoglycans, glycoproteins, elastin
• 3 layers seen microscopically:
  1. Superficial layer: woven collagen fiber pattern
  2. Surface layer: randomly oriented collagen fiber pattern
  3. Middle (deepest) layer: circumferential (longitudinal) oriented fibers. These fibers dissipate hoop stresses. Radial fibers. These fibers acts as “ties” to hold the circumferential fibers.
• Vascular supply from superior and inferior medial and lateral geniculate arteries. They form perimeniscal plexus in synovium/capsule. Peripheral portion (10-30% medially, 10-25% laterally) is vascular via vessels from the perimeniscal plexus. 3 zones:
  - Red zone: 3mm from capsular junction (most tears will heal)
  - Red/white zone: 3-5mm from capsular junction (some tears will heal)
  - White zone: >5mm from capsular junction (most tears will not heal)
  The central, avascular ⅔ of the menisci receive nutrition from the synovial fluid
• Medial meniscus: C-shaped, less mobile, firmly attached to tibia (via coronary ligaments) and capsule (via deep MCL) at midbody
• Lateral meniscus: “circular”, more mobile, loose peripheral attachments, no attachment at popliteal hiatus (where popliteus tendon enters joint)

Function

1. Load transmission and shock absorption: the menisci absorb 50% (in extension) or 85% (in flexion) of forces across femorotibial joint. The transmission of this load to the meniscus helps protect the articular cartilage
2. Joint congruity and stability: the menisci create congruity between the curved condyles and flat plateaus, which increases stability. The menisci (esp. PHMM) also act as secondary stabilizers to translation (esp. in the ligament-deficient knee)
4. Joint nutrition: the menisci absorb, then release synovial fluid nutrients for the cartilage.
5. Proprioception: nerve endings provide sensory feedback for joint position.
Patellofemoral Joint

**Function**

- Composed of quadriceps tendon, patella, patellar tendon (ligament), and additional patella-stabilizing ligaments.
- Extensor mechanism (of the knee) is primary role of this joint. The patella increases the moment arm from joint axis, increasing the mechanical advantage and quadriceps pull in extension.
- Stability of the patella in the trochlear groove results from both bony morphology and static and dynamic stabilizers. Hypoplastic LFC or patellar ridge, a flat trochlea, or increased “Q” angle can all predispose the patella to dislocation.
- The patella begins to engage the trochlea at 20° of flexion and is fully engaged by 40°. The articulation point moves proximally with increased flexion. The odd facet (far medial) of the patella articulates in full flexion.
- Joint reaction forces can be very high in this joint: $3/300$ body weight with stairs, $7/300$ body weight with deep bending. The articular cartilage is up to 5mm (thickest in the body) to accommodate for these high forces.

**Structure**

<table>
<thead>
<tr>
<th>Ligaments</th>
<th>Attachments</th>
<th>Function/Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patellar tendon (ligament)</td>
<td>Inferior pole of patella to tibial tuberosity</td>
<td>Can rupture with eccentric contraction (usu. &gt;40y.o.)</td>
</tr>
<tr>
<td>Patellar retinaculum (med. &amp; lat.)</td>
<td>Inserts on both the femur and tibia</td>
<td>Minor patellar stabilizer</td>
</tr>
<tr>
<td>Patellar tendon</td>
<td>Superior pole of patella</td>
<td>Can rupture with eccentric contraction (usu. &gt;40y.o.)</td>
</tr>
<tr>
<td>Patellomeniscal ligaments (med. &amp; lat.)</td>
<td>Patella to periphery of menisci</td>
<td>Secondary stabilizers of patella</td>
</tr>
<tr>
<td>Patellofemoral ligaments Medial (MPFL), lateral (LPFL)</td>
<td>Femoral epicondyles to medial/lateral patella</td>
<td>Primary stabilizers of patella (esp. MPFL)</td>
</tr>
<tr>
<td>Patellotibial ligaments (med. &amp; lat.)</td>
<td>Tibial plateaus to medial/lateral patella</td>
<td>Minor patellar stabilizer</td>
</tr>
</tbody>
</table>

**Other**

- Patella position can be evaluated on lateral radiograph (30° flexion) with Insall ratio (patella [diagonal] length/patellar tendon length). Normal ratio is 1.0 (0.8 to 1.2). >1.2 indicates patella baja, <0.8 indicates patella alta.
- Dynamic stabilizers: quadriceps, adductor magnus, ITB, and vastus medialis and lateralis
- Medial patellofemoral ligament (MPFL): primary restraint to lateral dislocation (most common)
**LIGAMENTS**  | **ATTACHMENTS**  | **FUNCTION/COMMENT**
--- | --- | ---
**PROXIMAL TIBIOFIBULAR JOINT**
Anterior tibiofibular ligament  | Fibular head to anterior lateral tibia  | Broader and stronger than posterior ligament
Posterior tibiofibular ligament  | Fibular head to posterior lateral tibia  | Weaker than anterior ligament

**Other**
Interosseous membrane  | Lateral tibia to medial fibula  | Stout fibrous membrane separates anterior & posterior compartments. Is disrupted in Maisonneuve fracture

- This joint has minimal motion. Dislocation or disruption of this joint indicates high-energy trauma to the knee region.
- For distal tibiofibular joint, please see Chapter 10, Foot/Ankle.
**STEPS**

**INJECTION**

1. Ask patient about allergies.
2. Place patient in seated position with knee flexed and hanging.
3. Prep skin (iodine/soap) over the anterior knee.
4. Prepare syringe with local/steroid mixture on 21/22 gauge needle.
5. Palpate the “soft spot” between the border of the patellar tendon, the tibial plateau, and the femoral condyle.
6. May locally anesthetize the skin over the “soft spot.”
7. Horizontally insert the needle into the “soft spot,” aiming approximately 30° to the midline toward the intercondylar notch. If the needle hits the condyle, redirect it more centrally into the notch.
8. Gently aspirate to confirm that you are not in a vessel.
9. Inject solution into knee. The fluid should flow easily.
10. Withdraw needle and dress the injection site.

**ASPIRATION/ARTHROCENTESIS**

1. Ask patient about allergies.
2. Place patient supine with the knee fully extended.
3. Palpate the borders of the patella and femoral condyle.
4. Prep skin (iodine/antiseptic soap) over this area.
5. Insert needle, usually 21 or 18 gauge (for thick fluid), horizontally into suprapatellar pouch at level of superior pole of the patella.
6. Aspirate fluid into syringe (may use multiple syringes if needed).
7. Gently compress knee to “milk” fluid to the pouch for aspiration.
8. Withdraw needle and dress the injection site.
<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>Young</td>
<td>Trauma: ligamentous or meniscal injury, fracture</td>
</tr>
<tr>
<td>Middle aged, elderly</td>
<td>Arthritis</td>
<td></td>
</tr>
<tr>
<td>2. Pain</td>
<td>Acute</td>
<td>Trauma: fx, dislocation, soft tissue (ligament/meniscus) injury, septic bursitis/arthrosis</td>
</tr>
<tr>
<td>a. Onset</td>
<td>Chronic</td>
<td>Arthritis, infection, tendinitis/bursitis, overuse, tumor</td>
</tr>
<tr>
<td>b. Location</td>
<td>Anterior</td>
<td>Quadriceps or patellar tear or tendinitis, prepatellar bursitis, patellofemoral dysfunction</td>
</tr>
<tr>
<td></td>
<td>Posterior</td>
<td>Meniscus tear (posterior horn), Baker’s cyst, PCL injury</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>Meniscus tear (joint line), collateral lig. injury, arthritis, ITB syndrome</td>
</tr>
<tr>
<td>c. Occurrence</td>
<td>Medial</td>
<td>Meniscus tear (joint line), collateral ligament injury, arthritis, pes bursitis</td>
</tr>
<tr>
<td></td>
<td>Night pain</td>
<td>Tumor, infection</td>
</tr>
<tr>
<td></td>
<td>With activity</td>
<td>Etiology of pain likely from joint</td>
</tr>
<tr>
<td>3. Stiffness</td>
<td>Without locking</td>
<td>Arthritis, effusion (trauma, infection)</td>
</tr>
<tr>
<td>With locking/catching</td>
<td>Loose body, meniscal tear (esp. bucket handle), arthritis, synovial plica</td>
<td></td>
</tr>
<tr>
<td>4. Swelling</td>
<td>Intraarticular</td>
<td>Infection, trauma (OCD, meniscal tear, ACL/PCL injury, fracture)</td>
</tr>
<tr>
<td>Extraarticular</td>
<td>Collateral ligament injury, bursitis, contusion, sprain</td>
<td></td>
</tr>
<tr>
<td>Acute (post injury)</td>
<td>Acute (hours): ACL injury; subacute (day): meniscus injury, OCD</td>
<td></td>
</tr>
<tr>
<td>Acute (without injury)</td>
<td>Infection: prepatellar bursitis, septic joint</td>
<td></td>
</tr>
<tr>
<td>5. Instability</td>
<td>Giving away/collapse</td>
<td>Cruciate or collateral ligament injury/extensor mechanism injury</td>
</tr>
<tr>
<td>Giving away &amp; pain</td>
<td>Patellar subluxation/dislocation, pathologic plica, OCD</td>
<td></td>
</tr>
<tr>
<td>6. Trauma</td>
<td>Mechanism: valgus</td>
<td>MCL injury (+/- terrible triad: MCL, ACL, medial meniscus injuries)</td>
</tr>
<tr>
<td>Varus force</td>
<td>LCL or posterolateral corner injury</td>
<td></td>
</tr>
<tr>
<td>Flexion/posterior</td>
<td>PCL injury (e.g., dashboard injury)</td>
<td></td>
</tr>
<tr>
<td>Twisting</td>
<td>Noncontact: ACL injury; Contact: multiple ligaments</td>
<td></td>
</tr>
<tr>
<td>Popping noise</td>
<td>Cruciate ligament injury (esp. ACL), osteochondral fx, meniscal tear</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Degenerative and overuse etiology</td>
<td></td>
</tr>
<tr>
<td>7. Activity</td>
<td>Agility/cutting sports</td>
<td>Cruciate (ACL #1) or collateral ligament</td>
</tr>
<tr>
<td>Running, cycling etc.</td>
<td>Patellofemoral etiology</td>
<td></td>
</tr>
<tr>
<td>Squatting</td>
<td>Meniscus tear</td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>Distance able to ambulate equates with severity of arthritic disease</td>
<td></td>
</tr>
<tr>
<td>8. Neurologic sx</td>
<td>Numbness, tingling</td>
<td>Neurologic disease, trauma (consider L-spine etiology)</td>
</tr>
<tr>
<td>9. Systemic</td>
<td>Fevers, chills</td>
<td>Infection, septic joint, tumor</td>
</tr>
<tr>
<td>10. Hx of arthritides</td>
<td>Multiple joints involved</td>
<td>Rheumatoid arthritis, gout, etc</td>
</tr>
</tbody>
</table>

PCL Injury
Usual causes include hyperextension injury, as occurs from stepping into hole, and direct blow to flexed knee

Sprains
Usual cause is forceful impact on posterolateral aspect of knee with foot anchored, producing valgus stress on knee joint

ACL Injury
Usual cause is twisting of hyperextended knee, as in landing after basketball jump shot

NETTER’S CONCISE ORTHOPAEDIC ANATOMY 307
### EXAM TECHNIQUE/FINDINGS

#### INSPCTION

<table>
<thead>
<tr>
<th>EXAM</th>
<th>TECHNIQUE/FINDINGS</th>
<th>CLINICAL APPLICATION/DDDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait</td>
<td>Varus thrust, Patella tracking, Flexed knee gait</td>
<td>Can indicate LCL or posterolateral corner injury/insufficiency. Maltracking can lead to patellofemoral symptoms from tight Achilles tendon or hamstrings, can lead to patellofemoral symptoms.</td>
</tr>
<tr>
<td>Anterior</td>
<td>Knee alignment</td>
<td>Normal knee alignment is clinically neutral (6° valgus radiographically). Evaluate while weight-bearing. Variations can be developmental or post-traumatic. Can predispose to lateral compartment DJD, patella instability/maltracking. Can predispose to medial compartment DJD, ligamentous incompetency. Angle from ASIS to mid-patella to tibial tubercle. Ni: male ≤10°, female ≤15°; increased angle predisposes to patellar subluxation, patellofemoral symptoms.</td>
</tr>
<tr>
<td>Swelling</td>
<td>Prepatellar bursitis (housemaid's knee)</td>
<td>Prepatellar: prepatellar bursitis (inflammatory or septic); intraarticular effusion: arthritis, infection, trauma (hemarthrosis); intraarticular fracture, meniscal tear, ligament rupture.</td>
</tr>
<tr>
<td>Posterior</td>
<td>Mass</td>
<td>Baker's cyst</td>
</tr>
</tbody>
</table>

#### Lateral

<table>
<thead>
<tr>
<th>EXAM</th>
<th>TECHNIQUE/FINDINGS</th>
<th>CLINICAL APPLICATION/DDDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral</td>
<td>Knee alignment, Recurvatum, Patella position, High-riding patella, Low-riding patella</td>
<td>Evaluated while weight-bearing. Possible PCL injury. Best evaluated radiographically with Insall ratio (see Joints, Patellofemoral). Patella alta: can predispose to patella instability. Patella baja: usually posttraumatic or postsurgical (possible arthrofibrosis).</td>
</tr>
<tr>
<td>Musculature</td>
<td>Quadriceps, Vastus medialis</td>
<td>Atrophy can result from injury, postoperative, or neurologic conditions. VMO atrophy may contribute to patellofemoral symptoms.</td>
</tr>
<tr>
<td>EXAM</td>
<td>TECHNIQUE/FINDINGS</td>
<td>CLINICAL APPLICATION/DDX</td>
</tr>
<tr>
<td>----------</td>
<td>-------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Bony structures</td>
<td>Patella T Tibial tubercle</td>
<td>Tenderness at distal pole: tendinitis (jumper’s knee) Tenderness with Osgood-Schlatter disease</td>
</tr>
<tr>
<td>Soft tissues</td>
<td>Quadriceps tendon Patellar tendon</td>
<td>Defect: tendon rupture; tenderness: tendinitis Defect: tendon rupture; tenderness (esp. at insertion): tendinitis (jumper’s knee)</td>
</tr>
<tr>
<td></td>
<td>Compress suprapatellar pouch Prepatellar bursa Pes anserine bursa Retinaculum/plica Medial joint line and MCL Lateral joint line and LCL Iliotibial band/LFC (anterolateral knee) Popliteal fossa Compartments of leg (anterior, posterior, lateral)</td>
<td>Ballotable patella (effusion); arthritis, trauma, infection Edematous/tender bursae indicate correlating bursitis Tenderness indicates bursitis Thickened, tender plica is pathologic Tenderness: medial meniscus tear or MCL injury Tenderness: lateral meniscus tear or LCL injury Pain or tightness is pathologic Mass consistent with Baker’s cyst, popliteal aneurysm Firm or tense compartment: compartment syndrome</td>
</tr>
</tbody>
</table>
RANGE OF MOTION

<table>
<thead>
<tr>
<th>EXAM</th>
<th>TECHNIQUE/FINDINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion/extension</td>
<td>Supine: heel to buttocks, then straight</td>
</tr>
<tr>
<td></td>
<td>Note patellar tracking, pain, and crepitus</td>
</tr>
<tr>
<td></td>
<td>Normal: flex 0 to 125-135°, extend 0 to 5-15°</td>
</tr>
<tr>
<td></td>
<td>Flexion contracture: common in OA/DJD</td>
</tr>
<tr>
<td></td>
<td>Extensor lag (final 20° difficult): weak quadriceps</td>
</tr>
<tr>
<td></td>
<td>Decreased extension with effusion</td>
</tr>
<tr>
<td></td>
<td>Abnormal tracking leads to anterior knee pain</td>
</tr>
<tr>
<td>Tibial IR &amp; ER</td>
<td>Stabilize femur, rotate tibia</td>
</tr>
<tr>
<td></td>
<td>Normal 10-15° IR/ER</td>
</tr>
</tbody>
</table>

NEUROVASCULAR

Sensory

<table>
<thead>
<tr>
<th>Femoral nerve/saphenous (L4)</th>
<th>Medial leg</th>
<th>Deficit indicates corresponding nerve/root lesion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peroneal nerve (L5)</td>
<td>Lateral sural</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td></td>
<td>Superficial branch</td>
<td>Distal lateral leg</td>
</tr>
<tr>
<td>Tibial nerve (S1)</td>
<td>Proximal posterolateral leg</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
<tr>
<td>Medial sural</td>
<td>Distal posterolateral leg</td>
<td>Deficit indicates corresponding nerve/root lesion</td>
</tr>
</tbody>
</table>

Motor

| Femoral nerve (L2-4)        | Knee extension | Weakness = Quadriceps or nerve/root lesion |
| Sciatric: Tibial (L4-S3)    | Knee flexion  | Weakness = Biceps (LH) or nerve/root lesion |
| Peroneal (L4-S3)            | Knee flexion  | Weakness = Biceps (SH) or nerve/root lesion |
| Tibial nerve (S1)           | Foot plantarflexion | Weakness = TP, FHL, FDL, or nerve/root lesion |
| Peroneal (deep) n. (L4)     | Foot dorsiflexion | Weakness = TA or nerve/root lesion |
| Peroneal (superficial) n. (L5) | Hallux dorsiflexion | Weakness = EHL or nerve/root lesion |

Other

| Reflex (L4)                | Patellar | Hypoactive/absence indicates L4 radiculopathy |
|                           |          | Hyperactive may indicate UMN/myelopathic condition |
| Pulse                     | Popliteal | Diminished pulse can result from trauma |
### PHYSICAL EXAM • Leg/Knee

<table>
<thead>
<tr>
<th>EXAM</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION/DDX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SPECIAL TESTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patellofemoral Joint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patella displacement</td>
<td>Translate patella medially &amp; laterally</td>
<td>Divide patella into 4 quadrants. Patella should translate 2 quadrants in both directions. Decreased mobility indicates a tight retinaculum.</td>
</tr>
<tr>
<td>Patella apprehension</td>
<td>Relax knee, push patella laterally</td>
<td>Pain/apprehension of subluxation: patellar instability or medial retinaculum/MPFL injury</td>
</tr>
<tr>
<td>J sign</td>
<td>Actively extend knee from flexed position</td>
<td>Lateral displacement of patella in full extension: maltracking</td>
</tr>
<tr>
<td>Patella compression/grind</td>
<td>Extend knee, fire quads, compress patella</td>
<td>Pain: chondromalacia, OCD, PF arthritis/DJD of patella</td>
</tr>
</tbody>
</table>

| Meniscus |
| Joint line tenderness | Palpate both joint lines | Most sensitive exam for meniscal tear when tender (see page 309) |
| McMurray | Flex/varus/ER knee, then extend Flex/valgus/IR knee, then extend | Pop or pain suggests medial, meniscal tear Pop or pain suggests lateral, meniscal tear |
| Apley’s compression | Prone, knee 90°, compress & rotate | Pain or pop indicates meniscal tear |

| Anterior Cruciate Ligament |
| Lachman | Flex knee 20-30°, anterior force on tibia | Laxity indicates ACL injury. Most sensitive exam for ACL rupture. Grade 1: 0-5mm, 2: 6-10mm, 3: >10mm; A: good, B: no endpoint |
| Anterior drawer | Flex knee 90°, anterior force on tibia | Laxity/anterior translation: ACL injury |
| Pivot shift | Supine, extend knee, IR, valgus force on proximal tibia, then flex knee | Clunk with knee flexion indicates ACL injury. (If ACL is deficient, the tibia starts subluxated and reduces with flexion, causing the clunk.) |

---

**Lachman test**

With patient’s knee bent 20°–30°, examiner’s hands grasp limb over distal femur and proximal tibia. Tibia pulled forward with femur stabilized. Movement of 5 mm or more than that in normal limb indicates rupture of anterior cruciate ligament.

**Apprehension (Fairbank) test**

As examiner displaces patella laterally, patient feels pain and forcefully contracts quadriceps femoris muscle.

**Anterior drawer test**

Patient supine on table, hip flexed 45°, knee 90°. Examiner sits on patient’s foot to stabilize it, places hands on each side of upper calf and firmly pulls tibia forward. Movement of 5 mm or more is positive test. Result also compared with that for normal limb, which is tested first.
Pivot shift test for anterolateral knee instability

Patient supine and relaxed. Examiner lifts heel of foot to flex hip 45° keeping knee fully extended; grasps knee with other hand, placing thumb beneath head of fibula. Examiner applies strong internal rotation to tibia and fibula at both knee and ankle while lifting proximal fibula. Knee permitted to flex about 20°; examiner then pushes medially with proximal hand and pulls with distal hand to produce a valgus force at knee.

As internal rotation, valgus force, and forward displacement of lateral tibial condyle maintained, knee passively flexed. If anterior subluxation of tibia (anterolateral instability) present, sudden visible, audible, and palpable reduction occurs at about 20°–40° flexion. Test positive if anterior cruciate ligament ruptured, especially if lateral capsular ligament also torn.

Posterior drawer test

Procedure same as for anterior drawer test, except that pressure on tibia is backward instead of forward.

Leg drops backward
### Posterior Cruciate Ligament

- **Posterior drawer**: Flex knee 90°, posterior force on tibia. Posterior translation: PCL injury.
- **Posterior sag**: Supine, hip 45°, knee 90°, view laterally. Posterior translation of tibia (by gravity) on femur indicates PCL injury.
- **Quadriceps active**: Supine, knee 90°, fire quadriceps. Posteriorly subluxated tibia translates anteriorly if PCL is deficient.
- **Reverse pivot shift**: Supine, flex knee 45°, ER, valgus force on proximal tibia, then extend knee. Clunk with knee extension indicates PCL injury. (If PCL is deficient, the tibia is subluxated posteriorly, then reduces w/extension, causing the clunk.)

### Collateral Ligaments

- **Valgus stress**: Lateral force to knee at 30°, then 0°. Laxity at 30°—MCL injury; 0°—MCL and cruciate ligament injury.
- **Varus stress**: Medial force to knee at 30°, then 0°. Laxity at 30°—LCL injury; 0°—LCL and cruciate ligament injury.

### Other

- **Prone ER at 30° & 90° (Dial)**: Prone, ER both knees at 90°, then 30° (can be done supine). Increased ER at 30°: posterolateral corner (PLC) injury; at 90° PLC & PCL injuries.
- **ER recurvatum**: Supine, legs straight, raise legs by toes. Recurvatum, varus, and IR of knee indicates PLC (+/- PCL) injury.
- **Posterior lateral drawer**: Knee 90°, ER tibia 15°, posterior force. Laxity indicates posterolateral corner and/or PCL injury.
- **Posterior medial drawer**: Knee 90°, IR tibia 30°, posterior force. Laxity indicates PCL and medial ligament (MCL, POL) injury.
### LATERAL FEMORAL CONDYLE
- Lateral gastrocnemius
- Plantaris
- Popliteus (ant. & inf. to LCL)

### MEDIAL FEMORAL CONDYLE
- Medial gastrocnemius
- Soleus

### FIBULAR HEAD
- Quadriceps femoris
- Popliteus

### PROXIMAL TIBIA
- Tibialis anterior (Gerdy’s tub.)
- Extensor digitorum longus

### ORIGINS

<table>
<thead>
<tr>
<th>LATERAL FEMORAL CONDYLE</th>
<th>MEDIAL FEMORAL CONDYLE</th>
<th>FIBULAR HEAD</th>
<th>PROXIMAL TIBIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral gastrocnemius</td>
<td>Medial gastrocnemius</td>
<td>Soleus</td>
<td>Tibialis anterior (Gerdy’s tub.)</td>
</tr>
<tr>
<td>Plantaris</td>
<td></td>
<td></td>
<td>Extensor digitorum longus</td>
</tr>
<tr>
<td>Popliteus (ant. &amp; inf. to LCL)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### INSERTIONS

<table>
<thead>
<tr>
<th>LATERAL FEMORAL CONDYLE</th>
<th>MEDIAL FEMORAL CONDYLE</th>
<th>FIBULAR HEAD</th>
<th>PROXIMAL TIBIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adductor magnus (ad-</td>
<td>Biceps femoris</td>
<td>Quadriceps</td>
<td></td>
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<tr>
<td>ductor tub.)</td>
<td></td>
<td>(tibial tubercle)</td>
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<tr>
<td>Ligaments:</td>
<td>Ligaments:</td>
<td>Ligaments:</td>
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<tr>
<td>Medial collateral</td>
<td>Lateral collateral</td>
<td>Popliteofibular</td>
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<tr>
<td>lig. (MCL)</td>
<td>lig. (LCL)</td>
<td>ligament</td>
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<td></td>
<td></td>
<td>Arcuate ligament</td>
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<td></td>
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<td>Fabellofibular ligament</td>
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</tbody>
</table>

Note: Attachments of intrinsic muscles of foot not shown.
### COMPARTMENT MUSCLES NEUROVASCULAR STRUCTURE

#### COMPARTMENTS (4)

<table>
<thead>
<tr>
<th>COMPARTMENT</th>
<th>MUSCLES</th>
<th>NEUROVASCULAR STRUCTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>Tibialis anterior (TA)</td>
<td>Deep peroneal nerve</td>
</tr>
<tr>
<td></td>
<td>Extensor hallucis longus (EHL)</td>
<td>Anterior tibial artery and vein</td>
</tr>
<tr>
<td></td>
<td>Extensor digitorum longus (EDL)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peroneus tertius</td>
<td></td>
</tr>
<tr>
<td>Lateral</td>
<td>Peroneus longus</td>
<td>Superficial peroneal nerve</td>
</tr>
<tr>
<td></td>
<td>Peroneus brevis</td>
<td></td>
</tr>
<tr>
<td>Superficial posterior</td>
<td>Gastrocnemius</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Soleus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plantaris</td>
<td></td>
</tr>
<tr>
<td>Deep posterior</td>
<td>Posterior tibialis (PT)</td>
<td>Tibial nerve</td>
</tr>
<tr>
<td></td>
<td>Flexor hallucis longus (FHL)</td>
<td>Posterior tibial artery and vein</td>
</tr>
<tr>
<td></td>
<td>Flexor digitorum longus (FDL)</td>
<td>Peroneal artery and vein</td>
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<tr>
<td></td>
<td>Popliteus</td>
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</table>

#### FASCIOTOMIES

<table>
<thead>
<tr>
<th>Incision</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Anterolateral</td>
<td>Centered over the intermuscular septum between the anterior and lateral compartments</td>
</tr>
<tr>
<td>Medial</td>
<td>Centered over the posterior tibial border/septum between the superficial and deep posterior compartments</td>
</tr>
<tr>
<td>MUSCLE</td>
<td>ORIGIN</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Tibialis anterior (TA)</td>
<td>Proximal lateral tibia, (Gerdy's tubercle)</td>
</tr>
<tr>
<td>Extensor hallucis longus (EHL)</td>
<td>Medial fibula, interosseous membrane</td>
</tr>
<tr>
<td>Extensor digitorum longus (EDL)</td>
<td>Lateral tibia condyle &amp; proximal fibula</td>
</tr>
<tr>
<td>Peroneus tertius</td>
<td>Distal fibula, interosseous membrane</td>
</tr>
<tr>
<td>MUSCLE</td>
<td>ORIGIN</td>
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<tr>
<td>--------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Peroneus longus</td>
<td>Proximal lateral fibula</td>
</tr>
<tr>
<td>Peroneus brevis</td>
<td>Distal lateral fibula</td>
</tr>
<tr>
<td>MUSCLE</td>
<td>ORIGIN</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>Lateral and medial femoral condyles</td>
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</tr>
<tr>
<td>Soleus</td>
<td>Posterior fibular head/soleal line of tibia</td>
</tr>
<tr>
<td>Plantaris</td>
<td>Lateral femoral supracondylar line</td>
</tr>
<tr>
<td>MUSCLE</td>
<td>ORIGIN</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Popliteus</td>
<td>Lateral femoral condyle (anterior and distal to LCL)</td>
</tr>
<tr>
<td>Flexor hallucis longus (FHL)</td>
<td>Posterior fibula</td>
</tr>
<tr>
<td>Flexor digitorum longus (FDL)</td>
<td>Posterior tibia</td>
</tr>
<tr>
<td>Tibialis posterior (TP)</td>
<td>Posterior tibia, fibula, interosseous membrane</td>
</tr>
</tbody>
</table>
### LUMBAR PLEXUS

#### Posterior Division

**Saphenous (L2-4):** Branch of femoral nerve, enters leg posteromedially, superficial to sartorial fascia (at risk in direct medial approach, e.g., MMR). It then gives off infrapatellar branch (at risk in anteromedial & midline approaches, e.g., ACLR), and descends in medial leg.

**Sensory:** Infrapatellar region: via infrapatellar branch  
Medial leg: via medial cutaneous nerves  
**Motor:** None (in leg)

### SACRAL PLEXUS

#### Anterior Division

**Tibial (L4-S3):** Descends b/w heads of gastrocnemius into leg, posterior to posterior tibialis muscle (in deep posterior compartment) to ankle just posterior to medial malleolus b/w FDL and FHL tendons.

**Sensory:** Proximal posterolateral leg: via medial sural nerve  
**Motor:**  
- Super. post. compartment  
  - Plantaris  
  - Gastrocnemius  
  - Soleus: via n. to soleus  
- Deep post. compartment  
  - Popliteus: via n. to popliteus  
  - Posterior tibialis (PT)  
  - Flexor digitorum longus  
  - Flexor hallucis longus

---

**Diagram Notes:**
- Infrapatellar branch of saphenous nerve
- Medial cutaneous nerves of leg (branches of saphenous nerve)
- Tibial nerve (L4, 5, S1, 2, 3)
- Medial sural cutaneous nerve (cut)
- Articular branches
- Plantaris muscle
- Gastrocnemius muscle (cut)
- Nerve to popliteus muscle
- Popliteus muscle
- Interosseous nerve of leg
- Soleus muscle (cut and partly retracted)
- Flexor digitorum longus muscle
- Flexor hallucis longus muscle
- Sural nerve (cut)
- Lateral calcaneal branch (from sural n.)
- Medial calcaneal branch (from tibial n.)
- Flexor retinaculum (cut)
- Lateral dorsal cutaneous nerve
- Common fibular (peroneal) nerve
- Articular branch
- Lateral sural cutaneous nerve (cut)
SACRAL PLEXUS

**Posterior Division**

Common peroneal (L4-S2): divides from sciatic nerve in distal posterior thigh, runs posteroinferior to biceps femoris, around fibular neck (can be compressed or injured), then divides into 2 branches.

**Sensory:** Proximal lateral leg: via lateral sural nerve

**Motor:** None (before dividing)

Deep peroneal: runs in anterior compartment of leg with anterior tibial artery, posterior to tibialis anterior on interosseous membrane.

**Sensory:** None (in leg)

**Motor:**
- Anterior compartment
  - Tibialis anterior (TA)
  - Extensor hallucis longus
  - Ext. digitorum longus
  - Peroneus tertius

Superficial peroneal: Runs in lateral compartment of leg, crosses anteriorly 12 cm above lateral malleolus (injured in lateral ankle approach, e.g., ankle ORIF) to dorsal foot, then divides into 2 branches.

**Sensory:** Anterolateral leg

**Motor:**
- Lateral compartment
  - Peroneus longus (PL)
  - Peroneus brevis (PB)

Other

Sural: Formed from medial sural cutaneous (tibial nerve) & lateral sural cutaneous (peroneal nerve), runs subcutaneously in posterolateral leg, crosses Achilles tendon 10 cm above insertion, then to lateral heel.

**Sensory:** Posteriolateral distal leg

**Motor:** None

### SACRAL PLEXUS Diagram

- Common fibular (peroneal) nerve via lateral sural cutaneous nerve
- Medial sural cutaneous nerve
- Superficial fibular (peroneal) nerve
- Sural nerve
- Tibial nerve via medial calcanean branches

**Common Peroneal Nerve**

- Lateral sural cutaneous nerve
- Biceps femoris tendon
- Common fibular (peroneal) nerve (phantom)
- Head of fibula
- Fibularis (peroneus) longus muscle (cut)
- Fibularis (peroneus) brevis muscle
- Superficial fibular (peroneal) nerve
- Braches of lateral sural cutaneous nerve
- Fibularis (peroneus) longus muscle
- Fibularis (peroneus) brevis muscle
- Medial dorsal cutaneous nerve
- Intermediate dorsal cutaneous nerve
- Inferior extensor retinaculum (partially cut)
- Lateral dorsal cutaneous nerve (branch of sural nerve)
- Dorsal digital nerves
- Deep branch of deep fibular (peroneal) nerve to Extensor hallucis brevis and
- Extensor digitorum brevis muscles
- Medial branch of deep fibular (peroneal) nerve
- Lateral branch of deep fibular (peroneal) nerve to Extensor hallucis brevis and
- Extensor digitorum brevis muscles
- Intermediate dorsal cutaneous nerve
- Extensor digitorum longus muscle
- Extensor hallucis longus muscle
COURSE BRANCHES COMMENT/SUPPLY

POPLITEAL ARTERY

Begins at adductor hiatus and runs through the popliteal fossa, posterior to PCL (can be injured here), then divides at the popliteus muscle

Superior medial and lateral geniculate
Inferior medial and lateral geniculate
Middle geniculate
Anterior and posterior tibial arteries

SLGA at risk in lateral release
ILGA separates lateral knee layer 3 ligaments/structures
Supplies ACL, PCL, and synovium
Terminal branches of popliteal artery

• All four geniculate arteries anastomose around the knee and the patella.

ANTERIOR TIBIAL ARTERY

Passes b/w the two heads of the posterior tibialis into the anterior compartment and lies on interosseous membrane w/deep peroneal n.

Anterior tibial recurrent
Circumflex fibular
Anterior medial and lateral malleolar
Dorsalis pedis

Supplies and anastomoses at knee
Supplies fibular head and lateral knee
Supplies anterior portion of malleoli
Terminal branch in foot

• Supplies muscles of the anterior compartment of the leg

POSTERIOR TIBIAL ARTERY

Runs with tibial nerve in deep posterior compartment, posterior to posterior tibialis muscle to the ankle, where it lies between the FDL and FHL tendons posterior to the medial malleolus (pulse is palpable here).

Posterior tibial recurrent
Peroneal artery
Perforating muscular branches
Posterior medial malleolar
Medial calcaneal
Medial and lateral plantar

Supplies and anastomoses at knee
Supplies lateral compartment
To muscles of post. compartments
Supplies posterior medial malleolus
Supplies medial calcaneus/heel
Terminal branches in the foot

• Supplies muscles of the superficial and deep posterior compartments of the leg

PERONEAL ARTERY

Branches from posterior tibial artery, runs between PT & FHL muscles in posterior compartment

Posterior lateral malleolar
Lateral calcaneal

Supplies posterior lateral malleolus
Supplies lateral calcaneus/heel

• Supplies muscles of the lateral compartment of the leg

• See muscle pages 315-319 for additional pictures of the arteries
**ARThRITIS**

**Osteoarthritis**

- Primary/idiopathic or secondary (e.g., posttraumatic)
- Loss/deterioration of articular cartilage
- Can affect 1 (medial #1) or all 3 compartments in knee

**Hx & PE**

- **Hx**: Older, decreasing activity level. Pain w/ weight-bearing and activities
- **PE**: Effusion, joint line tenderness, +/- contracture or deformity (varus #1)

**XR**

1. Arthritis series
   - Joint space narrowing
   - Osteophytes
   - Subchondral sclerosis
   - Subchondral cysts
   - Alignment views

**TREATMENT**

1. NSAIDs, activity modification
2. Physical therapy, brace, cane
3. Glucocorticosteroid injections
4. Unicompartmental
   - HTO
   - Unicompartment arthroplasty
5. Tricompartmental: Total knee arthroplasty (TKA)

**Inflammatory**

- Multiple types: rheumatoid, gout, seronegative (e.g., Reiter’s)
- In RA, synovitis/pannus formation destroys cartilage & eventually whole joint.

**Hx**: Usually younger pts. Pain, often multiple joints

**PE**: Effusion, +/- warmth, decr. ROM & deformity

**XR**: Arthritis series: joint narrowing, joint erosions, ankylosis, joint destruction

**LABS**: CBC, RF, ANA, CRP, crystals, culture

1. Early: manage medically
2. Late
   - Nonop: like osteoarthritis
   - Synovectomy
   - Total knee arthroplasty

---

**Joint Pathology in Osteoarthritis**

Knee joint opened anteriorly reveals large erosion of articular cartilages of femur and patella with cartilaginous excrescences at intercondylar notch.

**Joint Pathology in Rheumatoid Arthritis**

Progressive stages in joint pathology:
1. Acute inflammation of synovial membrane (synovitis) and beginning proliferative changes.
2. Progression of inflammation with pannus formation; beginning destruction of cartilage and mild osteoporosis.
3. Subsidence of inflammation; fibrous ankylosis.
4. Bony ankylosis; advanced osteoporosis.

Knee joint opened anteriorly, patella reflected downward. Thickened synovial membrane inflamed; polypoid outgrowths and numerous villi (pannus) extend over rough articular cartilages of femur and patella.
### Patellofemoral Syndrome
- **Hx:** Young female and athletes. Pain with activities (e.g., running, stairs) and prolonged sitting
- **PE:** Patella compression, +/- incr. Q angle and/or J-sign
- **XR:** 4 views: AP & notch; eval. for OCD, OA
- **TREATMENT:** NSAIDs, activity modification
  - Physical therapy: ROM, quad. strengthening, hamstring stretching, +/- foot orthoses
  - Patella realignment (if malalignment is present)

### Chondromalacia Patellae
- **Hx:** Usually younger pts.; pain, often multiple jts.
- **PE:** Effusion, decr. ROM & deformity
- **XR:** 4 view: evaluate like PFS (see above)
- **TREATMENT:** NSAIDs, activity modification
  - Physical therapy
  - Arthroscopic debridement/ chondroplasty may help

### Lateral Patellar Compression Syndrome
- **Hx:** Usually younger pts.; anterior knee pain
- **PE:** PF pain, decreased mobility/patella glide
- **XR:** 3 or 4 views: Sunrise/merchant: evaluate for lateral patella tilt
- **TREATMENT:** PT: stretch lateral tissues, quad. strengthening +/- taping or centralizing brace
  - Arthroscopic lateral release

### Iliotibial Band Syndrome
- **Hx:** Pain w/activity
- **PE:** Lateral femoral condyle; TTP (knee at 30°)
- **XR:** AP/lateral: normal, r/o tumor
- **TREATMENT:** NSAIDs, activity modification, stretching (ITB)
  - Partial excision (rare)

---

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP/FINDINGS</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANTERIOR KNEE PAIN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patellofemoral Syndrome</td>
<td>• Pain in patellofemoral joint</td>
<td>• Contributing factors: overuse, subtle instability or malalignment, quadriceps weakness</td>
<td>• NSAIDs, activity modification</td>
</tr>
<tr>
<td></td>
<td>• Chondromalacia may be present, but not necessarily</td>
<td></td>
<td>Physical therapy: ROM, quad. strengthening, hamstring stretching, +/- foot orthoses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Patella realignment (if malalignment is present)</td>
</tr>
<tr>
<td>Chondromalacia Patellae</td>
<td>• Softening or wear of the articular cartilage of the patella</td>
<td></td>
<td>NSAIDs, activity modification</td>
</tr>
<tr>
<td></td>
<td>• Term often misused to imply any anterior knee pain</td>
<td></td>
<td>Physical therapy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Arthroscopic debridement/ chondroplasty may help</td>
</tr>
<tr>
<td><strong>LATERAL PATELLAR COMPRESSION SYNDROME</strong></td>
<td></td>
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<tr>
<td></td>
<td>• Overloading of lateral facet during flexion</td>
<td></td>
<td>PT: stretch lateral tissues, quad. strengthening +/- taping or centralizing brace</td>
</tr>
<tr>
<td></td>
<td>• Due to tight lateral structures (esp. lateral retinaculum)</td>
<td></td>
<td>Arthroscopic lateral release</td>
</tr>
<tr>
<td>Lateral Iliotibial Band Syndrome</td>
<td></td>
<td></td>
<td>NSAIDs, activity modification, stretching (ITB)</td>
</tr>
<tr>
<td></td>
<td>• ITB rubs on lateral femoral condyle</td>
<td></td>
<td>Partial excision (rare)</td>
</tr>
<tr>
<td></td>
<td>• Common w/runners/cyclists</td>
<td></td>
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</tr>
</tbody>
</table>
Anterior Knee Pain

**Patellar Instability**
- Subluxation or dislocation of patella (lateral #1)
- Associated with anatomic variants
- MPFL is key structure

**Hx:** Pain & patella instability
**PE:** + patellar apprehension, +/- increased Q angle, genu valgum, femoral anteversion

**XR:** 3 or 4 views: eval. for fx and patella position (lateral and/or patella alta)
**MR:** eval. MPFL if acute

**Treatment:**
- Acute: MPFL repair
- Recurrent/chronic: physical therapy, brace; patellar realignment surgery

**Patellar Tendinitis**
- Seen in jumpers (e.g., basketball/volleyball players)
- Microtears at tendon insertion at distal pole

**Hx:** Sports, anterior knee pain (worse with activity)
**PE:** Patellar inferior pole TTP

**XR:** AP/lateral: normal

**MR:** Increased signal at insertion (inferior pole) or intrasubstance

**Treatment:**
- NSAIDs, stretch and strengthen quadriceps and hamstrings
- Surgical debridement (rare)

**Plica**
- Fold in synovium (embryonic remnant) becomes thickened or inflamed
- Medial plica #1

**Hx:** Anteromedial pain, +/- popping/catching
**PE:** Tender, palpable plica, +/- snap with flexion

**XR:** Knee series. Eval. for other pain sources
**MR:** Of questionable value

**Treatment:**
- Ice, NSAIDs
- Activity modification
- Arthroscopic debridement (if symptoms persist)

**Prepatellar Bursitis**
- Etiology: trauma or overuse (e.g., prolonged kneeling)
- “Housemaid’s knee”
- Inflammatory or septic

**Hx:** Knee pain & swelling
**PE:** Egg-shaped swelling on anterior patella, TTP, +/- signs of infection

**XR:** Knee series: usu. normal
**LAB:** CBC, ESR, +/- aspirate: gram stain & cell count

**Treatment:**
- Inflammatory: ice, NSAIDs, knee pads, rest, +/- aspiration; bursectomy if persistent
- Septic: bursectomy, abx
LIGAMENT INJURIES

**Anterior Cruciate**
- **Mechanism:** twisting injury, often noncontact pivoting
- **Associated with other injuries:** meniscal tears, collateral ligament (all 3 = terrible triad)
- **Common in female athletes**

**Hx:** Twisting injury, “pop,” swelling, inability to continue playing

**PE:** Effusion (hemarthrosis) + Lachman (most sensitive), + anterior drawer, + pivot shift

**XR:** Knee series (Segond fx is pathognomonic for ACL)

**MR:** Absent/detached ACL, +/- bone bruise (middle LFC–posterior lateral tibia plateau)

**Arthrocentesis:** Hemarthrosis

**Based on functional stability**
- Stable/low demand pt: activity modification, PT, brace
- Unstable/athletes/active pt: surgical reconstruction (grafts: BTB, hamstring, allograft)

**Complications:** arthrofibrosis, failure/recurrence (1. technical error, 2. missed ligamentous injury, 3. recurrent trauma)

**Posterolateral Corner**
- **Mechanism:** direct blow or hyperextension/varus injury
- **LCL, popliteus, popliteofibular ligament are injured.** These are focus of surgical reconstruction.
- **Can be associated w/PCL injury**

**Hx:** Trauma, pain, instability

**PE:** +/- effusion, + prone ER test at 30°, +/- posterolateral drawer & ER recurvatum tests

**XR:** Knee series. Avulsions can occur (fibular head). Alignment: eval. for varus

**MR:** To evaluate all ligaments and other soft tissues

**Surgical repair: acute grade 3**

**Surgical reconstruction:** chronic or combined injury, HTO if varus

**Nonoperative:** low grade (grades 1 & 2 injury): brace & physical therapy
### Ligament Injuries

#### Posterior Cruciate
- **Mechanism:** Anterior force on tibia (e.g., dashboard injury) or sports (hyperextension)
- **Associated with collateral and/or PL corner injuries**
- **Hx:** Trauma (dashboard) or sports injury, pain
- **PE:** +/- effusion, +/- posterior drawer, quadriceps active test, & posterior sag
- **XR:** Knee series. Look for avulsion fracture.
- **MR:** Confirms diagnosis. Evaluates meniscus and articular cartilage.
- **Treatment:**
  - Nonoperative: isolated (esp. grades 1 & 2 injury): brace & PT
  - Surgical reconstruction: failed nonop treatment, combined injury, some isolated grade 3’s

#### Medial Collateral
- **Mechanism:** Valgus force
- **Common in football**
- **Usually injured at femoral origin (medial epicondyle)**
- **Hx:** Trauma, pain, instability
- **PE:** Tenderness at medial epicondyle along tendon. Pain/laxity w/valgus stress
- **XR:** Knee series. Medial epicondyle avulsion can occur (calcified = Pelligrini-Steida).
- **MR:** Confirms diagnosis
- **Treatment:**
  - Hinged knee brace
  - Physical therapy: ROM and strengthening
  - Surgery: uncommon

#### Lateral Collateral
- **Mechanism:** Varus force
- **Isolated injuries are rare, usually combined with posterolateral corner (PLC)**
- **Hx:** Trauma, pain, instability
- **PE:** Lateral tenderness. Pain/laxity w/varus stress
- **XR:** Knee series. Fibular head avulsions can occur.
- **MR:** Confirms diagnosis
- **Treatment:**
  - Isolated injury: hinged brace
  - Combined injury: surgical repair or reconstruction
### Intraarticular Conditions

#### Meniscus Tear
- **Description:**
  - Acute: young, twisting injury
  - Degenerative: older +/- OA
  - Multiple tear patterns
  - Associated w/other injuries (ACL rupture, OCD, etc)
  - Medial>lateral 3:1 (posterior horn most common)

- **Hx & PE:**
  - Pain & swelling esp. w/flexion activities, +/- catching or locking (e.g., bucket handle tear)
  - Effusion, joint line tenderness, +/- McMurray/Apley tests

- **Workup/Finding:**
  - XR: Knee series: usually normal. Early OA often seen in pts w/degenerative tears
  - MR: Very sensitive for tears. “Double PCL” sign for displaced bucket handle tears

- **Treatment:**
  - Small/minimally symptomatic: treat conservatively
  - Peripheral tears (red zone): repair (heal best w/ACL reconstruction)
  - Central tears (white zone): partial meniscectomy

#### Osteochondral Defect
- **Description:**
  - Spectrum: purely chondral to osteochondral lesions
  - Traumatic or degenerative
  - Osteochondritis dissecans is separate but similar entity

- **Hx & PE:**
  - Often young/active pts. Pain (usually w/WB), +/- popping, catching
  - Inconsistent: +/- effusion, bony tenderness

- **Workup/Finding:**
  - XR: Knee series: 4 views (need 45° PA & notch views), consider alignment series
  - MR: Good modality for purely chondral lesions

- **Treatment:**
  - Displaced OCD: internal fixation
  - Chondral:
    - Debridement
    - Microfracture
    - Osteochondral transfer
    - Chondrocyte implantation
### Quadriceps Tendon Rupture

- **Mechanism:** Eccentric contraction or indirect trauma
- **Patients usually:** >40y.o.
- **Usually at musculotendinous junction**

**Hx:** Older, fall/trauma

**PE:** Effusion, palpable defect above patella. Inability to do or maintain straight leg raise

**XR:** Knee series. Look for patella baja

**MR:** Will show tendon tear. Usually not needed. May be helpful in partial tears.

**TREATMENT**
- **Acute:** Primary surgical repair
- **Chronic:** Surgical reconstruction (tendon lengthening or allograft procedure)

### Patellar Tendon Rupture

- **Mechanism:** Direct or indirect (eccentric load) trauma
- **Patients usually:** <40y.o.
- **Associated with underlying tendon and/or metabolic disorder**

**Hx:** Younger pts, trauma, pain, loss of knee extension

**PE:** Effusion, palpable defect in tendon. Cannot do straight leg raise

**XR:** Knee series. Look for patella alta

**MR:** Will show tendon tear. Usually not needed. May be helpful in partial tears.

**TREATMENT**
- **Acute:** Primary surgical repair
- **Chronic:** Surgical reconstruction (tendon lengthening or allograft procedure)

### Tumor

- **#1 in adolescents:** osteosarcoma; **#1 in adults:** chondrosarcoma; **#1 benign (young adults):** giant cell tumor

---

**DESCRIPTION** | **Hx & PE** | **WORKUP/FINDINGS** | **TREATMENT**
--- | --- | --- | ---
**Quadriceps Tendon Rupture** | | | |
- Mechanism: eccentric contraction or indirect trauma  
- Patients usually >40y.o.  
- Usually at musculotendinous junction | Hx: Older, fall/trauma  
PE: Effusion, palpable defect above patella. Inability to do or maintain straight leg raise | XR: Knee series. Look for patella baja  
Chronic: surgical reconstruction (tendon lengthening or allograft procedure) |
**Patellar Tendon Rupture** | | | |
- Mechanism: direct or indirect (eccentric load) trauma  
- Patients usually <40y.o.  
- Associated with underlying tendon and/or metabolic disorder | Hx: Younger pts, trauma, pain, loss of knee extension  
PE: Effusion, palpable defect in tendon. Cannot do straight leg raise | XR: Knee series. Look for patella alta  
Chronic: surgical reconstruction (tendon lengthening or allograft procedure) |
**Tumor** | #1 in adolescents: osteosarcoma; #1 in adults: chondrosarcoma; #1 benign (young adults): giant cell tumor

---
TOTAL KNEE ARTHROPLASTY

General Information

- Goals: 1. Clinical: alleviate pain, maintain personal independence, allow performance of activities of daily living (ADLs) & recreation; 2. Surgical: restore mechanical alignment, restore joint line, balance soft tissues (e.g., collateral ligs.)
- Common procedure with high satisfaction rates for primary procedure. Revisions are also becoming more common. Advances in techniques and materials are improving implant survival; this procedure now available to younger pts.

Materials and Designs

Materials
- Femur component: cobalt-chrome commonly used for femoral-bearing surface with titanium stem
- Tibia component/tray: does not articulate with femoral component. Often made of titanium.
- Tibial tray insert: articulates with femoral component; made of polyethylene (UHMWPE, ultra high molecular weight PE)
  - Polyethylene (PE) wears well but does produce microscopic particles that may lead to implant loosening & failure.
  - Polyethylene should be at least 8mm thick, cross-linked for better wear, & sterilized in inert (non-O2) environment.
  - Congruent design (not flat) improves wear rate and rollback (increased knee flexion).
  - Direct compression molding is preferred manufacturing technique.
- Cement: methylmethacrylate

Prosthetic Designs
- Unconstrained: 2 types. These are most common for primary surgical procedures with minimal deformity.
  - Posterior cruciate (PCL) retaining (“CR”): preserves femoral rollback for incr. knee flexion but has incr. PE wear.
  - Posterior cruciate (PCL) substituting (“posterior stabilized”) (“PS”): provides mechanical rollback, but may dislocate. Indicated for patellectomy, inflammatory arthritis, incompetent PCL (e.g., previous PCL rupture, etc).
- Constrained (non-“hinged”): Used for moderate ligament (MCL/LCL) deficiency. Uses a central post to provide stability.
- Constrained (“hinged”): Used for global ligament deficiency. Has high wear and failure rates.
- Other: Mobile-bearing designs are available.

Fixation
- Cement. Most common.
- Biologic. Bone ingrowth techniques. Theoretically have longer life, but have higher failure rates.

Indications

- Arthritis of knee
  - Common etiologies: osteoarthritis (idiopathic, posttraumatic), rheumatoid arthritis, osteonecrosis
  - Clinical symptoms: knee pain, worse with activity, gradually worsening over time, decreased ambulatory capacity.
  - Radiographic findings: appropriate radiographic evidence of knee arthritis

OSTEOARTHRITIS
- 1. Joint space narrowing
- 2. Sclerosis
- 3. Subchondral cysts
- 4. Osteophyte formation

RHEUMATOID ARTHRITIS
- 1. Joint space narrowing
- 2. Periarticular osteoporosis
- 3. Joint erosions
- 4. Ankylosis

- Failed conservative treatment: NSAIDs, activity modification, weight loss, physical therapy, orthosis (e.g., medial off-loader brace), ambulatory aid (e.g., cane in contralateral hand), injections (corticosteroid, viscosupplementation)

Contraindications

- Absolute: Neuropathic joint, infection, extensor mechanism dysfunction, medically unstable patient (e.g., severe cardiopulmonary disease). Patient may not survive the procedure.
- Relative: Young, active patients. These patients can wear out the prostheses many times in their lives.

Alternatives

- Considerations: age, activity level, overall medical health
- Osteotomy: relatively young patients with unicompartimental disease
  - Valgus knee/lateral compartment DJD: distal femoral varus–producing osteotomy
  - Varus knee/medial compartment DJD: proximal tibia valgus–producing osteotomy
- Unicompartmental arthroplasty: unicompartimental disease
- Arthrodesis/fusion: young laborers with isolated unilateral disease (e.g., normal spine, hip, ankle)
TOTAL KNEE ARTHROPLASTY

**Procedure**

**Approaches**
- Midline incision with medial parapatellar arthrotomy is most common.
- Minimally invasive incisions are also being used. Special equipment is often needed for the smaller incisions.

**Steps**
- **Bone cuts**
  - Cut femur and tibia perpendicular to mechanical axis. Can use intramedullary (femur/tibia) or extramedullary (tibia) reference; this will restore the mechanical alignment.
  - Bone removed from femur and tibia should be equal to that replaced by the implants to maintain/restore joint line.
- **Implants**—trial implants are first inserted to test adequacy of the bone cuts
  - Implants should be best fit possible to native bone
  - Femur placed in 3º of external rotation to accommodate a perpendicular bone cut of the proximal tibia (typically in 3º of varus)
  - Femoral axis determined in 3 ways: 1. epicondylar axis, 2. posterior condylar axis, 3. AP axis—perpendicular to trochlea
- **Balancing**
  - Sagittal plane: goal is to make flexion & extension gaps equal. May need to cut more bone or add implant augments.
  - Coronal plane: soft tissues are of primary concern. Rule is to release the concave side of the deformity.
  - Varus deformity: release medial side: 1. deep MCL, 2. postmed capsule/semimemb insertion, 3. superficial MCL
  - Valgus deformity: release lateral side: 1. lateral capsule, 2a. ITB (tight in ext.), 2b. popliteus (tight in flexion), 3. LCL
  - Polyethylene trial: the knee should be stable and well balanced with the trial polyethylene in place.
- **Final implantation of components**

**Complications**
- Patellofemoral complications are most common: patella maltracking, patellofemoral pain, patellar fracture.
- Arthrofibrosis: may respond early (<6 wk) to manipulation under anesthesia.
- Extensor mechanism failure: patellar tendon rupture or avulsion (difficult to repair/reconstruct); patellar fracture
- Infection; diagnose with labs and aspiration. Prevention is mainstay: perioperative antibiotics, meticulous prep/drape technique, etc. Treatment: acute/subacute: irrigation & debridement with PE exchange. Late: 1- or 2-stage revision
- Loosening: more common with biologic fixation. Also caused by microscopic particles from polyethylene wear
- Neurovascular injury
  - Peroneal nerve: esp. after mechanical axis correction of a valgus knee (nerve is stretched)
  - Superolateral geniculate artery: should be identified and cauterized
- Medical complications: Deep venous thrombosis (DVT) and pulmonary embolus (PE) are known risks of TKA. Prophylaxis must be initiated.
- Periprosthetic fracture
  - Femur: stable implant—nail or fixed angle device; unstable implant—replace with longer stem that passes fx site
**GENU VARUM**

- **Normal (physiologic):** ages 0-2
- **Pathologic:** Blount's disease
  - Infantile: <3y.o., obesity, early walking
  - Adolescent: insidious onset >8y.o.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hx: Parents notice a deformity</td>
<td>PE: Unilateral or bilateral genu varum</td>
<td>TMDA: &lt;9° is normal, &gt;16° is pathologic/Blount's</td>
</tr>
<tr>
<td>Xr: Tibia metadiaphyseal angle</td>
<td></td>
<td>Physiologic: observation</td>
</tr>
</tbody>
</table>

**GENU VALGUM**

- **Normal (physiologic):** ages 2-5
- **Pathologic:** skeletal tumors
  - Metabolic: renal osteodystrophy
  - Other: trauma, infection

<table>
<thead>
<tr>
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<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hx: Parents notice a deformity</td>
<td>PE: Unilateral or bilateral genu valgum</td>
<td>Xr: Alignment x-rays: valgus is 6° in normal adults</td>
</tr>
</tbody>
</table>

Two brothers, younger (left) with bowleg, older (right) with knock-knee. In both children, limbs eventually became normally aligned without corrective treatment.
**Posteromedial Bowing**

Convexity of bow in distal third of tibia and fibula directed posteriorly and medially. Spontaneous correction usually obviates need for realignment osteotomy, but leg-length discrepancy often persistent.

**Anterolateral Bowing**

Medullary canal present but narrow with sclerotic changes; cyst apparent. Prone to spontaneous fracture and pseudarthrosis.

**Congenital pseudoarthrosis of the tibia.**

Angulation of right leg. Café au lait spots on thigh and abdomen suggest relationship to neurofibromatosis.

**Anterolateral Bowing.**

In infancy it may be difficult to predict if anterolateral bowing will correct spontaneously or if bone will progress to fracture and congenital pseudarthrosis. Progression to pseudarthrosis is more likely if the medullary canal is narrow and has sclerotic changes.
**Osgood-Schlatter Disease**

- Traction apophysitis/osteochondrosis of the tibial tubercle (2° ossification site)
- Repetitive stress to extensor mechanism (e.g., in athletics [most common])

**EVALUATION**

- **Hx:** Adolescent w/knee pain, worse after activity
- **PE:** Tibial tubercle swollen & tender to palpation
- **XR:** Shows ossification center at tibial tubercle +/- heterotopic ossification

**TREATMENT**

- Symptoms resolve w/apophysis closure (during adolescence)
- Activity modification/restriction
- Cast/brace if symptoms severe
- Excision of unfused ossicle

**Tibial Torsion**

- Congenital internal rotation of tibia
- Assoc. w/decreased intrauterine space & other “packaging problems”
- Most common cause of intoeing gait

**EVALUATION**

- **Hx:** 1-2y.o., frequent tripping, “pigeon toed”
- **PE:** Intoing gait, negative foot to thigh angle, medial foot progression angle, transmalleolar axis IR/medial with thigh/patella pointed forward

**TREATMENT**

- Will spontaneously resolve
- Orthoses of no proven benefit
- Supramalleolar osteotomy if deformity persists into late childhood
**Anteromedial Approach to Knee Joint**

**USES**
- Ligament reconstruction
- Total knee arthroplasty
- Meniscectomy

**INTERNERVOS PLANE**
- No planes: capsule is under skin

**DANGERS**
- Infrapatellar branch of saphenous nerve

**COMMENT**
- Most commonly used approach
- Most/best exposure
- Neuroma may develop from cut nerve

**KNEE: MEDIAL PARAPATELLAR APPROACH**

**LEG/TIBIA: POSTEROLATERAL APPROACH (HARMON)**
- Fractures
- Nonunions
- Gastrocnemius/soleus/ FHL (tibial)
- Peroneus longus/brevis (superficial peroneal)
- Lesser saphenous vein
- Posterior tibial artery

**COMMENT**
- A technically difficult approach
- Bone grafting of nonunion

**FASCIOTOMY**

See pages 294 and 315
**USES** | **INTERNERVIOUS PLANE** | **DANGERS** | **COMMENT**
--- | --- | --- | ---
Anteromedial (inferomedial) | Just above joint line, 1 cm inferior to patella; 1 cm medial to patellar tendon | Anterior horn of medial meniscus | Most common portal to use instruments; also helpful for viewing lateral compartment
Anterolateral (inferolateral) | Just above joint line, 1 cm inferior to patella; 1 cm lateral to patellar tendon | Anterior horn of lateral meniscus | Most common portal for the arthroscope
Superolateral/ superomedial | 2.5 cm above joint line, lateral or medial to quadriceps tendon | | Used to view patellofemoral articulation, patella tracking, also inflow/outflow
Posteromedial | Flex knee to 90°, 1 cm above joint line, posterior to MCL | Saphenous nerve | Used to view PCL, posterior horns of menisci, retrieve loose bodies
Posterolateral | Flex knee, 1 cm above joint line, posterior to LCL | Peroneal nerve | Used to view PCL, posterior horns of menisci, retrieve loose bodies
Transpatellar | 1 cm below inferior pole of patella in midline | Patellar tendon | Central joints and notch viewing

**Posterolateral approach to tibia**

**Portals for arthroscopy of knee**
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<td>Nerves</td>
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<td>Arteries</td>
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<td>Surgical Approaches</td>
<td>383</td>
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</table>
Anterior compartment muscles

Peroneal nerve injury results in weakness and foot drop.

Gastrocnemius muscle

Muscle tears/strains commonly occur at musculotendinous junction.

Achilles tendon

Loss of contour and/or defect occurs when tendon is ruptured.

Valgus heel

Best seen posteriorly; heel should be in a valgus position.

Medial and lateral malleoli

Swelling indicates ankle injury: fracture or sprain.

Longitudinal arch of foot

Loss of arch indicates pes planus: congenital or acquired.

Plantar foot

Site of many ulcers; site of pain in plantar fasciitis.

1st metatarsal head

Head is prominent and painful in hallux valgus/bunion.

1st metatarsophalangeal joint

Common site for gout. Joint will be red and swollen.

Proximal interphalangeal joints

Hammertoes cause these joints to be prominent dorsally.
**DISTAL FIBULA**

<table>
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<tr>
<th>CHARACTERISTICS</th>
<th>OSSIFY</th>
<th>FUSE</th>
<th>COMMENTS</th>
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<tr>
<td>Lateral malleolus</td>
<td>Distal physis</td>
<td>4yr</td>
<td>18-20yr</td>
</tr>
</tbody>
</table>

**DISTAL TIBIA**

<table>
<thead>
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<th>CHARACTERISTICS</th>
<th>OSSIFY</th>
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<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plafond: weight-bearing portion of distal tibia</td>
<td>Distal physis</td>
<td>1yr</td>
<td>18-20yr</td>
</tr>
<tr>
<td>Lateral distal tibia</td>
<td>Anterior tubercle&lt;br&gt;Posterior tubercle</td>
<td>6mo&lt;br&gt;9yr</td>
<td>13-15yr</td>
</tr>
<tr>
<td>Medial malleolus</td>
<td>Anterior colliculus&lt;br&gt;Posterior colliculus</td>
<td>6mo&lt;br&gt;9yr</td>
<td>13-15yr</td>
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</tbody>
</table>

**CALCANEUS**

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>OSSIFY</th>
<th>FUSE</th>
<th>COMMENTS</th>
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</thead>
<tbody>
<tr>
<td>Body</td>
<td>Primary&lt;br&gt;Body&lt;br&gt;Medial process&lt;br&gt;Lateral process&lt;br&gt;Peroneal tubercle</td>
<td>Secondary&lt;br&gt;Tuberosity</td>
<td>6mo&lt;br&gt;fetal</td>
</tr>
<tr>
<td>Sustentaculum tali</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple facets</td>
<td>Posterior: largest&lt;br&gt;Medial: on sust. tali&lt;br&gt;Anterior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Borders of ankle mortise: superior: tibia (plafond), medial: medial malleolus (tibia), lateral: lateral malleolus (fibula)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**TALUS**

- **Head**
  - Primary ossification
  - Talar head is supported by the spring ligament
  - Convex head forms tight articulation with navicular
  - Neck is site of entry for most of the blood supply
  - Body is mostly covered with articular cartilage
  - AVN is a concern owing to retrograde blood supply
  - Body weight is transmitted from tibia to dome
  - FHL tendon runs between medial and lateral tubercles
  - Os trigonum may be an unfused lateral tubercle
  - Lateral process often fractured by snowboarders

- **Neck**
  - Body/trochlea (dome) 7mo (fetal) 13-15yr
  - Neck is site of entry for most of the blood supply
  - Body is mostly covered with articular cartilage
  - AVN is a concern owing to retrograde blood supply
  - Body weight is transmitted from tibia to dome
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  - FHL tendon runs between medial and lateral tubercles
  - Os trigonum may be an unfused lateral tubercle
  - Lateral process often fractured by snowboarders

**NAVICULAR**

- Curved/"boat" shape
- Multiple facets
  - Proximal: concave for talus
  - Distal: facet for each cuneiform & cuboid
  - Tuberosity: medial/plantar
- Primary ossification 4yr 13-15yr
- Forms "acetabulum pedis" for talar head (along with strong plantar ligaments)
- Is the "keystone" of the transverse arch of foot
- Posterior tibialis tendon inserts on tuberosity
- Susceptible to stress fracture
- Kohler's disease: osteonecrosis of navicular

**CUBOID**

- Tuberosity; inferiorly
- 4 facets: calcaneus, lat. cuneiform, 4th & 5th MTs
- Cuboid groove; inferiorly
- Primary ossification Birth 13-15yr
- Most lateral tarsal bone
- Peroneus longus tendon passes through groove on inferior surface

**CUNEIFORMS**

- Three bones
  - Medial: largest
  - Intermediate: shortest
  - Lateral
  - Trapezoidal
  - Primary ossification 3yr 4yr 13-15yr
  - Medial: largest
  - Intermediate: shortest
  - Lateral
  - Trapezoidal shape strengthens transverse arch

- 2nd MT "keys" into recess of short intermediate bone; can lead to fracture of MT base
- TA, PL, PT tendons partially insert on medial cuneiform

---

**CHARACTERISTICS**

<table>
<thead>
<tr>
<th>OSSIFY</th>
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<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TALUS</td>
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<td></td>
</tr>
<tr>
<td>Head</td>
<td>Primary</td>
<td></td>
</tr>
<tr>
<td>Neck</td>
<td>Body 7mo (fetal) 13-15yr</td>
<td></td>
</tr>
<tr>
<td>Body/trochlea (dome)</td>
<td>Body/trochlea (dome)</td>
<td></td>
</tr>
<tr>
<td>Posterior process</td>
<td>Posterior process</td>
<td></td>
</tr>
<tr>
<td>Medial tubercle</td>
<td>Medial tubercle</td>
<td></td>
</tr>
<tr>
<td>Lateral tubercle</td>
<td>Lateral tubercle</td>
<td></td>
</tr>
<tr>
<td>Lateral process</td>
<td>Lateral process</td>
<td></td>
</tr>
</tbody>
</table>

**NAVICULAR**

- Curved/"boat" shape
- Primary ossification 4yr 13-15yr
- Forms "acetabulum pedis" for talar head (along with strong plantar ligaments)
- Is the "keystone" of the transverse arch of foot
- Posterior tibialis tendon inserts on tuberosity
- Susceptible to stress fracture
- Kohler's disease: osteonecrosis of navicular

**CUBOID**

- Primary ossification Birth 13-15yr
- Most lateral tarsal bone
- Peroneus longus tendon passes through groove on inferior surface

**CUNEIFORMS**

- Three bones
  - Primary ossification 3yr 4yr 13-15yr
  - Medial: largest
  - Intermediate: shortest
  - Lateral
  - Trapezoidal shape strengthens transverse arch

---

340 NETTER'S CONCISE ORTHOPAEDIC ANATOMY
**CHARACTERISTICS**

- Long bone characteristics
- Base of 2nd MT keys into tarsal recess
- 1st MT head has crista that separates two sesamoids

<table>
<thead>
<tr>
<th>METATARSALS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
</tr>
<tr>
<td><strong>Shaft</strong> (fetal)</td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
</tr>
</tbody>
</table>

- **COMMENTS**
  - Numbered medial to lateral, I to V
  - Only one physis per bone (in neck) except in 1st metatarsal (in base)
  - Peroneus brevis inserts on base of 5th MT (avulsion fracture can occur)

**PHALANGES**

- Toes 2-5 have three phalanges
- Great toe has only two phalanges

<table>
<thead>
<tr>
<th>PHALANGES</th>
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</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
</tr>
<tr>
<td><strong>Shaft</strong> (fetal)</td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
</tr>
</tbody>
</table>

- 14 total phalanges in each foot
- Only one physis per bone (in the base)
- Sesamoid bones with other toes can occur as a normal variant (usually b/w MT head)

**OSSICLES**

- Separated by cristae plantarly (1st MT head)
- Part of flexor mechanism (in FDB tendons)
- Can be fractured or dislocated
- Can cause medial foot prominence/pain
- Can cause heel pain (e.g., ballet dancers)
### RADIOGRAPH TECHNIQUE FINDINGS CLINICAL APPLICATION

#### ANKLE

<table>
<thead>
<tr>
<th>Technique</th>
<th>Findings</th>
<th>Clinical Application</th>
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</thead>
<tbody>
<tr>
<td>Anteroposterior (AP)</td>
<td>Ankle (distal tibia, fibula, and talus)</td>
<td>Fractures, malalignment, arthritis</td>
</tr>
<tr>
<td>Lateral</td>
<td>Tibia (anterior lip &amp; posterior malleolus), talus, calcaneus, subtalar joint</td>
<td>Fractures: tibia, talus, calcaneus; Bohler’s angle (nl: 25-40°)</td>
</tr>
<tr>
<td>Mortise view</td>
<td>Best view of ankle mortise, plafond</td>
<td>Fractures; widening = ligament injury</td>
</tr>
<tr>
<td>Stress view</td>
<td>ER: synodesmosis widening (nl &lt;6mm)</td>
<td>ER: synodesmosis injury, deltoid ligament injury</td>
</tr>
<tr>
<td></td>
<td>Medial clear space widening (nl&lt;4mm)</td>
<td>Inv: lateral ligament (CFL) injury</td>
</tr>
<tr>
<td></td>
<td>Inversion/tilt: joint space widening</td>
<td>Ant: lateral ligament (ATFL) injury</td>
</tr>
<tr>
<td></td>
<td>Anterior/drawer: ant. talus subluxation</td>
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</table>

### OTHER STUDIES

<table>
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<tr>
<th>Modality</th>
<th>Techniques</th>
<th>Findings</th>
<th>Clinical Application</th>
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<tbody>
<tr>
<td>CT</td>
<td>Axial, coronal, sagittal</td>
<td>Articular congruity, fracture fragments</td>
<td>Intraarticular or comminuted fxs</td>
</tr>
<tr>
<td>MRI</td>
<td>Sequence protocols vary</td>
<td>Ligaments, tendons, and cartilage</td>
<td>OCD lesions, ligament or tendon tears</td>
</tr>
<tr>
<td>Bone scan</td>
<td>All bones evaluated</td>
<td></td>
<td>Stress fractures, infection</td>
</tr>
</tbody>
</table>
RADIOGRAPH TECHNIQUE FINDINGS CLINICAL APPLICATION

FOOT

<table>
<thead>
<tr>
<th>RADIOGRAPH</th>
<th>TECHNIQUE</th>
<th>FINDINGS</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anteroposterior (AP)</td>
<td>Beam perpendicular to midfoot; WB used to evaluate deformity</td>
<td>Tarsals, metatarsals, and phalanges; 2nd MT should align w/medial cuneiform</td>
<td>Fractures/dislocations mid &amp; forefoot; used to measure hallux valgus angles</td>
</tr>
<tr>
<td>Lateral</td>
<td>Beam aimed laterally at tarsals</td>
<td>Hind, mid, and forefoot</td>
<td>Fractures and dislocations</td>
</tr>
<tr>
<td>Oblique</td>
<td>AP with 45° of internal rotation</td>
<td>Mid &amp; forefoot, TMT jt.</td>
<td>4th MT aligns with cuboid</td>
</tr>
<tr>
<td>Harris</td>
<td>DF foot, beam 45° to heel</td>
<td>Calcaneal tuberosity, post. facet</td>
<td>Calcaneus fractures</td>
</tr>
<tr>
<td>Canale</td>
<td>15° foot eversion, tilt beam 15°</td>
<td>Talar neck</td>
<td>Talar neck fractures</td>
</tr>
<tr>
<td>Broden</td>
<td>IR leg 40°, tilt beam 10, 20, 30, 40°</td>
<td>Posterior subtalar facet</td>
<td>Fx of posterior facet or sustentaculum</td>
</tr>
<tr>
<td>Stress views</td>
<td>AP with abd/add or inv/eversion</td>
<td>Bony and joint alignment</td>
<td>Lisfranc fracture/dislocations</td>
</tr>
<tr>
<td>Axial/sesamoid view</td>
<td>DF hallux, beam along foot axis</td>
<td>Shows sesamoid bones/articulation</td>
<td>Sesamoid fracture or dislocation</td>
</tr>
</tbody>
</table>
### Description

- Very common in all ages
- One or both malleoli involved
- 1 malleolus fx: usually stable
- Bimalleolar fx OR lateral malleolus fx with medial ligament rupture: unstable
- Congruent mortise required
- Fibular length & rotation must be correct

### Evaluation

**Hx:** Trauma, pain, swelling, +/- inability to bear weight

**PE:** Effusion, soft tissue swelling. One or both malleoli TTP +/- proximal fibula tenderness

**XR:** Ankle trauma series

**Stress XR:** If stability of fx is in question (esp. Weber B/SER II)

### Classification

#### Weber/AO:

- Location of fibula fx
  - A: distal to plafond
  - B: at the plafond
  - C: above the plafond

#### Lauge-Hansen:

- Based on foot position & mechanism
  - Supination/adduction I-II
  - Pronation/abduction I-III

### Treatment

- Dislocation: reduce joint immediately
- Stable/nondisplaced/avulsion: short leg cast for 4-6wk
- Unstable/displaced: ORIF. Restore congruent mortise & fibular length. Add syndesmosis fixation for unstable syndesmosis.

### Complications

- Posttraumatic osteoarthritis/pain, limited range of motion, nonunion/malunion, instability, RSD

See Chapter 9, Knee/Leg for pilon fracture and Maisonneuve fracture

---

**TABLE**

<table>
<thead>
<tr>
<th><strong>Description</strong></th>
<th><strong>Evaluation</strong></th>
<th><strong>Classification</strong></th>
<th><strong>Treatment</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Very common in all ages</td>
<td>Hx: Trauma, pain, swelling, +/- inability to bear weight</td>
<td>Weber/AO: location of fibula fx</td>
<td>Dislocation: reduce joint immediately</td>
</tr>
<tr>
<td>One or both malleoli involved</td>
<td>PE: Effusion, soft tissue swelling. One or both malleoli TTP +/- proximal fibula tenderness</td>
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<td>Stress XR: If stability of fx is in question (esp. Weber B/SER II)</td>
<td>Pronation/abduction I-III</td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibular length &amp; rotation must be correct</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Calcaneus Fracture**

- Most common tarsal fracture
- Mechanism: high energy/axial load (e.g., MVA, high fall)
- Most fractures intraarticular
- Intraarticular fractures affect subtalar joint (esp. posterior facet)
- Skin at risk from extensive edema
- Rule out spine injury in a fall
- Associated with poor outcomes and long-term disability

**Evaluation**

- **Hx:** Trauma, pain, swelling, inability to bear weight
- **PE:** Marked edema & arch swelling, +/- fx blisters. Widened heel. Check nerve function and pulses.
- **XR:** AP, lateral (Böhler's angle 25-40°), Harris view
- **CT:** To better define fx lines, displacement, comminution

**Classification**

- **Extraarticular**
  - Body, tuberosity, anterior or medial process, sustentaculum tali
- **Intraarticular**
  - **Essex-Lopresti**
    - Joint depression
  - **Sanders**:
    - I-IV: how many fragments/fracture lines?
    - A-C: lateral to medial

**Treatment**

- **Extraarticular**
  - Nondisplaced: cast 10-12wk
  - Displaced: perc. pinning
- **Intraarticular**
  - Nondisplaced: cast 12 wk
  - Displaced: ORIF
  - Comminuted, low demand/elderly smokers: closed reduction, cast
  - Comminuted, laborer: primary subtalar fusion

**Complications:** Skin/wound slough (delay surgery until edema has resolved), malunion (varus), subtalar OA, pain
### Fracture of Talar Neck

**Usual cause is impact on anterior margin of tibia due to forceful dorsiflexion.**

#### Type I. No displacement

- Mechanism: high energy (e.g., MVA, fall from height)
- Neck fractures #1
- Talus has tenuous blood supply
- Neck fx can result in AVN
- Displaced neck fractures are a surgical emergency
- AVN decreased with ORIF
- Hawkins sign = no AVN
- Lateral process fx: snowboarders

#### Type II. Fracture of talar neck with subluxation or dislocation of subtalar joints

- Hx: Trauma, pain, swelling, inability to bear weight
- PE: Edema, tenderness, +/− deformity. Check pulses.
- XR: AP, lateral, Canale (neck) & Broden (post. facet) views
- Hawkins sign: resorption of subchondral bone (lucency on XR) indicates fracture healing
- CT: To better define fx lines

#### Type III. Fracture of talar neck with dislocation of subtalar and tibiotalar joints

- Head
- Process: lateral, posterior
- Neck: Hawkins (predicts risk of AVN)
- I: Nondisplaced (<10%)
- II: Subtalar dx (40%)
- III: II + tibiotalar dx (90%)
- IV: III + talonavicular dx (100%)

### Body (dome)
- Osteochondral fx/
- Injury

### Body/head/process fractures
- Nondisplaced: cast
- Displaced: ORIF

### Osteochondral fx/injury
- Large bony piece: repair
- Small/mostly cartilaginous: arthroscopic debride/drilling

### Neck fractures
- Type I: percutaneous pin
- Types II-IV: ORIF

### COMPLICATIONS: Ankle or subtalar osteoarthritis/pain, malunion (varus #1), osteonecrosis, arthrosis/stiffness
**Description**

- **Mechanism:** Torque of fixed foot or axial load to vertical foot
- **Recessed 2nd MT base** gives stability to joint
- **Can have fx or purely ligamentous injury**
- **“Fleck” sign** is avulsion of Lisfranc ligament from 2nd MT base
- **Easily missed injury**
- **Assoc. w/other injuries including tarsal fractures**

---

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EVALUATION</th>
<th>CLASSIFICATION</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homolateral dislocation. All five metatarsals displaced in same direction. Fracture of base of 2nd metatarsal</td>
<td>Hx: Trauma to planted foot, pain, swelling</td>
<td>By direction</td>
<td>Nondisplaced (no widening)</td>
</tr>
<tr>
<td>Isolated dislocation. One or two metatarsals displaced; others in normal position</td>
<td>PE: Edema &amp; ecchymosis. Careful vascular exam.</td>
<td>Isolated: a single metatarsal is affected (usu. 1st or 2nd)</td>
<td>NWB cast: 8wk</td>
</tr>
<tr>
<td>Divergent dislocation. 1st metatarsal displaced medially, others superolaterally</td>
<td>XR: AP, lateral, oblique; &gt;2mm b/w 2nd MT base and cuneiform is pathologic. WB/stress views if needed; consider comparison view</td>
<td>Homolateral: all metatarsals dislocate in same direction</td>
<td>&gt;2mm needs surgical fixation</td>
</tr>
<tr>
<td>Dorsolateral dislocation often best seen in lateral view</td>
<td>CT: Usually not needed</td>
<td>Divergent: metatarsals dislocate in different directions</td>
<td>Minimally displaced</td>
</tr>
<tr>
<td>Injury may occur from seemingly trivial event, eg, misstep into a hole with axial compression and abduction force on plantarflexion foot.</td>
<td></td>
<td>Many different combinations are possible.</td>
<td>Closed reduction and percutaneous pinning</td>
</tr>
</tbody>
</table>

**Tarsometatarsal (Lisfranc) Fracture/Dislocation**

| COMPLICATIONS: Posttraumatic arthritis/pain, altered gait/limp, compartment syndrome (1st intermetatarsal br. of DPA) |

**Nondisplaced (no widening)**

- NWB cast: 8wk
- >2mm needs surgical fixation

**Minimally displaced**

- Closed reduction and percutaneous pinning

**Displaced**

- ORIF (screws and K-wires)
- External fixation if needed preliminarily
## Metatarsal Fractures

**Types of fractures of metatarsal:**


**Common injuries:**
- Most benign
- Prox. 5th MT is watershed area. Nutrient artery injury can result in nonunion
- Prox. 5th MT avulsion fx by lateral plantar aponeurosis or peroneus brevis tendon
- Stress fractures in runners

**Hx:** Trauma, pain, swelling

**PE:** Edema & ecchymosis, TTP

**XR:** AP, lateral, oblique

**BS:** To evaluate for stress fx

**Location:**
- Head, neck, shaft, base
- 5th MT base fracture:
  - Zone 1: avulsion fx
  - Zone 2: metadiaphyseal jxn
  - Zone 3: proximal diaphysis

**Treatment:**
- Nondisplaced: hard shoe/cast
- Displaced/angulated: PCP or ORIF
- 5th MT base:
  - Zone 1: hard shoe
  - Zone 2: SLNWC 6-8wk
  - Zone 3: SLNWC 8wk/ORIF; zones 2&3: ORIF in elite athletes

**Complications:**
- Nonunion (esp. proximal 5th metatarsal), malunion, posttraumatic osteoarthritis/pain

## Phalangeal Fractures

**Common injuries:**
- Most benign
- Usually from "stubbing" toe or dropping object on toe
- Rarely need surgical treatment

**Hx:** Trauma, pain, swelling

**PE:** Edema & ecchymosis, TTP

**XR:** AP, lateral, oblique

**Location:**
- Head
- Shaft
- Base

**Treatment:**
- Non/minimally displaced: buddy tape & hard shoe
- Displaced/unstable: PCP
- Intraarticular hallux fx: ORIF
**LIGAMENTS**

<table>
<thead>
<tr>
<th><strong>ATTACHMENTS</strong></th>
<th><strong>COMMENTS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DISTAL TIBIOFIBULAR</strong></td>
<td></td>
</tr>
<tr>
<td>Syndesmosis</td>
<td>Primary support of ankle</td>
</tr>
<tr>
<td>Anterior inferior tibiofibular (AITFL)</td>
<td>Anterior tibia (ant. tubercle) to distal fibula</td>
</tr>
<tr>
<td>Posterior inferior tibiofibular (PIFTL)</td>
<td>Posterior tibia to distal fibula</td>
</tr>
<tr>
<td>Inferior transverse ligament (ITL)</td>
<td>Inferior &amp; deep to PITFL</td>
</tr>
<tr>
<td>Interosseous ligament (IOL)</td>
<td>Lateral tibia to medial fibula</td>
</tr>
</tbody>
</table>

If the syndesmosis is torn, the ankle mortise is disrupted. The fibula (& firmly attached talus) will displace laterally.

**ANKLE**

The ankle is ginglymus, or hinge joint. It primarily provides plantarflexion & dorsiflexion motion. ROM: DF 20°, PF 50°

Capsule | Tibia and fibula to talus | Gives varying amount of support to the ankle

**Lateral**

- Anterior talofibular (ATFL) | Lateral malleolus to: Neck of talus |
- Calcaneofibular (CFL) | Calcaneus (peroneal tub.) |
- Posterior talofibular (PTFL) | Talus (posterior process) |


**Medial: deltid ligament (4 parts)**

**Superficial deltid**

- Anterior tibiotalar
- Tibionavicular
- Tibiocalcaneal

- Posterior tibiotalar

Anterior colliculus of MM to: Anteromedial talus Navicular tuberosity Sustentaculum talus

Origin on medial malleolus (MM) Resists eversion of the ankle Weak ligament. Can cause impingement Restraint to medial migration of talar head Strongest portion of the superficial deltoid, resists valgus

Resists external rotation and lateral migration

Nearly horizontal; strongest portion of deltoid
Posterior talofibular ligament
Calcaneofibular ligament
Anterior talofibular ligament
Interosseous talocalcaneal ligament
Cervical ligament
Dorsal talonavicular ligament
Calcaneonavicular ligament
Calcaneocuboid ligament
Bifurcate ligament
Dorsal tarsometatarsal ligament
Dorsal calcaneocuboid ligament

Components of lateral (collateral) ligament of ankle

Right foot: lateral view

**Ankle MRI, axial**

**Ankle MRI, coronal**
### Intertarsal

#### Articulation of 3 facets. Allows inversion/version (e.g., walking on uneven surfaces) as well as rotation.

<table>
<thead>
<tr>
<th>LIGAMENT</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extrinsic</strong></td>
<td></td>
</tr>
<tr>
<td>Calcaneofibular</td>
<td>Primary support for subtalar joint. Also a main support for ankle joint.</td>
</tr>
<tr>
<td>Interosseous talocalcaneal</td>
<td>Strong stabilizer in sinus tarsi. Injury can be cause of chronic instability.</td>
</tr>
<tr>
<td>Cervical</td>
<td>Less stout secondary stabilizer. Also in sinus tarsi.</td>
</tr>
<tr>
<td><strong>Intrinsic</strong></td>
<td></td>
</tr>
<tr>
<td>Medial talocalcaneal</td>
<td>Medial tubercle to sustentaculum tal. Provides minimal support.</td>
</tr>
<tr>
<td>Lateral talocalcaneal</td>
<td>Deep to calcaneofibular. Provides minimal support.</td>
</tr>
<tr>
<td><strong>Capsular thickenings</strong></td>
<td></td>
</tr>
<tr>
<td>Inferior peroneal retinaculum</td>
<td>Multiple insertions within sinus tarsi.</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
</tr>
</tbody>
</table>

Dislocations: Closed reductions can be blocked by: EDB (medial dislocation) or PT tendon (lateral dislocation)

#### Transverse Tarsal/Midtarsal (Chopart’s)

Two articulations: 1. talonavicular, 2. calcaneocuboid. Motion: abduction/adduction. Function depends on foot/subtalar position:

- **Eversion**—joints are parallel, permits motion (supple), occurs in early stance/"heel strike".
- **Inversion**—joints not parallel, no motion (stiff joint makes foot a rigid lever), occurs in late stance/"toe off."

#### Talonavicular

Highly congruent “ball & socket” type joint. Convex talar head in concave navicular (“acetabulum pedis”)

- **Plantar calcaneonavicular (Spring)**: Strong plantar support for talar head, from sustentaculum to navicular.
- **Dorsal talonavicular Calcaneonavicular**: Dorsal support, Half of bifurcate ligament

#### Calcaneocuboid

- **Calcaneocuboid**: Half of bifurcate ligament
- **Dorsal calcaneocuboid**: Dorsal support, minimal strength
- **Plantar calcaneocuboid (short plantar)**: Strong plantar support, from sustentaculum tal to plantar cuboid
- **Calcaneocuboid metatarsal (long plantar)**: Crosses multiple joints with multiple insertions

The tendon of the peroneus longus also crosses this joint and adds support.

### OTHER INTERTARSAL JOINTS

Each of these joints has dorsal, plantar, and interosseous ligaments that bear the name of the corresponding joint.

- **Cuboideonavicular**
- **Cuneonavicular**
- **Intercuneiform**
- **Cuneocuboid**

These joints are small, have very little motion or clinical significance.

The plantar ligaments are the strongest.
**Ligaments**

**Ligaments Comments**

<table>
<thead>
<tr>
<th>Other Joints</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tarsometatarsal (Lisfranc)</strong></td>
<td>Gliding joints. Make up the transverse arch of foot. 2nd MT base is the “keystone”</td>
</tr>
<tr>
<td>Intermetatarsal Lisfranc: medial cuneiform to 2nd MT base Dorsal, plantar, interosseous tarsometatarsal</td>
<td>• B/w 2nd &amp; 5th metatarsal bases. No ligament b/w 1st &amp; 2nd MT • Primary stabilizer of articulation. Avulsion of ligament = “fleck” sign • Plantar ligaments are the strongest.</td>
</tr>
<tr>
<td><strong>Metatarsophalangeal</strong></td>
<td></td>
</tr>
<tr>
<td>Collateral Plantar plate</td>
<td>• Strong medial and lateral support; limits varus and valgus • Primary support. Loose origin on MT neck to strong insertion on P1 • Injured (avulsion from MT) in hyperextension injury/turf toe • Sesamoids adherent to plantar plate (within FHB tendon)</td>
</tr>
<tr>
<td>Deep transverse metatarsal</td>
<td>• B/w metatarsal heads. Can compress nerve = Morton’s neuroma • The 1st/2nd ligament also attaches to and stabilizes lateral sesamoid • Runs between the two sesamoid bones, stabilizing them • Tendinous insertions on P1 add medial and lateral joint stability</td>
</tr>
<tr>
<td>Intersesamoidal Abd. &amp; add. hallucis tendons</td>
<td></td>
</tr>
<tr>
<td><strong>Interphalangeal</strong></td>
<td></td>
</tr>
<tr>
<td>Capsule Collateral and plantar plate</td>
<td>• Gives primary support • Additional support medial, lateral, and plantar</td>
</tr>
</tbody>
</table>
## STRUCTURE FUNCTION COMMENT

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>FUNCTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior extensor retinaculum</td>
<td>Covers tendons, nerves, vessels of anterior compartment at ankle</td>
<td>Distal fibula to medial tibia</td>
</tr>
<tr>
<td>Inferior extensor retinaculum</td>
<td>Surounds &amp; covers tendons, etc. of anterior compartment in foot</td>
<td>“Y” shaped; calcaneus to medial malleolus and navicular</td>
</tr>
<tr>
<td>Flexor retinaculum</td>
<td>Covers tendons of posterior compartment</td>
<td>Medial malleolus to calcaneus; roof of tarsal tunnel</td>
</tr>
</tbody>
</table>
| Superior & inferior peroneal retinaculum       | Covers tendons & sheaths of lateral compartment at hind foot             | Superior: lateral malleolus to calcaneus
|                                                |                                                                          | Inferior: inf. extensor retinaculum to calcaneus |
| Plantar aponeurosis (plantar fascia)           | Supports longitudinal arch                                               | Inflamed: plantar fasciitis; can develop nodules |
### STEPS

**ANKLE ARTHROCENTESIS**

1. Ask patient about allergies.
2. Plantarflex foot, palpate medial malleolus and sulcus between it and the tibialis anterior tendon.
3. Prep skin over ankle joint (iodine/antiseptic soap).
4. Anesthetize skin locally (quarter size spot).
5. Insert 20-gauge needle perpendicularly into the sulcus/ankle joint (medial to the tendon, inferior to distal tibia articular surface, lateral to medial malleolus). Gentle ankle distraction may assist in entering the joint. Aspirate fluid. If suspicious for infection, send fluid for gram stain and culture. Alternatively, may inject into the joint. The fluid should flow easily if needle is in joint.
6. Dress aspiration/injection site.

**ANKLE BLOCK**

Five separate nerves are blocked. Based on the necessary anesthesia, a complete or partial block can be performed.

1. Ask patient about allergies.
2. Prep skin (iodine/antiseptic soap) circumferentially around the ankle immediately above and below the malleoli.
3. Prepare syringe with 22- to 25-gauge needle with local anesthetic.
4. **Superficial peroneal nerve**: raise a wheal at least 3-4cm across anterolateral ankle from LM to midline.
5. **Deep peroneal nerve**: palpate TA and EHL tendons. Insert needle between tendons to bone, then withdraw slightly. *Aspirate* to ensure the needle is not in the *anterior tibial artery*. Inject 2-3ml of local anesthetic.
6. **Saphenous nerve**: raise a wheal at least 2-3cm across the anteromedial ankle anterior to medial mall.
7. **Tibial nerve**: palpate posterior tibial artery pulse, FHL (if possible), and Achilles tendon behind the MM. Insert needle posterior to artery, anterior to FHL/Achilles tendon down to bone, then withdraw slightly. *Aspirate* to ensure the needle is not in the *posterior tibial artery*. Pull back from bone slightly and inject 2-3ml.
8. **Sural nerve**: raise a subcutaneous wheal at least 2-3cm across the posterolateral ankle b/w LM and Achilles tendon.
9. Dress each injection site.

**DIGITAL BLOCK**

1. Ask patient about allergies.
2. Prep skin (iodine/soap) over the proximal dorsal toe and adjacent web space(s).
3. Prepare syringe with local *without epinephrine* and 25-gauge needle.
4. Insert needle along medial and lateral borders of the proximal phalanx to plantar surface. *Aspirate* to confirm needle is not in a vessel. Slowly inject as you withdraw the needle dorsally. 2-3ml of local should be adequate on either side. Raising a wheal dorsally across the proximal toe may improve the block.
5. Take care not to inject *too much fluid* into this closed space.
6. Dress the injection sites.
<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>Young</td>
<td>Sprain, fractures</td>
</tr>
<tr>
<td></td>
<td>Middle aged–elderly</td>
<td>Overuse injuries, arthritis, gout, hallux valgus, hammertoes</td>
</tr>
<tr>
<td>2. Pain</td>
<td>Acute (less common)</td>
<td>Fracture, sprain, dislocation</td>
</tr>
<tr>
<td></td>
<td>Chronic</td>
<td>Most foot/ankle disorders are chronic, runners</td>
</tr>
<tr>
<td></td>
<td>After ankle sprain</td>
<td>Talar OCD, subluxating peroneal tendons or tendon tear, lateral process (talus) fracture, SPN injury</td>
</tr>
<tr>
<td>a. Onset</td>
<td>Ankle</td>
<td>Fracture, osteoarthritis, instability, posterior tibial tendinitis</td>
</tr>
<tr>
<td></td>
<td>Hind foot</td>
<td>Fracture, retrocalcaneal bursitis, Achilles tendinitis, arthritis</td>
</tr>
<tr>
<td></td>
<td>Plantar foot</td>
<td>Plantar fasciitis, nerve compression, ulcer, metatarsalgia</td>
</tr>
<tr>
<td></td>
<td>Midfoot</td>
<td>Osteoarthritis of the tarsus, fracture (Lisfranc), PTTD</td>
</tr>
<tr>
<td></td>
<td>Forefoot</td>
<td>Fractures, metatarsalgia, Morton’s neuroma, hammertoes</td>
</tr>
<tr>
<td></td>
<td>1st MTPJ</td>
<td>Hallux vagus, hallux rigidus, sesamoiditis, fx, turf toe, gout</td>
</tr>
<tr>
<td>b. Location</td>
<td>Bilateral</td>
<td>Consider systemic illness, RA, CMT</td>
</tr>
<tr>
<td></td>
<td>Morning pain</td>
<td>Plantar fasciitis (improves with stretching)</td>
</tr>
<tr>
<td>c. Occurrence</td>
<td>With activity</td>
<td>Overuse type injuries: stress fx, tendinitis, bursitis</td>
</tr>
<tr>
<td>3. Stiffness</td>
<td>Without locking</td>
<td>Ankle sprain, RA, osteoarthritis</td>
</tr>
<tr>
<td></td>
<td>With locking</td>
<td>Loose body</td>
</tr>
<tr>
<td>4. Swelling</td>
<td>Yes</td>
<td>Fracture, sprain, arthritis, gout</td>
</tr>
<tr>
<td>5. Trauma</td>
<td>Can bear weight</td>
<td>Sprain, contusion, minor fracture</td>
</tr>
<tr>
<td></td>
<td>Cannot bear weight</td>
<td>Fracture: ankle, tarsal, metatarsal</td>
</tr>
<tr>
<td></td>
<td>Fall</td>
<td>Calcaneus fracture, pilon fracture</td>
</tr>
<tr>
<td>6. Activity/occupation</td>
<td>Sports, repetitive motion</td>
<td>Achilles tendinitis, overuse injuries (e.g., stress fx)</td>
</tr>
<tr>
<td></td>
<td>Standing all day</td>
<td>Overuse injuries: tendinitis, bursitis</td>
</tr>
<tr>
<td>7. Shoe type</td>
<td>Tight/narrow toe box</td>
<td>Hallux valgus (bunion most common in women)</td>
</tr>
<tr>
<td>8. Neurologic symptoms</td>
<td>Pain, numbness, tingling</td>
<td>Tarsal tunnel syndrome, diabetic neuropathy, other nerve compression</td>
</tr>
</tbody>
</table>
EXAM TECHNIQUE CLINICAL APPLICATION/DDX

INSPECTION

<table>
<thead>
<tr>
<th>EXAM</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION/DDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot (weight-bearing)</td>
<td>Anterior view</td>
<td>Hallux valgus (bunion), hammertoes, other deformities (clubfeet, MT adductus)</td>
</tr>
<tr>
<td></td>
<td>Posterior view</td>
<td>Slight valgus is normal; “pump-bump” seen with Achilles tendinitis</td>
</tr>
<tr>
<td></td>
<td>Medial view</td>
<td>Increased valgus: posterior tibialis dysfunction, tarsal coalition, planovalgus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Varus alignment: neurologic disease (e.g., Charcot-Marie-Tooth)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pes planus (flat foot): posterior tibialis dysfunction, tarsal coalition, pediatric pes planovalgus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pes cavus (high arch): neurologic disease (e.g., Charcot-Marie-Tooth)</td>
</tr>
<tr>
<td>Foot (non-WB)</td>
<td>Plantar view</td>
<td>Ulcers (esp. in diabetics), callus, transfer lesions (callus under 2nd MT head)</td>
</tr>
<tr>
<td>Swelling</td>
<td>Ankle</td>
<td>Sprain, fracture</td>
</tr>
<tr>
<td></td>
<td>Foot: Dorsal</td>
<td>Fracture, contusion</td>
</tr>
<tr>
<td></td>
<td>Medial</td>
<td>Posterior tibialis dysfunction</td>
</tr>
<tr>
<td></td>
<td>Diffuse</td>
<td>Consider cardiovascular etiology</td>
</tr>
<tr>
<td>Skin</td>
<td>Color</td>
<td>Pallor may indicate vascular disease; congestion may indicate venous insufficiency</td>
</tr>
<tr>
<td></td>
<td>Hair</td>
<td>Decreased hair may indicate peripheral vascular disease</td>
</tr>
<tr>
<td>Shoes</td>
<td>Narrow toe box</td>
<td>Associated with hallux valgus (esp. in women)</td>
</tr>
<tr>
<td></td>
<td>Abnormal wear</td>
<td>May indicate malalignment (e.g., pes planus or cavus) or dysfunction (e.g., foot drop)</td>
</tr>
</tbody>
</table>
## Palpation

<table>
<thead>
<tr>
<th>EXAM</th>
<th>TECHNIQUE</th>
<th>CLINICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bony structures</td>
<td>1st MP joint/MT &amp; head</td>
<td>Bunion, pain: hallux rigidus, sesamoids, turf toe, gout</td>
</tr>
<tr>
<td></td>
<td>Lesser MPT joint/MT</td>
<td>Pain: metatarsalgia, Freiberg’s infraction, fx, tailor’s bunion (5th MT head)</td>
</tr>
<tr>
<td>Tarsal bones/midfoot</td>
<td>Tenderness suggests fracture, osteoarthritis, dislocation</td>
<td></td>
</tr>
<tr>
<td>Calcaneus/heel</td>
<td>Pain: fracture; posterior: bursitis (pump bump); plantar: spur, plantar fascitis; medial: nerve entrapment</td>
<td></td>
</tr>
<tr>
<td>Malleoli</td>
<td>Pain indicates fracture, syndesmosis injury in leg</td>
<td></td>
</tr>
<tr>
<td>Soft tissue</td>
<td>Skin</td>
<td>Cool: peripheral vascular disease</td>
</tr>
<tr>
<td></td>
<td>Between metatarsal heads</td>
<td>Swelling: trauma/infection vs venous insufficiency</td>
</tr>
<tr>
<td></td>
<td>Medial ankle ligaments</td>
<td>Pain: neuroma</td>
</tr>
<tr>
<td></td>
<td>Tendons (at med. malleolus)</td>
<td>Pain suggests ankle sprain (deltoid ligament)</td>
</tr>
<tr>
<td></td>
<td>Lateral ankle ligaments</td>
<td>Pain indicates tendinitis, rupture</td>
</tr>
<tr>
<td></td>
<td>Peroneal tendons (LM)</td>
<td>Pain suggests ankle sprain (ATFL, CFL, PTFL [rare])</td>
</tr>
<tr>
<td></td>
<td>Achilles tendon</td>
<td>Pain indicates tendinitis, tear, dislocation/subluxation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pain: tendinitis; defect suggests Achilles rupture</td>
</tr>
</tbody>
</table>

## Range of Motion

<table>
<thead>
<tr>
<th>ANKLE: dorsiflex/plantarflex</th>
<th>Stabilize subtalar joint</th>
<th>Normal: flex 50°/extend 25°</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUBTALAR: inversion/eversion</td>
<td>Stabilize tibia</td>
<td>Normal: invert 5-10°/evert 5°</td>
</tr>
<tr>
<td>TRANSVERSE/MIDTARSAL: adduction/abduction</td>
<td>Stabilize heel/hind foot, give abd./add. stress</td>
<td>Normal: adduct 20°/abduct 10°</td>
</tr>
</tbody>
</table>

Great toe:

- MTP: flex/extend
- IP: flex/extend

Stabilize foot, flex/extend

Normal: flex 75°/extend 75°; decreased in hallux rigidus

Stabilize foot, flex/extend

Normal: flex 90°/extend 0°

Combine motions; Pronation: dorsiflexion, eversion, abduction; Supination: plantarflexion, inversion, adduction
### PHYSICAL EXAM • Foot/Ankle

#### EXAM TECHNIQUE CLINICAL APPLICATION

<table>
<thead>
<tr>
<th>NEUROVASCULAR</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensory</strong></td>
<td></td>
</tr>
<tr>
<td>Saphenous (L4)</td>
<td>Medial foot (med. cutaneous)</td>
</tr>
<tr>
<td>Tibial (L4-S1)</td>
<td>Plantar foot (med. &amp; lat./plantar)</td>
</tr>
<tr>
<td>Superficial peroneal</td>
<td>Dorsal foot</td>
</tr>
<tr>
<td>Deep peroneal (L5)</td>
<td>1st dorsal web space</td>
</tr>
<tr>
<td>Sural (S1)</td>
<td>Lateral foot</td>
</tr>
<tr>
<td>Deep peroneal (L4)</td>
<td>Foot inversion/dorsiflexion</td>
</tr>
<tr>
<td>Deep peroneal (L5)</td>
<td>Great toe dorsiflex</td>
</tr>
<tr>
<td>Tibial (S1)</td>
<td>Foot plantarflexion</td>
</tr>
<tr>
<td>Superficial peroneal</td>
<td>Foot eversion</td>
</tr>
<tr>
<td><strong>Motor</strong></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>Achilles reflex</td>
</tr>
<tr>
<td>Upper motor neuron</td>
<td>Babinski reflex</td>
</tr>
<tr>
<td>Pulsed</td>
<td>Dorsalis pedis (on dorsum)</td>
</tr>
<tr>
<td>Post. tibial (post. med. mall.)</td>
<td></td>
</tr>
<tr>
<td><strong>Reflex</strong></td>
<td></td>
</tr>
<tr>
<td>Thompson</td>
<td>Prone: squeeze calf</td>
</tr>
<tr>
<td>Anterior drawer</td>
<td>Stabilize tibia, PF foot, anterior force on heel</td>
</tr>
<tr>
<td>Talar tilt</td>
<td>Stabilize tibia, DF foot, invert foot</td>
</tr>
<tr>
<td>Ext. rotation stress</td>
<td>Stabilize tibia, ER foot</td>
</tr>
<tr>
<td>Eversion stress</td>
<td>Stabilize tibia, evert foot</td>
</tr>
<tr>
<td>Squeeze</td>
<td>Compress distal tibia/fibula</td>
</tr>
<tr>
<td>Heel rise</td>
<td>Standing, rise onto toes</td>
</tr>
<tr>
<td>Coleman block</td>
<td>Lateral foot and heel on block; 1st ray hangs free</td>
</tr>
<tr>
<td>Tinel's sign</td>
<td>Tap nerve posterior to MM</td>
</tr>
<tr>
<td>Compression</td>
<td>Squeeze foot at MT heads</td>
</tr>
</tbody>
</table>
GAIT CYCLE

General
Complex interaction of multiple muscles and joints within both lower extremities to produce propulsion of the body

Definitions
Gait: the manner in which a person walks
Step: from heel strike of one foot to heel strike of the opposite foot
Stride: from heel strike of one foot to the subsequent heel strike of the same foot

Phases

Stance (62%): Part of gait when foot is in contact with ground. Can be subdivided into 3 (or 5) subcategories
- Initial phase—double stance (12%): both feet in stance, opposite foot in toe off
- Intermediate phase—single stance (38%): opposite foot in swing phase
- Terminal phase—double stance (12%): both feet in stance, opposite foot in heel strike

Swing (38%): Part of gait with foot in air, advancing forward

Sequence
1. Heel strike: Ankle is plantar flexed against the eccentrically contracting TA. The subtalar joint begins everting, allowing IR of tibia.
2. Foot flat: The gastrocnemius fires eccentrically to limit DF of ankle. The foot pronates and subtalar joint everts, resulting in a parallel and supple transverse tarsal joint, which allows the foot to accept the weight and accommodates for uneven surfaces.
3. Midstance: Body weight is over stance leg. The ankle is neutral. The foot begins to transition to a rigid position to allow for push off.
4. Heel off: The posterior tibialis (PT) initiates subtalar inversion (making the transverse tarsal joint unparallel and rigid). The foot supinates, the tibia externally rotates, and the gastrocnemius concentrically contracts producing plantar flexion of the ankle/heel off.
5. Toe off: The passive dorsiflexion of the toes initiates the windlass mechanism, which tightens the plantar fascia, deepening the arch and further inverting the subtalar joint, locking the transverse tarsal joint making the foot a rigid lever upon which to push off.
6. Preswing: the knee flexes to begin to give clearance for the swinging foot.
7. Midswing: knee and hip flexion as well as concentric anterior compartment (TA) contraction provide foot clearance
8. Terminal swing: The transition to heel strike begins
**CALCANEUS**
- Dorsal: Extensor hallucis brevis
  - Insertions: Peroneus brevis, Peroneus tertius, Dorsal interosseous
- Plantar: Flexor digitorum brevis
  - Insertions: Abductor hallucis, Abductor digiti minimi
- Posterior: Gastrocnemius/soleus (Achilles tendon)

**METATARSAL**
- Dorsal: Extensor hallucis brevis
  - Origins: Peroneus brevis, Peroneus tertius, Dorsal interosseous
- Plantar: Flexor digitorum brevis
  - Origins: Abductor hallucis, Abductor digiti minimi
- Dorsal interossei

**PHALANGES—DORSAL**
- Dorsal: Extensor hallucis brevis
  - Origins: Peroneus brevis, Peroneus tertius, Dorsal interosseous
  - Insertions: Extensor hallucis brevis, Extensor hallucis longus, Extensor digitorum brevis, Extensor digitorum longus, Dorsal interosseous

**PHALANGES—PLANTAR**
- Plantar: Flexor digitorum brevis
  - Origins: Adductor hallucis, Flexor digitorum brevis, Flexor digitorum longus, Flexor digitorum brevis, Flexor digitorum longus
  - Insertions: Flexor digiti minimi brevis, Abductor digiti minimi, Lumbricals, Plantar interosseous

**FLEXOR DIGITI MINIMI TENDON**
- Origins: Flexor digitorum longus tendon
- Insertions: Adductor hallucis, Flexor digitorum brevis, Adductor digiti minimi
STRUCTURE/FUNCTION

<table>
<thead>
<tr>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PLANTAR FASCIA</strong></td>
</tr>
<tr>
<td><strong>Structure:</strong> 3 portions</td>
</tr>
<tr>
<td>1. Central band (considered the plantar aponeurosis)</td>
</tr>
<tr>
<td>2. Medial band</td>
</tr>
<tr>
<td>3. Lateral band</td>
</tr>
<tr>
<td>Disorders affecting the fascia include plantar fasciitis and fibromatosis</td>
</tr>
<tr>
<td>Thick single band runs from calcaneus and fans out and divides distally to insert on each toe</td>
</tr>
<tr>
<td>From medial calcaneal tuberosity to: Superficial—flexor tendon sheaths</td>
</tr>
<tr>
<td>Deep—deep transverse metatarsal ligaments</td>
</tr>
<tr>
<td>Supports the abductor hallucis muscle</td>
</tr>
<tr>
<td>Supports the abductor digitii minimi muscle</td>
</tr>
<tr>
<td>Inserts on the base of 5th metatarsal. Can be cause of avulsion fracture</td>
</tr>
</tbody>
</table>

**Function**

1. Stabilizes longitudinal arch
2. Protects underlying structures
3. Stabilizes foot in gait via the windlass mechanism

**LAYER STRUCTURES**

<table>
<thead>
<tr>
<th>LAYERS OF THE FOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantar fascia</td>
</tr>
<tr>
<td>1: 3 muscles</td>
</tr>
<tr>
<td>2: 2 muscles</td>
</tr>
<tr>
<td>3: 3 muscles</td>
</tr>
<tr>
<td>4: 2 muscles</td>
</tr>
<tr>
<td>MUSCLE</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Abductor hallucis</td>
</tr>
<tr>
<td>Flexor digitorum brevis (FDB)</td>
</tr>
<tr>
<td>Abductor digiti minimi (ADM)</td>
</tr>
<tr>
<td>MUSCLE</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Quadratus plantae</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Lumbricals</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

- Medial and lateral plantar nerves are terminal branches of the tibial nerve; they run in the 2nd layer.
- Tendons of FHL and FDL also pass through in the second layer.
- FHL tendon courses between tubercles of posterior process of talus, under sustentaculum tali, then deep to FDL at knot of Henry (crossing of FHL & FDL).
<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexor hallucis brevis (FHB)</td>
<td>Cuboid, lateral cuneiform</td>
<td>Through sesamoids to proximal phalanx of great toe</td>
<td>Medial plantar artery and nerve</td>
<td>Assists great toe flexion at MTPJ</td>
<td>Sesamoid bones are within the tendons</td>
</tr>
<tr>
<td>Adductor hallucis</td>
<td>Oblique: base 2-4 MT Transverse: lateral 4 MTP</td>
<td>Through lateral sesamoid to lateral proximal phalanx of great toe</td>
<td>Lateral plantar artery</td>
<td>Adducts great toe</td>
<td>2 heads have different orientations; contributes to hallux valgus deformity</td>
</tr>
<tr>
<td>Flexor digiti minimi brevis (FDMB)</td>
<td>Base of 5th metatarsal</td>
<td>Base of proximal phalanx of small toe</td>
<td>Lateral plantar artery</td>
<td>Flex small toe</td>
<td>Small, relatively insignificant muscle</td>
</tr>
</tbody>
</table>
### FOURTH LAYER

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantar interosseus (3)</td>
<td>Medial 3rd, 4th, 5th MTs</td>
<td>Medial proximal phalanges: toes 3-5</td>
<td>Lateral plantar</td>
<td>Adduct toes, flex MTPJ; extend LPJ</td>
<td>Attachment to MT is medial for all 3</td>
</tr>
<tr>
<td>Dorsal interosseus (4)</td>
<td>Adjacent MT shafts</td>
<td>Medial proximal phalanx (2nd toe)</td>
<td>Lateral plantar</td>
<td>Abduct toes</td>
<td>Larger than the plantar interosseus (bipennate)</td>
</tr>
</tbody>
</table>

*Peroneus longus* and *tibialis posterior* tendons pass through the fourth layer.

PAD = Plantar ADduct, DAB = Dorsal ADduct (the 2nd digit is reference point for abduction/adduction in the foot).
<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>INSERTION</th>
<th>NERVE</th>
<th>ACTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensor hallucis brevis (EHB)</td>
<td>Dorsolateral calcaneus</td>
<td>Base of proximal phalanx of great toe</td>
<td>Deep peroneal</td>
<td>Extends great toe at MCPJ</td>
<td>Assists EHL with its action</td>
</tr>
<tr>
<td>Extensor digitorum brevis (EDB)</td>
<td>Dorsolateral calcaneus</td>
<td>Base of proximal phalanx: toes 2-4</td>
<td>Deep peroneal</td>
<td>Extends lesser toes at MCPJ</td>
<td>No tendon to small toe</td>
</tr>
</tbody>
</table>
Superficial fibular (peroneal) nerve (cut)

Fibularis (peroneus) longus tendon

Fibularis (peroneus) brevis muscle and tendon

Extensor digitorum longus muscle and tendon

Fibula

Perforating branch of fibular (peroneal) artery

Anterior lateral malleolar artery

Anterior lateral malleolus

Fibularis (peroneus) longus tendon (cut)

Extensor digitorum brevis and extensor hallucis brevis muscles (cut)

Fibularis (peroneus) brevis tendon (cut)

Fibularis (peroneus) tertius tendon (cut)

Abductor digiti minimi muscle

Dorsal metatarsal arteries

Metatarsal bones

Dorsal interosseous muscles

Lateral dorsal cutaneous nerve (continuation of sural nerve) (cut)

Anterior perforating branches from plantar metatarsal arteries

Dorsal digital arteries

Dorsal branches of proper plantar digital arteries and nerves

Soleus muscle

Tibialis anterior muscle and tendon

Tibia

Anterior tibial artery and deep fibular (peroneal) nerve

Extensor hallucis longus muscle and tendon

Anterior medial malleolar artery

Medial malleolus

Dorsalis pedis artery

Medial branch of deep fibular (peroneal) nerve

Medial tarsal arteries

Tuberosity of navicular bone

Arcuate artery

Posterior perforating branches from deep plantar arch

Deep plantar artery to deep plantar arch

Abductor hallucis muscle

Extensor hallucis longus tendon

Extensor hallucis brevis tendon (cut)

Extensor digitorum brevis tendons (cut)

Extensor digitorum longus tendons (cut)

Extensor expansions

Dorsal digital branches of deep fibular (peroneal) nerve

Dorsal digital branches of superficial fibular (peroneal) nerve
### Compartment Contents

<table>
<thead>
<tr>
<th>Compartment</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial</td>
<td>Abductor hallucis, flexor hallucis brevis, FHL tendon</td>
</tr>
<tr>
<td>Lateral</td>
<td>Abductor digiti minimi, flexor digiti minimi</td>
</tr>
<tr>
<td>Superficial central</td>
<td>Flexor digitorum brevis, lumbricals (4), FDL tendons</td>
</tr>
<tr>
<td>Deep central (calcaneal)</td>
<td>Quadratus plantae, posterior tibial neurovascular bundle</td>
</tr>
<tr>
<td>Adductor</td>
<td>Adductor hallucis</td>
</tr>
<tr>
<td>Interosseous (1-2)</td>
<td>Dorsal interosseous muscle</td>
</tr>
<tr>
<td>Interosseous (2-3)</td>
<td>Dorsal and plantar interosseous muscles</td>
</tr>
<tr>
<td>Interosseous (3-4)</td>
<td>Dorsal and plantar interosseous muscles</td>
</tr>
<tr>
<td>Interosseous (4-5)</td>
<td>Dorsal and plantar interosseous muscles</td>
</tr>
<tr>
<td>Deep central (calcaneal) compartment</td>
<td>communicates with the deep posterior compartment of the leg.</td>
</tr>
</tbody>
</table>

### Fasciotomies

<table>
<thead>
<tr>
<th>Incisions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorsal (1)</td>
<td>3 incisions (2 dorsal and 1 medial) can release all compartments.</td>
</tr>
<tr>
<td>Dorsal (2)</td>
<td>Over 2nd metatarsal, dissect on both sides: release medial 2 interosseous, adductor, deep central</td>
</tr>
<tr>
<td>Medial</td>
<td>Over 4th metatarsal, dissect on both sides: release lateral 2 interosseous, lateral, and both central</td>
</tr>
<tr>
<td></td>
<td>Along medial border of hind foot &amp; midfoot: release medial, superficial, and deep central compartments</td>
</tr>
</tbody>
</table>

---

**Note:** The table and diagram illustrate the anatomical compartments and fasciotomy incisions of the foot and ankle, highlighting the muscles and fascias involved in compartment syndrome and their respective incision approaches. The text provides a detailed breakdown of the content within each compartment and the fasciotomy routes to release pressure and improve circulation.
### LUMBAR PLEXUS

**Posterior Division**

**Saphenous** (L2-4): Branch of femoral nerve, descends in superficial medial leg then anterior to medial malleolus to medial arch of foot.

- **Sensory:** Medial ankle and foot (arch)
- **Motor:** None

### SACRAL PLEXUS

**Anterior Division**

**Tibial** (L4-S3): Posterior to medial malleolus, into tarsal tunnel, divides on plantar surface into **medial** and **lateral plantar nerves.**

- **Sensory:** Medial heel, via **medial calcaneal nerve**
- **Motor:** None (before dividing)

**Medial plantar:** Runs medially in foot within the 2nd plantar layer. Compression can cause medial foot/arch pain (esp. in runners).

- **Sensory:** Medial plantar foot and toes
- **Motor:**
  - First plantar layer
    - Abductor hallucis
    - Flexor digitorum brevis (FDB)
  - Second plantar layer
    - Lumbricals (medial 2)
  - Third plantar layer
    - Flexor hallucis brevis (FHB)

**Lateral plantar:** Gives branch to ADM (can be entrapped by abductor hallucis fascia), then runs laterally within the 2nd plantar layer.

- **Sensory:** Lateral plantar foot and toes
- **Motor:**
  - First plantar layer
    - Abductor digit minimi (ADM): via 1st branch (Baxter’s n.)
  - Second plantar layer
    - Quadratus plantae
    - Lumbricals (lateral 2)
  - Third plantar layer
    - Flexor digiti minimi brevis
  - Fourth plantar layer
    - Dorsal interosseous
    - Plantar interosseous
**Deep fibular (peroneal) nerve**

- Superficial peroneal nerve (SPN)
- Sural nerve

**Superficial peroneal nerve**

- Sensory: Dorsal foot: intermediate dorsal cutaneous n.
  - Medial hallux: via medial dorsal cutaneous nerve
- Motor: None (in foot and ankle)

**Sural nerve**

- Sensory: Lateral heel: via lateral calcaneal nerve
  - Lateral foot: via lateral dorsal cutaneous nerve
- Motor: None

**Other**

- Dorsal foot sensory innervation: 3 cutaneous nerves
  - (2 from superficial peroneal nerve, 1 from sural nerve)

---

**Sacral Plexus**

**Posterior Division**

**Deep peroneal:** Runs in anterior compartment of leg with anterior tibial artery, under inferior extensor retinaculum (can entrap nerve), then divides into motor (lateral) and sensory (medial) branches.

- Sensory: 1st/2nd toe interdigital space via *medial* branch
- Motor: Via *lateral* branch
  - Extensor hallucis brevis (EHB)
  - Extensor digitorum brevis (EDB)

**Superficial peroneal:** Runs in lateral compartment of leg, crosses anteriorly 12cm above LM to dorsal foot, then divides into 2 nerves. Can be injured during ORIF of ankle or by anterolateral arthroscopy portal.

- Sensory: Dorsal foot: intermediate dorsal cutaneous n.
  - Medial hallux: via medial dorsal cutaneous nerve
- Motor: None (in foot and ankle)

---

**From sciatic nerve**

- Superficial fibular (peroneal) nerve
- Sural nerve

**Lateral dorsal cutaneous nerve (from sural)**

**Lateral calcaneal branches**
**ARTERY** | **COURSE** | **BRANCHES** | **COMMENT/SUPPLY**
--- | --- | --- | ---
**ANTERIOR TIBIAL ARTERY**
Anterior medial malleolar | Under TA & EHL tendons to medial malleolus | None | Supplies medial malleolus
Anterior lateral malleolar | Under EDL tendon to lateral malleolus | None | Supplies lateral malleolus
Dorsalis pedis | Along dorsum of foot with deep peroneal nerve | Continuation of anterior tibial artery in foot | Supplies dorsum of foot via multiple branches (see foot table)

**POSTERIOR TIBIAL ARTERY**
Posterior medial malleolar | Under PT and FDL tendons to medial malleolus | None | Supplies medial malleolus
Medial calcaneal | With med. calcaneal nerve (tibial) | None | Supplies heel/calcaneus

**Terminal Branches**
Lateral plantar | Between quadratus plantae & FDB in 2nd layer w/lateral plantar n. | Deep plantar arch | Larger of the terminal branches
Medial plantar | Between abductor hallucis and FDB in 2nd layer with medial plantar nerve | Superficial branch 1 proper plantar digital Deep branch | Runs in medial foot

**PERONEAL ARTERY**
Perforating artery | Pierces interosseous membrane going to anterior ankle | Branches or contributes to tarsal sinus artery | Joins with ant. lat. malleolar a. Direct supply to posterior talus
Posterior lateral malleolar | Under PL and PB tendons to lateral malleolus | None | Supplies lateral malleolus
Lateral calcaneal | With lat. calcaneal nerve (sural) | None | Supplies heel/calcaneus

Ant. & post. medial malleolar arteries & ant. & post. lateral malleolar arteries form an anastomosis at each malleolus.
**Blood Supply of Talus**

1. Artery of tarsal canal
2. Deltoid artery
3. Direct superomedial arteries
4. Artery of tarsal sinus
5. Direct posterior arteries

**Posterior tibial (PT)**
- Artery of tarsal canal (or PT)
- Dorsalis pedis
- Dorsalis pedis and/or Peroneal (perforating br.)

**Artery of tarsal canal and tarsal sinus form a primary anastomosis inferior to talar neck that supplies the neck.**

**Intraosseous anastomoses allow talus to withstand a less severe vascular injury. Significant vascular injury (e.g., Hawkins type II or III talar neck fracture) often results in AVN.**
### Artery Course Branches Comment/Supply

#### Dorsalis Pedis Artery

<table>
<thead>
<tr>
<th>Artery</th>
<th>Course</th>
<th>Branches</th>
<th>Comment/Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct talar brs.</td>
<td>Directly into talus</td>
<td>None</td>
<td>Supplies head and neck</td>
</tr>
<tr>
<td>Medial tarsal</td>
<td>Across tarsals, under EHL tendon</td>
<td>None</td>
<td>Supplies dorsum &amp; medial tarsus</td>
</tr>
<tr>
<td>Lateral tarsal</td>
<td>With lateral br., deep peroneal n.</td>
<td>None</td>
<td>Supplies EDB, lateral tarsus</td>
</tr>
<tr>
<td>Arcuate</td>
<td>Transversely across metatarsal bases, under EDL tendons</td>
<td>3 dorsal MT arteries (2, 3, 4) 6 dorsal digital arteries 3 posterior perforating arteries 1 dorsal digital artery</td>
<td>Bifurcate at level of MT base Med. &amp; lat. aspects of toes From deep plantar arch Far lateral vessel to small toe</td>
</tr>
<tr>
<td>Deep plantar</td>
<td>Descends between 1st &amp; 2nd MTs</td>
<td>Terminates as deep arch</td>
<td>Forms deep plantar arch with terminal branch of lateral plantar artery</td>
</tr>
<tr>
<td>1st dorsal metatarsal</td>
<td>Terminal branch of DP 3 dorsal digital arteries</td>
<td></td>
<td>Medial dorsal halluc &amp; 1st web space</td>
</tr>
<tr>
<td>Deep plantar arch</td>
<td>On plantar interosseous muscles in the 4th plantar layer</td>
<td>3 posterior perforating arteries 4 planar MT arteries 1 common/proper plantar dig. 4 anterior perforating 4 common plantar digital 8 proper plantar digital 1 common/proper plantar</td>
<td>Anastomose with arcuate/dorsal MT Along plantar metatarsal Joins w/terminal br. of med. plantar artery To dorsal metatarsal arteries Continuation after perforators branch Medial, lateral aspects of toes Lateral aspect of small toe</td>
</tr>
</tbody>
</table>

- 10 dorsal digital arteries (8 from the 4 dorsal MT art. plus 2 that branch proximally) do not reach to distal tip of toe.
- 10 proper plantar digital arteries (8 from plantar MT arteries plus 2 that branch proximally) supply the distal tip of toe.
- Each toe has 2 dorsal digital arteries and 2 proper plantar digital arteries.
## DISORDERS • Foot/Ankle

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
<th>WORKUP/FINDINGS</th>
<th>TREATMENT</th>
</tr>
</thead>
</table>
| **ACHILLES TENDINITIS** | - Occurs at or above insertion of Achilles tendon  
- Microtrauma to insertion | Hx/PE: Heel pain, worse with push off; tender to palpation | XR: Standing lateral: +/- spur at Achilles insertion  
MR: Fusiform tendon | 1. Rest, NSAIDs, heel lift  
2. Excise—tendinosus  
3. Reconstruct w/FHL tendon |
| **ACHILLES TENDON RUPTURE** | - “Weekend warriors”—middle-aged men/athletics  
- Occurs with eccentric load | Hx: “Pop” sensation  
PE: Defect, + Thompson test | XR: Standing AP/lateral; usually normal | 1. Casting (in equinus) vs  
2. Surgical repair (decrease re-rupture) |
| **ANKLE INSTABILITY** | - Multiple/recurrent sprains  
- Associated with varus heel  
- Can be from subtalar joint | Hx: Pain and instability  
PE: ATFL/CFL TTP, check for varus heel; + ant. drawer/talar tilt | XR: AP/lateral/oblique Stress: Drawer and tilt show subluxation | 1. Rest, brace  
PT: strengthen peroneals  
2. Surgical reconstruction (Brostrom) if condition persists |
| **ANKLE SPRAIN** | - #1 musculoskeletal injury  
- Lateral 90%—ATFL only  
- 60% with CFL, (“high ankle sprain”) w/syndesmosis 5%  
- Inversion #1 mechanism | Hx: “Pop,” pain, swelling, +/- ability to bear weight  
PE: Edema, ecchymosis—ATFL (CFL) TTP, +/- ant. drawer, talar tilt tests | XR: AP, lateral, mortise: Rule out fracture (only if cannot WB, or bony point tenderness) | 1. RICE, NSAIDs  
2. Immobilize grade III  
3. PT & ROM exercises  
4. Surgery: severe injury or persistent instability |
| **ARTHROSIS (OA/DJD)** | - Can occur in any joint (ankle, subtalar, midtarsal, midfoot)  
- Associated with prior trauma, overuse, AVN, inflammatory arthropathy, obesity | Hx: Older; pain, +/- previous trauma  
PE: Pain at affected joint, +/- decreased range of motion | XR: Weight-bearing images  
Ankle: AP/lateral/mortise  
Foot: AP/lateral/oblique  
Look for classic OA findings | 1. NSAIDs, modify activities  
2. Orthotics: cup, AFO or double upright  
Midfoot: steel shank/rocker  
3. Fusion or arthroplasty |

---

**Achilles Tendinitis**  
Soleus m.  
Calcaneal tendon  
Calcaneal tuberosity  
Fat pad  
Achilles tendon pad with inflammation at insertion into calcaneal tuberosity

**Achilles Tendon Rupture**  
Gastrocnemius muscles  
Soleus muscles  
Achilles tendons  
Residual strand  
Plantaris tendon  
Calcaneo-fibular ligament  
Inversion sprain (rupture of calcaneo-fibular and talotibular ligaments)

**Ankle Sprain**  
Anterior talofibular ligament  
Calcaneo-fibular ligament

**Arthritis of midfoot**

---

**NETTER’S CONCISE ORTHOPAEDIC ANATOMY**  
375  
30  
Ch10_X9781416059875_337-383.indd375   375 8/5/09   12:34:25 PM
## Charcot Neuroarthropathy

- **End stage of diabetic foot**
- **Decreased sensation**—patient cannot detect fracture or dislocation
- **Multiple injuries, unhealed or malunited leads to joint destruction and deformity**

**Hx:** Diabetes. **DO NOT** complain of pain because they are insensate

**PE:** Red, warm, swollen joint, +/− deformity and/or ulcers (may look like infection)

**XR:** AP(WB)/lateral/oblique

**Findings:** Osteopenia, fracture, callus, bony prominences, joint destruction

**Indium scan:** r/o osteomyelitis

**TREATMENT:**
1. Immobilize, skin checks
2. Brace if possible
3. Treat ulcers as needed
4. Bony prominence excision
5. TAL if indicated
6. Selected fusions

## Corn

- **Two types**
  - Hard: hyperkeratosis—pressure on bones (5th toe #1)
  - Soft: interdigit maceration

**Hx/PE:** Tight shoes, pain at lesion site

**XR:** AP/lateral: look for bone spurs/bony prominence

**TREATMENT:**
1. Wide toe box shoe
2. Debride callus
3. Pads relieve pressure
4. Excise bony prominence

## Diabetic Foot

- **Ulcers from pressure & neuropathy** (sensory & autonomic); patient doesn’t feel pain of lesion
- **Previous ulcer #1 risk for ulcer**
- **15% of DM pts. have ulcers**
- **2nd infection can occur**
- **Vascular insufficiency leads to decreased healing potential**

**Hx:** NO pain, +/− wound drainage

**PE:** Skin changes (e.g., hair loss), diminished/absent pulses, decreased sensation (monofilament tests protective sensation: 5.07 or better), ulcer; erythema, swelling, drainage may be present in infection.

**XR:** Look for osteomyelitis

**MR/Indium scan:** evaluate for osteomyelitis

**Labs:** CBC/CRP (infection)

**Ulcer Healing Indicators:**
- Lymphocytes: >1500
- Albumin: >3.5
- ABI: >0.45 (non-Ca vessels)
- Toe pressures: >30 mmHg

**TREATMENT:**
1. Prevention: skin care, DM shoes
2. Debride ulcer/callus, total contact casting (TCC)
3. Infection: Superficial: debride, antibiotics; Deep: surgical debride-ment, IV antibiotics
4. Amputation for severe or persistent cases

---

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<td>Hx: Diabetes. <strong>DO NOT</strong> complain of pain because they are insensate</td>
<td><strong>XR:</strong> AP(WB)/lateral/oblique</td>
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<td>• Decreased sensation—patient cannot detect fracture or dislocation</td>
<td></td>
<td><strong>Findings:</strong> Osteopenia, fracture, callus, bony prominences, joint destruction</td>
<td>2. Brace if possible</td>
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<td><strong>Hx/PE:</strong> Tight shoes, pain at lesion site</td>
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<td></td>
<td></td>
<td>4. Excise bony prominence</td>
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<td><strong>DIABETIC FOOT</strong></td>
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<td><strong>MR/Indium scan:</strong> evaluate for osteomyelitis</td>
<td>2. Debride ulcer/callus, total contact casting (TCC)</td>
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<td>• 15% of DM pts. have ulcers</td>
<td><strong>Labs:</strong> CBC/CRP (infection)</td>
<td><strong>Ulcer Healing Indicators:</strong></td>
<td>3. Infection: Superficial: debride, antibiotics; Deep: surgical debride-ment, IV antibiotics</td>
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<td>• 2nd infection can occur</td>
<td></td>
<td>Lymphocytes: &gt;1500</td>
<td><strong>Amputation for severe or persistent cases</strong></td>
</tr>
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<td></td>
<td>Albumin: &gt;3.5</td>
<td></td>
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</tbody>
</table>

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**Figures:**

- Charcot Foot: Anteroposterior radiograph of Charcot ankle joint
- Diabetic Foot: Autonomic and Sensory Neuropathy
- Ulcer: Skin changes (e.g., hair loss), diminished/absent pulses, decreased sensation (monofilament tests protective sensation: 5.07 or better), ulcer; erythema, swelling, drainage may be present in infection.
- Treatment: Prevention: skin care, DM shoes; Debride ulcer/callus, total contact casting (TCC); Infection: Superficial: debride, antibiotics; Deep: surgical debride-ment, IV antibiotics; **Amputation for severe or persistent cases**
### GOUT (PODAGRA)

- **Hx:** Men; acute & exquisite pain
- **PE:** Red, swollen toe
- **XP:** Erosion on both sides of joint
- **Labs:**
  1. Elevated uric acid
  2. Negatively birefringent crystals (in aspirate)

**TREATMENT**

1. NSAIDs/colchicine
2. Rest
3. Allopurinol (prevention)
4. If DJD, fusion

### HALLUX RIGIDUS

- **Hx:** Middle age; painful, stiff toe (hallux)
- **PE:** MTP tender to palpation, decreased ROM
- **XR:** Standing AP/lateral; dorsal osteophyte or OA findings at 1st MTP

**TREATMENT**

1. NSAID, full length rigid orthosis
2. Cheilectomy
3. Fusion (adv. DJD)

### HALLUX VALGUS

- **Hx:** Pain (worse with shoe wear)
- **PE:** Valgus deformity/bunion; medial 1st MT head/MTPJ TTP; +/- MTPJ decr. ROM; check for 1st ray hypermobility
- **XR:** AP(WB)/lateral/oblique
  - Measure angles:
    1. Hallux valgus (nl <15°)
    2. Intermetatarsal (nl <9°)
    3. Interphalangeal (nl <10°)
    4. DMMA (nl <15°)

**TREATMENT**

1. Modify shoes: wide toe box
2. Operative:
   - Mild: Chevron or DSTP
   - Severe: Proximal osteotomy/DSTP
3. DJD: 1st MTPJ fusion
4. COMP: recurrence #1
### LESHER TOE DEFORMITIES

#### Claw Toes
- **1st deformity:** MTPJ hyperextension (extrinsics overpower weak intrinsic muscles)
- **2nd deformity:** PIP & DIP flexion
- Associated with neurologic disease

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx &amp; PE</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Claw Toes</td>
<td>Hx: Toe or plantar foot pain; neuro disease (e.g., DM, CMT)</td>
<td>XR: AP/lateral/oblique foot; subluxating P1 on MT head</td>
<td>1. Pads for callus, MT pads or inserts, extra-depth shoes</td>
</tr>
<tr>
<td></td>
<td>PE: Toe deformities, callus on dorsal PIPJ, &amp; plantar MT heads; assess flexibility of deformity</td>
<td>MR: Spine: r/o neurologic lesion</td>
<td>2. Flexible: FDL to P1 transfer; Fixed: FDL tx, EDB release, lengthen EDL, PIPJ resection</td>
</tr>
<tr>
<td></td>
<td>XR:</td>
<td>EMG: r/o neurologic disease</td>
<td></td>
</tr>
</tbody>
</table>

#### Hammertoes
- PIPJ flexed w/dorsal callus
- MTPJ & DIPJ extended
- Assoc. w/tight shoes and long 2nd or 3rd rays (>4mm)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Hammertoes</td>
<td>Hx: toe/plantar foot pain</td>
<td>XR: WB AP/lateral: Look for joint subluxation Evaluate for long metatarsal</td>
<td>1. Pads, hammertoe braces</td>
</tr>
<tr>
<td></td>
<td>PE: Toe deformity, callus on dorsal PIPJ, plantar MT head; assess flexibility of deformity</td>
<td>MR: Spine: r/o neurologic lesion</td>
<td>2. Flexible: FDL transfer; Fixed: PIPJ resection + /- tx.; extensor re-release if MTPJ fixed</td>
</tr>
<tr>
<td></td>
<td>XR:</td>
<td>EMG: r/o neurologic disease</td>
<td></td>
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</tbody>
</table>

#### Mallet Toes
- Flexion of DIPJ
- Assoc. w/long ray in tight shoes & arthritis of DIPJ

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Mallet Toes</td>
<td>Hx: Toe pain</td>
<td>XR: AP/lateral/oblique DIPJ deformity</td>
<td>1. Pads, extra-depth shoes</td>
</tr>
<tr>
<td></td>
<td>PE: Flexed DIP, dorsal callus over DIPJ</td>
<td>2. FDL tendon release</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>3. Partial amputation</td>
</tr>
</tbody>
</table>

### METATARSALGIA
- Metatarsal head pain
- Etiology: flexor tendinitis, ligament rupture, callus (#1)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Hx/PE: Pain under MT head (2nd MT most common)</th>
<th>WORKUP/FINDINGS</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metatarsal</td>
<td>Hx/PE: Pain under MT head (2nd MT</td>
<td>XR: Standing AP/lateral: look for short MT</td>
<td>1. Metatarsal pads</td>
</tr>
<tr>
<td></td>
<td>head (2nd MT most common)</td>
<td></td>
<td>2. Modify shoes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. Treat underlying cause</td>
</tr>
</tbody>
</table>

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**Foot/Ankle • DISORDERS**

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<table>
<thead>
<tr>
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</tr>
</thead>
</table>
| **MORTON’S NEUROMA (INTERDIGITAL)** | • Fibrosis of irritated nerve  
• Usually between 2nd and 3rd metatarsals  
• 5:1 female (shoes) | Hx: Pain w/shoes & walking, relief w/rest/no shoes  
PE: MT, web space, TTP, +/- numbness, + compression test | XR: Standing AP/lateral: MT heads may be close together  
1. Wide toe shoes, steroid injections, MT pads/bars  
2. Nerve excision & deep transverse MT lig. release |
| **PLANTAR FASCIITIS** | • Inflammation/degeneration of fascia; female 2:1  
• Associated with obesity | Hx: AM pain, improves w/ambulation or stretching  
PE: Medial plantar calcaneus TTP | XR: Standing lateral: +/- calcaneal bone spur  
1. Stretching, NSAIDs  
2. Heel cup  
3. Splint (night), casting  
4. Partial fascia release |
| **POSTERIOR TIBIALIS TENDON DYSFUNCTION (ACQUIRED FLATFOOT)** | • Failure of post. tib. tendon—foot deformity/loss of arch  
• Chronic (attrition) or acute (rupture [hx of trauma])  
• Assoc. w/obesity and DM  
• 3 stages:  
  I: tenosynovitis, no deformity (no pes planus)  
  II: pes planus, flexible hind foot; no single heel raise  
  III: rigid hind foot +/- DJD | Hx: Med. foot pain, “weakness”; deformity; lat. foot pain in late stages; hx of trauma in some cases  
PE: + pes planus, valgus heel, PT tendon TTP (b/w MM and navicular-hypovascular area), pain with or unable to do single heel raise, + “too many toes sign” | XR: AP (WB), lat. oblique; AP: subluxation of talar head; Lat: collapse of long. arch  
Ankle: AP & mortise (WB); look for valgus talar tilt (incompetent deltoid lig.) seen in late stages  
Stage:  
I: cast/boot 2-4mo, NSAIDs, custom-molded orthosis  
II: UCBL/AFO orthosis OR tendon transfer (use FDL) & medial slide calcaneal osteotomy  
III: Triple arthrodesis +/- TAL (tendoachillies lengthening) |
| **RETROCALCANEAL BURSITIS (HAGLUND’S DISEASE)** | • Bursitis at insertion of Achilles tendon on calcaneus | Hx: Pain on posterior heel  
PE: Red, TTP, “pump bump” | XR: Standing lateral: spur at Achilles insertion  
1. NSAID, heel lift, casting  
2. Excise bone/bursa (rare) |
RHEUMATOID ARTHRITIS

- Synovitis is 1° problem
- Forefoot: 1st MTPJ has HV, lesser claw toe deformities
- Hind foot: PT insufficiency and subtalar instability = valgus heel

Hx: Pain, swelling, deformity
PE: Hallux valgus, claw toes with plantar callus; hind foot in valgus

XR: AP(WB)/lateral/oblique: evaluate for joint destruction, osteopenia, joint subluxation, hallux valgus (measure angle)
Labs: Positive RF, ANA

1. Medical mgmt. of RA
2. Wide toe shoes and orthosis
3. Forefoot: 1st MTPJ fusion, 2-5 lesser toe MT head resection
4. Hind foot: triple arthrodesis

RUNNER’S FOOT

Multiple etiologies
- Medial plantar nerve entrapment
- Baxter's nerve (1st br LPN)
- Stress fracture

Hx: Avid runner, pain
PE: MPN: medial arch pain; Baxter’s n.; plantar/lat. pain
Bone TTP (MT, nav., etc)

XR: AP/lateral/oblique; usually normal
Bone scan: evaluate for stress fracture

Based on etiology:
MPN: release at knot of Henry
Baxter’s: release abductor hallucis fascia
Stress fx: immobilize, rest

SERONEGATIVE SPONDYLOARTHROPATHY (REITER’S, AS, PSORIASIS)

- Inflammatory arthritides: with symptoms in multiple joints
  Types: psoriatic arthritis, Reiter’s syndrome, ankylosing spondylitis

Hx: Foot pain, any joint
PE: Evaluate whole foot
Psoriatic: sausage digit Reiter/ankyl. spondylitis: Achilles/heel pain, bursitis, plantar fascitis

XR: AP/lateral/oblique Psoriatic: pencil/cup deformity; DIPJ joint erosion; Reiter/AS: +/- enthesophytes
Labs: Neg. RF, + HLA-B27

1. Medical management
2. Conservative care of arthritis, tendinitis, bursitis, fascitis
3. Surgical intervention is infrequent

TAILOR’S BUNION (BUNIONETTE)

- Prominent 5th metatarsal head laterally
- Bony exostosis/bursitis

Hx/PE: Difficulty fitting shoes, painful lateral 5th metatarsal prominence
XR: Standing
AP: 5th toe medially deviated, MT laterally deviated

1. Pads, wide toe box
2. Mild: chevron osteotomy
3. Severe: MT shelf osteotomy

TARSAL TUNNEL

- Tibial nerve entrapped by flexor retinaculum or space-occupying lesion (e.g., cyst) in tunnel
- Clinical diagnosis

Hx: Pain, numbness/tingling
PE: Pain at tarsal tunnel, +/- sensory changes and Tinel’s test
XR: AP/lateral; usu. normal
MR: Mass or lesion in tunnel
EMG: Confirm clinical diagnosis

1. NSAIDs, steroid inj.
2. Release retinaculum, abductor hallucis fascia, remove any mass (release plantar nerves)

TURF TOE

- Plantar plate injury (rupture) from MT neck
- Hyperextension of 1st MTPJ

Hx: Hyperextension, toe (MTP) pain
PE: Plantar pain, pain with extension (DF), decr. ROM
XR: AP/lateral/oblique; usually normal
Bone scan: r/o stress fx

1. Immobilize, rest, NSAIDs
2. Brace/orthosis to block dorsiflexion during activities
CLUBFOOT (TALIPES EQUINOVARUS)

- Idiopathic, congenital
- Boys 2:1, 50% bilateral, 1:1000
- Multifactorial etiology: genetic, environmental
- Assoc. w/other conditions
- 4 different deformities: **CAVE**
- Also seen in neuromuscular disease

**Hx:** Born with deformity

**PE:** 4 deformities (mnemonic **CAVE**)
- Cavus midfoot, forefoot **Adductus**, subtalar **Varus**, hindfoot **Equinus**

**XR:**
- AP/lateral: “parallelism” of talus & calcaneus
- Lateral: T-C angle: nl

**Treatment**
- Ponseti: serial casting + bars
  - Cavus: dorsiflex 1st ray
  - Adductus/Varus: talar head is the fulcrum for correction
  - Equinus: dorsiflex ankle, TAL
- Release if persistent >6-9 m.o.
- Neuromuscular: release 6-12mo

PES CAVUS (HIGH ARCH FOOT)

- High arch due to muscle imbalance in immature foot (TA and peroneus longus); TA weak, PL & PT strong
- Ankle flexed: causes pain
- Must rule out neuromuscular disease (e.g., Charcot-Marie-Tooth)
- May have claw toes

**Hx:** 8-10yr, ankle pain

**PE:** Toe walking, tight heel cord, decreased ankle dorsiflexion

**XR:** AP/lateral foot and ankle

**EMG/NCS:** Test for weakness

**MR:** Spine: r/o neuromuscular disease

**Treatment**
- Braces/inserts/AFO as needed (used w/mixed results)
- Various osteotomies
- Tendon transfer and balance

METATARSUS ADDUCTUS

- Forefoot adduction (varus)
- #1 pediatric foot disorder
- Assoc. w/intrauterine position or other “packaging” disorders

**Hx:** Parent notices deformity

**PE:** “Kidney bean” deformity, negative thigh/foot angle, + intoeing gait

**Treatment**
- Most spontaneously resolve with normal development
- Serial casing
- Abductor hallucis release
- Rarely, midfoot osteotomies
### Flexible Flatfoot

**Pes Planovalgus (Pes Planus)**
- **Normal variant**
- **Almost always bilateral**
- **Foot flat only with weight-bearing; forms an arch when non-weight-bearing**

**Evaluation**
- **Hx:** Usually asymptomatic, +/- pain w/activity
- **PE:** Pes planus when WB. NonWB arch reconstitutes; heel goes into varus on heel rise
- **XR:** Decreased arch, otherwise normal

**Treatment**
1. Observation, parental reassurance, no special shoes
2. Arch supports may help if sx mild
3. Calc. osteotomy for persistent pain

### Rigid Flatfoot

**Tarsal Coalition**
- **Congenital fusion of 2 tarsal bones**
- **Calcaneonavicular #1 (younger children)**
- **Talocalcaneal (subtalar) #2 (older)**
- **Coalitions can be fibrous, bony, or cartilaginous**

**Evaluation**
- **Hx:** Old child/adolescent with insidious onset of pain, worse w/activity
- **PE:** Rigid flat foot, peroneal spasm
- **XR:** Anteater sign (calcaneonavicular)
- **CT:** Best study to identify and measure coalition

**Treatment**
1. Cast, orthosis, NSAIDs
2. Persistent or recurrent pain
3. Calc. osteotomy for persistent pain
4. Coalition resection
5. Bone-block subtalar fusion

**Congenital Vertical Talus**
- **Talus plantarflexed. Irreducible dorsolateral talonavicular dislocation**
- **Also seen in neuromuscular disorders**

**Evaluation**
- **Hx:** Convex/rockertbottom sole, rigid flatfoot (always flat), +/- calcaneovalgus appearance
- **XR:** PF lateral: talar axis line below cuneiform MT joint

**Treatment**
1. Initial casting (in PF) for stretching
2. Complete release at 6-18mo
3. Talectomy in resistant cases
Anterolateral approach to ankle joint

USES
• Fusions/triple arthrodeses
• Fractures (e.g., pilon, talus)
• Intertarsal joint access

INTERNERVIOUS PLANE
• Peroneals (superficial peroneal)
• EDL (deep peroneal)

DANGERS
• Deep peroneal nerve
• Anterior tibial artery

COMMENT
• Can access hind foot
• Preserving fat pad (sinus tarsus) helps wound healing

ARTHROSCOPY PORTALS
Uses: synovectomy, loose body removal, osteochondral lesions, impingement, chondroplasty, some arthrodeses

Anteromedial
- Medial to tibialis anterior (TA) tendon at or just proximal to joint
- Saphenous nerve & vein
- Least risky portal, should be established first

Anterolateral
- Lateral to peroneus tertius tendon at or just proximal to joint
- Superficial peroneal nerve
- Can establish with needle under direct visualization

Posterolateral
- Lateral edge of Achilles tendon 1 cm proximal to fibula tip
- Sural nerve, lesser saphenous vein
- Can establish with needle under direct visualization

Anterocentral, posterocentral, posteromedial portals have been described but are not recommended due to NV risks.

FASCIOTOMIES
See page 369
## Abbreviations

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<th>artery</th>
<th>CNS</th>
<th>central nervous system</th>
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<td>abduct</td>
<td>c/o</td>
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<td>abx</td>
<td>antibiotics</td>
<td>CPK</td>
<td>creatine phosphokinase</td>
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<td>acromio-clavicular, anterior column</td>
<td>CPPD</td>
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<td>ACJ</td>
<td>acromioclavicular joint</td>
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<td>C-reactive protein</td>
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<td>ACL</td>
<td>anterior cruciate ligament</td>
<td>CR-PCP</td>
<td>closed reduction, percutaneous pinning</td>
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<td>ADI</td>
<td>atlanto-dens interval</td>
<td>C-spine</td>
<td>cervical spine</td>
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<td>ADM</td>
<td>abductor digit minimi</td>
<td>CT</td>
<td>carpal tunnel, computed tomography</td>
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<td>arthrogram</td>
<td>CTS</td>
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<td>anterior inferior iliac spine</td>
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<td>AIN</td>
<td>anterior intersosseous nerve</td>
<td>aka</td>
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<tr>
<td>ALL</td>
<td>anterior longitudinal ligament</td>
<td>AMBRI</td>
<td>Atraumatic, Multidirectional, Bilateral instability, Rehabilitation, Inferior capsular shift</td>
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<td>ATRA</td>
<td>antinuclear antibody</td>
<td>ANA</td>
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<td>ant.</td>
<td>anterior</td>
<td>anteroposterior</td>
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<td>anterior-posterior compression</td>
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<td>artery</td>
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<td>anterior superior iliac spine</td>
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<td>anterior talofibular ligament</td>
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<td>adenosine triphosphate</td>
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<td>avascular necrosis</td>
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<td>AW</td>
<td>anterior wall</td>
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<td>B</td>
<td>bone graft</td>
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<td>br.</td>
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<td>bone-tendon-bone</td>
<td>b/w</td>
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<td>cancer</td>
<td>Ca++</td>
<td>ionic calcium</td>
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<td>complete blood cell count</td>
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<td>coracohumeral</td>
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<td>capitate-lunate joint</td>
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<td>CMC</td>
<td>carpometacarpal</td>
<td>CMCJ</td>
<td>carpometacarpal joint</td>
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<td>external rotation</td>
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<tr>
<td>esp.</td>
<td>especially</td>
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<td>ESR</td>
<td>erythrocyte sedimentation rate</td>
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<td>EUA</td>
<td>exam under anesthesia</td>
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<td>ext.</td>
<td>extension, extensor</td>
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<td>IV</td>
<td>intravenous</td>
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<td>intravenous immunoglobulin</td>
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<td>J</td>
<td>joint</td>
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<td>FCR</td>
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<td>flexor carpi ulnaris</td>
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<td>FDMB</td>
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<td>fx, fxs</td>
<td>fracture, fractures</td>
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<td>fxn</td>
<td>function</td>
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<td>lat.</td>
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<td>loose bodies</td>
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<td>lateral collateral ligament</td>
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<td>lower extremity</td>
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<td>LFCN</td>
<td>lateral femoral cutaneous nerve</td>
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<tr>
<td>lig.</td>
<td>ligament</td>
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<td>LRL</td>
<td>long radiolunate</td>
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<td>lesser</td>
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<td>LT</td>
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<td>M</td>
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<td>MC</td>
<td>medial collateral ligament</td>
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<td>metacarpophalangeal</td>
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<td>MCP</td>
<td>metacarpophalangeal joint</td>
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<td>MDI</td>
<td>multidirectional instability</td>
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<td>mech.</td>
<td>mechanism/mechanism of injury</td>
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<td>med.</td>
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<td>MEN</td>
<td>multiple endocrine neoplasia</td>
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<td>MF</td>
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<td>MPFL</td>
<td>medial patellofemoral ligament</td>
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<td>MRI</td>
<td>magnetic resonance imaging</td>
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<td>MT</td>
<td>metatarsal</td>
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<tr>
<td>MTPJ</td>
<td>metatarsophalangeal joint</td>
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<td>MUA</td>
<td>manipulation under anesthesia</td>
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<td>MVA</td>
<td>motor vehicle accident</td>
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<td>n.</td>
<td>nerve</td>
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<td>NCS</td>
<td>nerve conduction study</td>
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<tr>
<td>nl</td>
<td>normal (within normal limits)</td>
</tr>
<tr>
<td>NSAID</td>
<td>nonsteroidal anti-inflammatory drug</td>
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<tr>
<td>NV</td>
<td>neurovascular</td>
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<tr>
<td>NWB</td>
<td>non-weight-bearing</td>
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OA osteoarthritis
OP opponens pollicis muscle
ORIF open reduction, internal fixation
P
PAD palmar adduct
PC posterior column
PCL posterior cruciate ligament
PCP percutaneous pinning
PE physical examination
pect. pectoral
peds pediatrics/pediatric patients
PF plantarflex, plantarflexion
PFCN posterior femoral cutaneous nerve
PFS patellofemoral syndrome
PG proteoglycan
PIN posterior intersosseous nerve
PIPJ proximal interphalangeal joint
PL palmaris longus
PLC posterolateral corner complex
PLL posterior longitudinal ligament
PLRI posterolateral rotary instability
PMHx past medical history
PMRI posteromedial rotary instability
PO per oral, postoperatively
poll. pollicus
post. posterior
PQ pronator quadratus
prox. proximal
PRUJ proximal radioulnar joint
PSIS posterosuperior iliac spine
PT posterior tibialis, pronator teres
PTH parathyroid hormone
pts. patients
PTTD posterior tibialis tendon dysfunction
PVNS pigmented villonodular synovitis
PW posterior wall
Q
Q quadriceps
R
RA rheumatoid arthritis
RAD radiation absorbed dose
RC rotator cuff
RCL radiosaphocapitate ligament
RF rheumatoid factor, ring finger
RH radial head
RICE rest, ice, compression, and elevation
r/o rule out
ROM range of motion
RSC radiosaphocapitate
RSD reflex sympathetic dystrophy
RSL radiosapholunate ligament
RTL radiolunotriquetral ligament
S
SAC short arm cast
SC scaphocapitate, sternoclavicular
SCM sternocleidomastoid
SF small finger
SFA superficial femoral artery
SGN superior gluteal nerve
SH short head
SI sacroiliac
SIJ sacroiliac joint
SL scapholunate
SLAC scapholunate advanced collapse
SLAP superior labrum anterior/posterior
SLNWC short leg non weightbearing cast
SPN superficial peroneal nerve
sRL short radiolunate
SS supraspinatus
STT scaphotrapeziotrapezoid
sup. superior
sx symptom
synd. syndrome
T
TA tibialis anterior
TAL transverse acetabular ligament, transverse atlantal ligament
TC triquetrocapitate
TCL transverse carpal ligament
Td tetanus and diphtheria toxoid
TFC triangular fibrocartilage complex
TFCC triangular fibrocartilage complex
TFL tensor fascia lata
TH triquetromamate
THA total hip arthroplasty
THC triquetromamapate
TIG tetanus immunoglobulin
TKA total knee arthroplasty
TLSO thoracolumbosacral orthosis
TP tibialis posterior
TTP tenderness to palpation
TUBS Traumatic, Unilateral instability, Bankart lesion, surgery
tx treatment
**Abbreviations cont.**

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<td>UE</td>
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<td>upper extremity</td>
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<td>UL</td>
<td>ulnolunate</td>
<td>WB</td>
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<td>UMN</td>
<td>UMN</td>
<td>upper motor neuron</td>
<td>WBAT</td>
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<td>usu.</td>
<td>usu.</td>
<td>usually</td>
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<td>UT</td>
<td>UT</td>
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<td>V</td>
<td>V</td>
<td>volar interosseus</td>
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<td>VISO</td>
<td>volar intercalated segment instability</td>
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<td>VMO</td>
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<td>vastus medialis obliquus</td>
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**Abbreviations cont.**

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