THE
2025-26

Musculoskeletal Imaging
UPDATE

A 20 Hour Comprehensive, Case-Based Review of MRI, Ultrasound, CT, And X-Ray Imaging of the Frequently Imaged Joints and other Musculoskeletal Pathology

American Educational Institute, Inc.

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David R. Victor, JD
CEO

Dear Registrant:

Advancements in musculoskeletal imaging continue to refine diagnostic precision, improve patient management, and expand the role of imaging in guiding treatment decisions. ***The 2025-26 Musculoskeletal Imaging Update*** is designed to provide radiologists with the latest insights and techniques in MRI, CT, ultrasound, and procedural guidance for evaluating musculoskeletal conditions.

This comprehensive 20-hour course, led by expert faculty, covers a broad range of critical topics, including MRI and ultrasound of the hip, knee, ankle, wrist, and shoulder, the evaluation of bone lesions, subtle fracture detection, musculoskeletal infections, and advanced imaging of degenerative and postoperative spine conditions. Additionally, ultrasound-guided procedures and emerging imaging strategies will be explored to enhance diagnostic accuracy and clinical decision-making.

To reinforce key concepts, this syllabus includes optional self-evaluation quizzes, marked by black-edged pages, which allow you to assess your comprehension before or after each lecture.

We value your feedback and encourage you to complete the evaluation questions for each lecture. Additionally, we welcome engagement with our expert faculty—your questions and insights contribute to a richer learning experience.

This course brings together a diverse group of radiologists and imaging specialists, offering a unique opportunity for collaboration and knowledge exchange. We encourage you to take advantage of this dynamic learning environment.

Thank you for your participation. We hope ***The 2025-26 Musculoskeletal Imaging Update*** provides you with valuable insights to enhance your practice and patient care.

Cordially,
American Educational Institute, Inc

David R. Victor, Esq.
CEO

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COURSE OBJECTIVES

After completing ***The 2025-26 Musculoskeletal Imaging Update*** you should have acquired the knowledge that will better enable you to better:

- Improve the ability to interpret **MRI of the hip joint**, including labral pathology, femoroacetabular impingement, osteonecrosis, fractures, and greater trochanteric pain syndrome, to enhance diagnostic accuracy and patient management.
- Improve proficiency in musculoskeletal **ultrasound of the hip** by identifying normal anatomy, recognizing common pathology in the anterior, lateral, and posterior hip, and evaluating complications in patients with hip arthroplasty.
- Develop a structured approach for evaluating **solitary bone lesions** using radiography, MRI, CT, and bone scans to differentiate benign from aggressive lesions and determine when biopsy is necessary.
- Enhance the ability to recognize and differentiate imaging findings of **musculoskeletal infections** to improve diagnostic accuracy.
- Enhance the ability to interpret **MRI of the ankle and foot** by recognizing key imaging findings in tendon injuries, ligament tears, osseous abnormalities, neuropathic changes, infections, and soft tissue masses to improve diagnostic accuracy and clinical management.
- Improve the use of **musculoskeletal ultrasound to evaluate ankle ligament injuries** by understanding normal ligament anatomy, common injury patterns, and dynamic imaging techniques.
- Improve the recognition of **subtle and clinically significant lower extremity fractures**, understand their hidden implications, and utilize MRI for cases where radiographs are inconclusive.
- Improve recognition of **upper extremity fracture** patterns by reviewing common injuries from shoulder to hand, with emphasis on radiographic evaluation, mechanism of injury, and clinical relevance.
- Improve the ability to interpret **MRI of the wrist and hand** by recognizing key imaging findings in tendon abnormalities, joint disease, ligament and triangular fibrocartilage complex (TFC) injuries, nerve entrapment, osseous pathology, and soft tissue masses.
- Enhance skills in musculoskeletal **ultrasound of the wrist** by reviewing dorsal and volar anatomy, identifying nerve, tendon, and joint pathology, and recognizing accessory muscles and anatomical variations.
- Understand ultrasound of the **elbow anatomy, protocol, and dynamic imaging**.
- Understand the usefulness of **ultrasound in musculoskeletal procedural guidance** and learn the techniques.
- Understand **MRI knee protocol**, knee anatomy, and common pathology and injurie patterns.
- Understand ultrasound **knee anatomy, protocol, and dynamic imaging**.
- Improve recognition and interpretation of **spinal infections and their mimics** on imaging, including key MRI and CT features, appropriate use of percutaneous biopsy, and diagnostic pitfalls that affect clinical decision-making.
- Improve diagnostic accuracy in evaluating **degenerative and postoperative spine conditions** by recognizing key imaging findings, surgical complications, and structural causes of persistent symptoms.
- Understand **MRI shoulder protocol, shoulder anatomy, and common pathology**.
- Understand **ultrasound shoulder anatomy, protocol, and dynamic imaging**.
- Understand metrics, analyses and strategies to better ensure **practice profitability**.
- Understand methods to optimize **retirement planning and practice value**.

All learning objectives above address IOM/ACGME core competencies.

THE 2025-26

Musculoskeletal Imaging UPDATE

FACULTY DISCLOSURES

The individuals listed below have control over the content of ***The 2025-26 Musculoskeletal Imaging Update***. None of them have a financial relationship with an ineligible company.

David R. Victor, Esq., CEO, American Educational Institute
Billy J. Allen, president, American Educational Institute
Michael P. Zintsmaster, MD, clinical content director
Stephen Zintsmaster, MD, peer reviewer
Steven Soliman, DO, RMSK, FAIUM, FAOCR, faculty member
Wende N. Gibbs, MD, faculty member
Kevin C. McGill, MD, MPH, RMSK, MRMD, faculty member
David B. Mandell, JD, MBA, faculty member
Carole C. Foos, CPA, faculty member

The following faculty members of ***The 2025-26 Musculoskeletal Imaging Update*** have a financial relationship with an ineligible company:

Jon A. Jacobson, MD, FACR, BioClinica, Samsung – consultant

All lectures presented by speakers with relevant financial relationships have been peer reviewed. All speakers with financial relationships have attested that clinical recommendations they make are evidence-based and free of commercial bias.

FACULTY

Jon A. Jacobson, MD, FACR

Jon A. Jacobson, MD, FACR is a board-certified musculoskeletal radiologist. His educational background includes radiology residency at Henry Ford Hospital and musculoskeletal fellowship at the University of California at San Diego. After working for 23 years at the University of Michigan as Division Director and Professor of Radiology developing their musculoskeletal ultrasound program, Dr. Jacobson currently works at Lenox Hill Radiology in New York City and University of California, San Diego. Dr. Jacobson's research interests include musculoskeletal ultrasound and MRI. His academic achievements include over 260 peer-reviewed publications and many invited national and international lectures or workshops. Dr. Jacobson has been a visiting professor on over 50 occasions, is President of the Society of Skeletal Radiology, and has received numerous teaching and mentoring awards, including the 2023 Distinguished Educator Award (American Roentgen Ray Society). He is also the author of the textbook *Fundamentals of Musculoskeletal Ultrasound*, which has been translated into 5 languages and is now in its third edition. Dr. Jacobson's curriculum vitae can be found at www.jacobsonmskus.com.

You may contact Dr. Jacobson with your questions or comments at jon.jacobson.rad@gmail.com.

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MR Imaging of the Hip

Take Home Points

- Joint: contrast, gradient echo, radiographs
- Imaging for FAI may be unreliable
- Bone marrow edema:
  - Is not early osteonecrosis
  - Is likely from insufficiency fracture
- Insufficiency fracture: MRI is best
- Trochanteric bursitis is uncommon

Outline:

- Hip joint
- Labrum and FAI
- Osteonecrosis
- Fractures
- Greater trochanteric pain syndrome

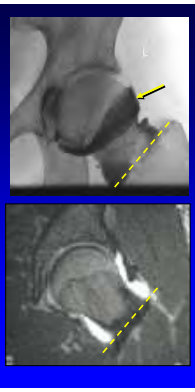
Joint Pathology

- Effusion:
  - Reactive, inflammation, hemarthrosis
- Synovial hypertrophy:
  - Inflammatory: rheumatoid, atypical infection
  - Proliferative: tenosynovial giant cell tumor, synovial chondromatosis
  - Characterized: enhancement

Hip Joint: *anatomy*

- Distal extent: to intertrochanteric line
- Recess: between labrum and capsule
- Does not collect dependently
  - Surrounds femoral neck[1]
- Iliopsoas bursa:
  - Normal joint communication in 15 - 20%
- Obturator externus bursa: <10%[2]

[1]Moss et al. Radiology 1998; 208:43
[2]Robinson P et al. Radiology 2003; 118:230



Injection / Aspiration: fluoroscopy

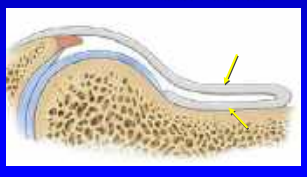
- 75% direct anterior
- 24% oblique anterior
- 1% direct lateral

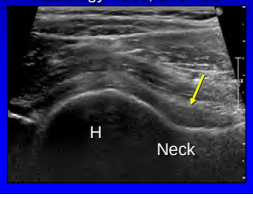
Shortt. Skeletal Radiol 2009; 38:377

Hip: anterior recess

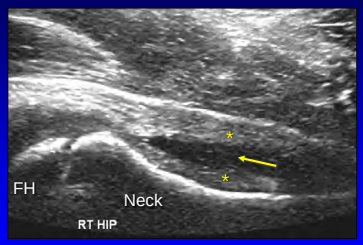
- Anterior and posterior layers
  - Fibrous tissue + minute layer of synovium
  - Hyperechoic
  - Each 2 - 4 mm thick

Radiology 1999; 210:499

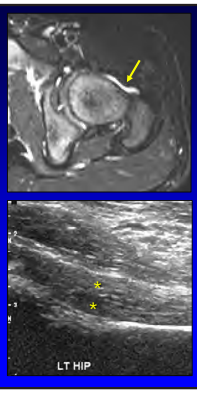




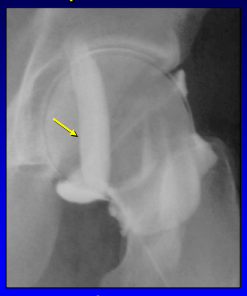
Hip Joint: septic effusion



Long Axis

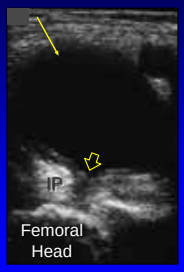


Iliopsoas Bursa

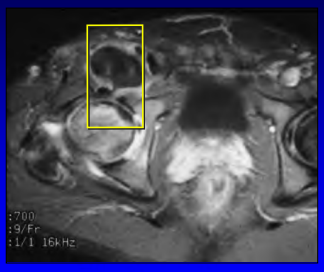


Arthrogram

Iliopsoas Bursa: distention



Axial



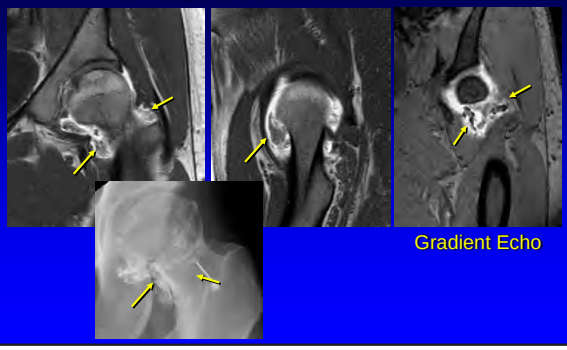
T1w IV gadolinium

Tenosynovial Giant Cell Tumor

- Know previously as PVNS
- Benign synovial proliferation
- Synovial hyperplasia
  - Multinucleated giant cells
  - Lipid-laden macrophages
  - Hemosiderin deposition
- Monoarticular: localized or diffuse

Lin et al. AJR 1999; 172:191

Tenosynovial Giant Cell Tumor

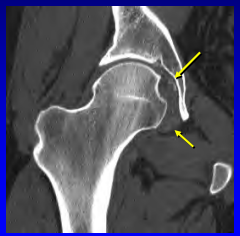


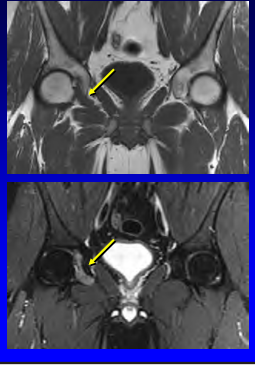
Gradient Echo

Synovial Chondromatosis

- Benign cartilaginous metaplasia
- Large joints: knee and hip
- May or may not ossify
- May detach: intra-articular bodies

Synovial Chondromatosis



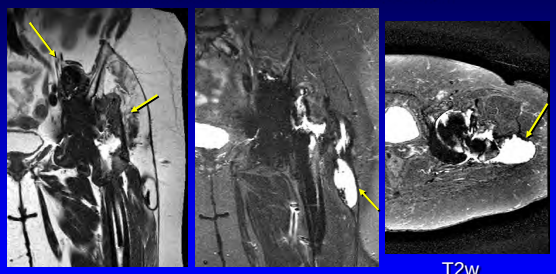


Total Hip Arthroplasty

- Metal-on-metal articulation
- Wear debris, hypersensitivity
  - Joint effusion synovitis
  - Bursa distention
- Pseudo-tumor:
  - Soft tissue: necrosis, inflammation
  - Ultrasound: 99% sensitive[1]
  - MRI: effective[2]

[1]Nawabi DH et al. Clin Orthop Relat Res 2014;472:471
[2]Garbuz DS Clin Orthop Relat Res 2014; 472:417

Metal-on-Metal: Pseudotumor



T1w STIR T2w

Take Home Points

- Joint: contrast, gradient echo, radiographs

Outline:

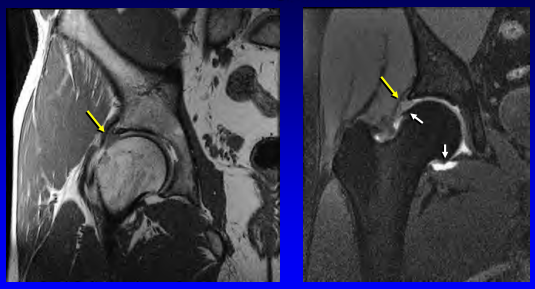
- Hip joint
- Labrum and FAI
- Osteonecrosis
- Fractures
- Greater trochanteric pain syndrome

Labral Tear: MR arthrography

- Abnormal contrast extension into labrum
- Improved sensitivity: 50% (MRI) to 81%[1]
- Anterior: most common
- Classify:
  - Degeneration: gray signal
  - Partial tear, full-thickness tear
  - Detachment

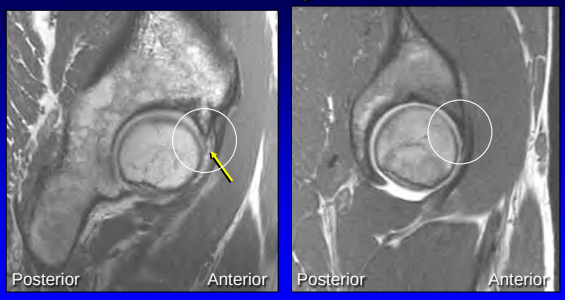
[1]Sutter R et al. AJR 2014; 202:160

Labrum: degeneration



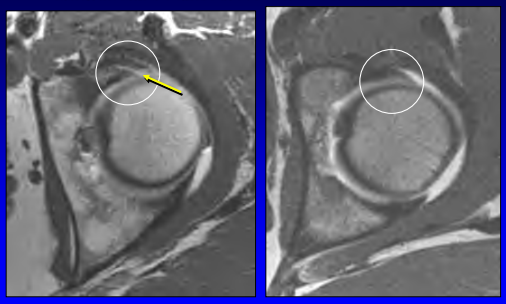
Note hip osteophytes (white arrows)

Anterior Labrum: sagittal T1-w fat sat



Tear Normal

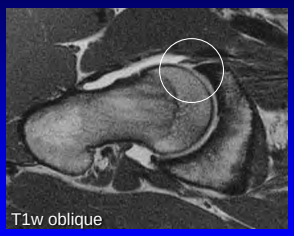
Anterior Labrum: axial T1-w fat sat

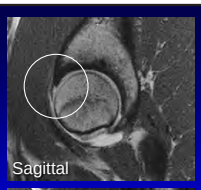


Tear Normal

Labrum Tear: full-thickness

Labral Detachment





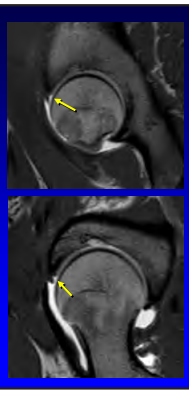
Hip Labrum: normal variants

- Sublabral sulcus
- Posteroinferior groove
- Pectinofoveal fold
- Supra-acetabular fossa

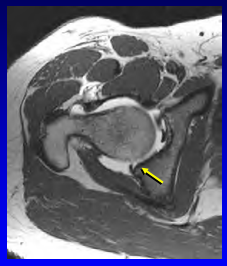
Hip Joint: sublabral sulcus

- Smooth contrast-filled cleft: <50%
- Junction of labrum and hyaline cartilage
- No labral detachment
- No labral abnormality

Saddik. AJR 2006; 187:W507



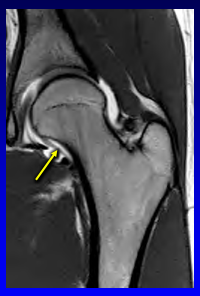
Posteroinferior Groove



Normal variant (22%): posterioinferior quadrant

Hip Joint: pectinofoveal fold

- Seen at MR arthrography: 95%
- Variable appearances
- Variable attachments
  - Usually inserts onto capsule
  - May insert onto femur



Blankenbaker D et al. AJR 2009; 192:93

Hip Joint: supra-acetabular fossa

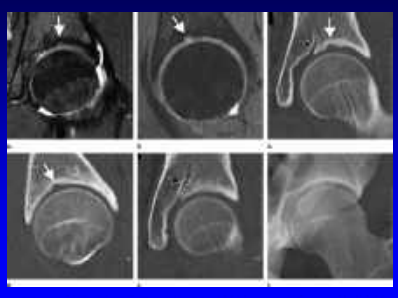
- Pseudodefect of acetabular cartilage
  - Type 1: 1.6%
    - Bony fossa filled with contrast
  - Type 2: 8.9%
    - Bony fossa filled with cartilage

Dietrich TJ et al. Radiology 2012; 263:484

Supra-acetabular Fossa: Type 1

From Dietrich TJ et al. Radiology 2012; 263:484

Supra-acetabular Fossa: Type 2 (white arrow)



Note (black arrow): supra-acetabular roof notch (another normal variant)

From Dietrich TJ el al. Radiology 2012; 263:484

Paralabral Cyst

- Multilocular, fluid signal
- Associated with labral tear: detachment
- Fill with intra-articular contrast: 94%
- Extend extra-articular: 72%
- Remodel adjacent ilium: 50%

Magerkurth O et al. Skeletal Radiol 2012; 41:1279

Labrum Tear + Paralabral Cyst

Labral Tear: location

- Anterior: iliopsoas tendon impingement
- Anterior or anterosuperior:
  - Associated with CAM-type femoroacetabular impingement
- Posterolateral tear:
  - Pincer-type femoroacetabular impingement
  - Leveraging effect

Aly AR et al. Skeletal Radiol 2013; 42:1245

Femoroacetabular Impingement

- CAM-type
- Pincer type
- Combination of both: most common

Brian P et al. Semin Roentgenol 2010; :230

CAM-type FAI:

- Extra bone:
  - Femoral head-neck junction
- Hip flexion / internal rotation:
  - Contact between extra bone and anterior labrum
- Labral tear, cartilage injury

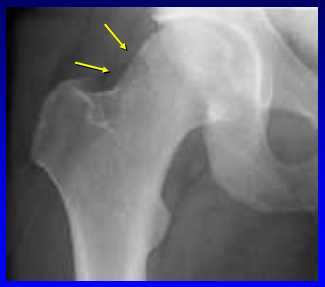
CAM = a mechanical linkage that translates motion

FAI: pathology

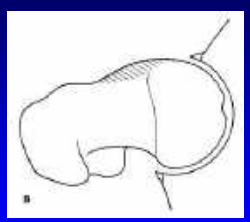
- Radiograph: femur
  - Pistol-grip deformity
  - Fibrocystic change
- MRI: alpha angle >50 degrees
- MR arthrography:
  - Improved sensitivity acetabular cartilage: 83% (MRI) to 92%[1]
  - No advantage: femoral cartilage defects

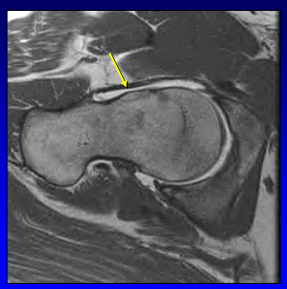
[1]Sutter R et al. AJR 2014; 202:160

CAM-type FAI: Pistol-grip deformity

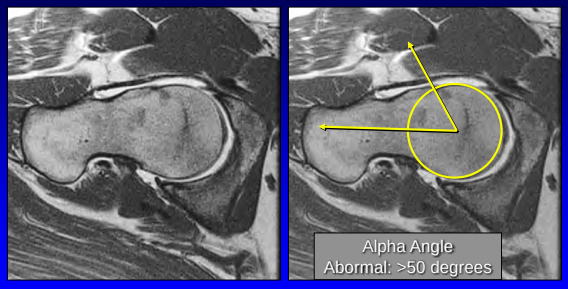


CAM-type FAI



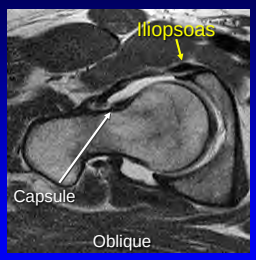


CAM-type FAI



Pitfalls

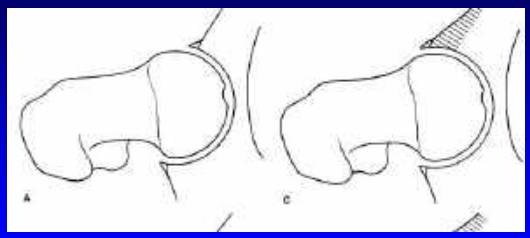
- Pseudo-bump
  - Capsular reflection
  - Low signal
- Pseudo-labral tear
  - Adjacent iliopsoas tendon
  - Low signal
  - Simulates displaced labral tissue



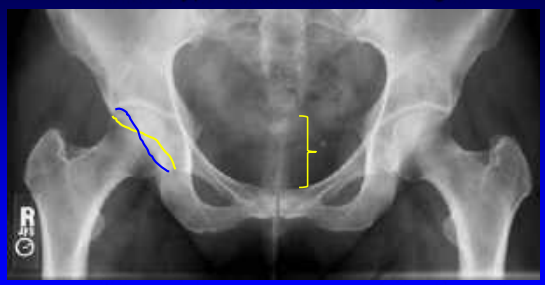
Pincer-type FAI:

- Deep hip socket or retroverted acetabulum
- Abnormal contact between acetabular rim and labrum
- Radiograph: cross-over sign
- MRI: acetabular retroversion

Pincer-type FAI



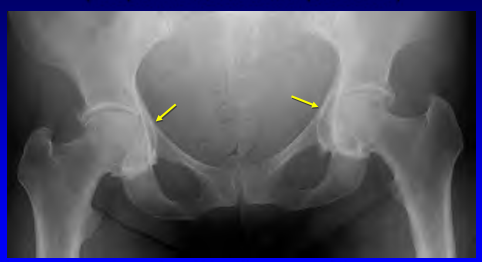
Pincer-type FAI: Cross-over sign



Note: distance between sacrococcygeal junction and pubis should be between 3 and 4 cm

FAI: Cross-over sign and fibrocystic change

Pincer-type FAI: Otto Pelvis (idiopathic acetabular protrusio)



Femoral head and acetabulum: medial to ilioischial line

FAI: imaging findings

- Radiography: inaccurate
  - Pistol-grip and fibrocystic change
  - Cross-over sign
- Alpha angle measurements:
  - Unacceptable intra- and inter-observer variability
  - Does not correlate with physical exam findings
  - Osseous bump: not always anterior

Take Home Points

- Joint: contrast, gradient echo, radiographs
- Imaging for FAI may be unreliable

Outline:

- Hip joint
- Labrum and FAI
- Osteonecrosis
- Fractures
- Greater trochanteric pain syndrome

Osteonecrosis: terminology

- Involving end of a bone:
  - Avascular necrosis
  - Aseptic necrosis
- Diaphysis or metaphysis:
  - Bone infarct

Osteonecrosis: etiology

- Anemia (sickle cell)
- Steroids
- Etoh
- Pancreatitis
- Trauma
- Idiopathic
- Caisson disease or Chronic renal failure (children)

Osteonecrosis: classification

- Modified Ficat
- 1: symptoms but normal radiographs
  - 1A: abnormal MRI; 1B: abnormal bone scan
- 2: radiograph positive- mixed lucent sclerotic
- 3: subchondral lucency (crescent sign)
  - 3A: without collapse; 3B: with collapse
- 4: osteoarthrosis

[1]Jawad MU et al. Clin Orthop Relat Res 2014; 470:2636

Osteonecrosis

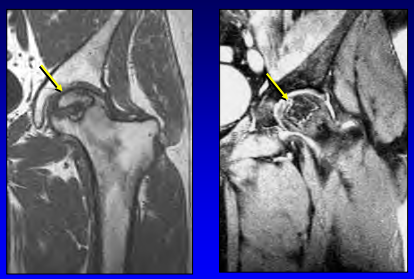
Note early flattening or collapse

Osteonecrosis: MRI findings

- Serpiginous, geographic low signal
  - Represents interface, not necessarily calcified
  - Bone marrow edema NOT early osteonecrosis[1]
  - Weight-bearing aspect of femoral head
- Internal signal: variable
- Double line sign: pathognomonic
  - High signal (T2w) inside low signal line[2]

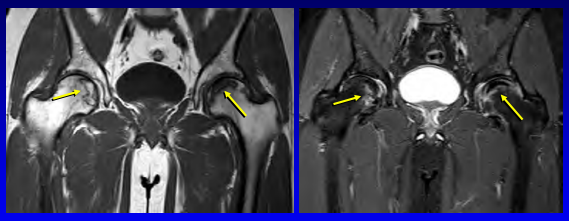
[1]Kim YM et al. JBJS 2010; 82B:837
[2]Apostolos HK et al. Sem Musculoskelet Radiol 2011; 15:281

Osteonecrosis

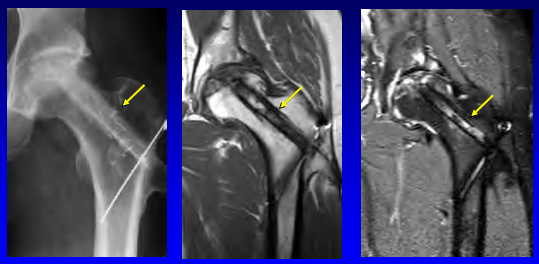


Note: double line sign

Osteonecrosis



Core Decompression and Fibula Graft



Osteonecrosis: MRI findings

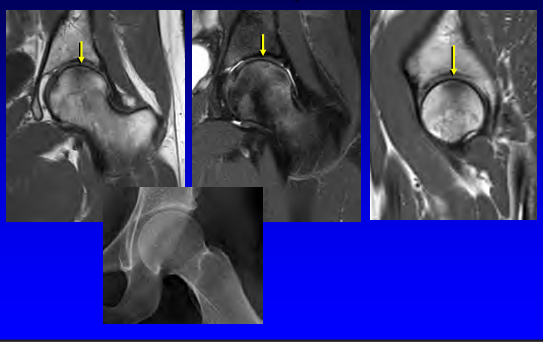
- Symptoms correlate with:
  - Bone marrow edema and volume of necrosis
- Secondary osteoarthrosis:
  - Seen in end-stage osteonecrosis
  - Findings should asymmetrically involve the femur > acetabulum
  - Unlike isolated OA: similar imaging findings across joint and marked femoral head findings

Isolated Bone Marrow Edema

- Several terms:
  - Transient osteoporosis of the hip
  - Transient bone marrow edema syndrome
- Often due to insufficiency fracture
  - Look for discontinuous linear low signal
  - Subcortical, parallel to cortex
  - Subtle collapse, little femoral head abnormality
- Is NOT a early finding of osteonecrosis

Yamamoto YM et al. Clin Ortho Surg 2012; 4:173

Insufficiency Fracture



Take Home Points

- Joint: contrast, gradient echo, radiographs
- Imaging for FAI may be unreliable
- Bone marrow edema:
  - Is not early osteonecrosis
  - Is likely from insufficiency fracture

Outline:

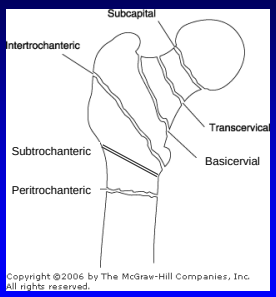
- Hip joint
- Labrum and FAI
- Osteonecrosis
- Fractures
- Greater trochanteric pain syndrome

Femur Fractures: etiology

- Traumatic
- Stress
  - Insufficiency-type:
    - Normal stress on abnormal bone
    - Osteopenia, bisphosphonate-related
  - Fatigue-type:
    - Abnormal stress on normal bone
- Pathologic

Fractures: femur

- Intra-capsular
  - Subcapital
  - Transcervical
  - Basicervical
- Extra-capsular
  - Inter-trochanteric
  - Sub-trochanteric
  - Peri-trochanteric
  - Trochanteric

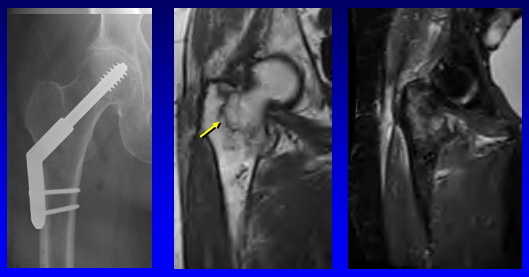


Fractures: femur

- MRI findings:
  - Bone marrow edema
  - T1w and PDw: linear low signal fracture line
  - T2w: low or high signal fracture line
- MRI is much better than CT[1]
  - Sensitivity (insufficiency): MRI 99%, CT 69%
- MRI most accurately shows extent of fracture

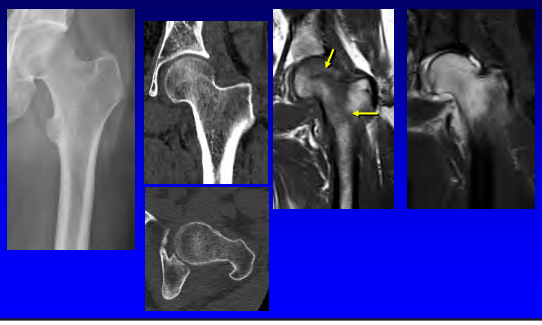
[1]Cabarrus MC et al. AJR 2008; 191:995

Proximal Femur Fracture: MRI



T1w T2w

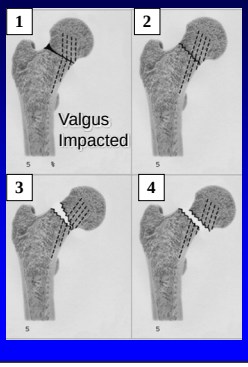
Femur Fracture: negative radiograph and CT



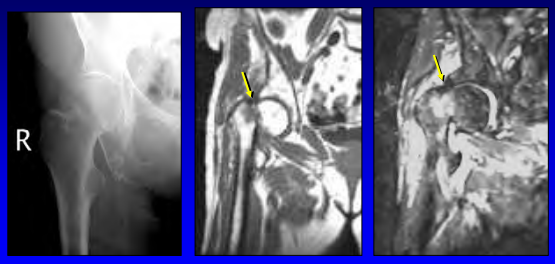
Garden Classification

1. Incomplete, valgus impacted
2. Complete, non-displaced
3. Displaced, angulated
4. Displaced

Garden 3 or 4 = hip replacement because of osteonecrosis risk

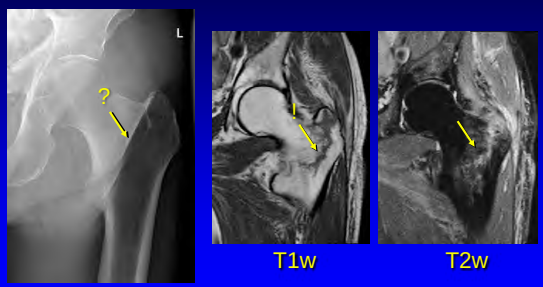


Femoral Neck Fracture: now displaced



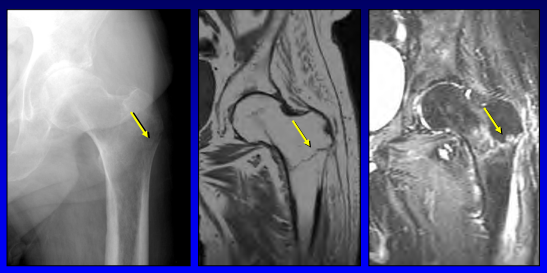
T1w T2w

Intertrochanteric Fracture



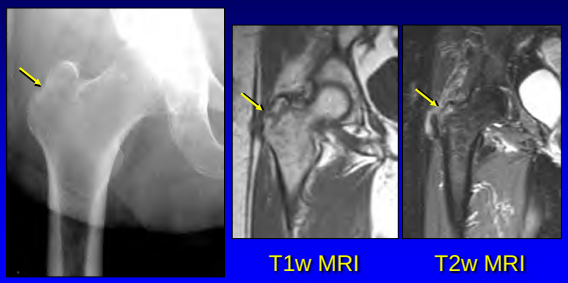
T1w T2w

Subtrochanteric Fracture



T1w T2w

Greater Trochanter Fracture



T1w MRI T2w MRI

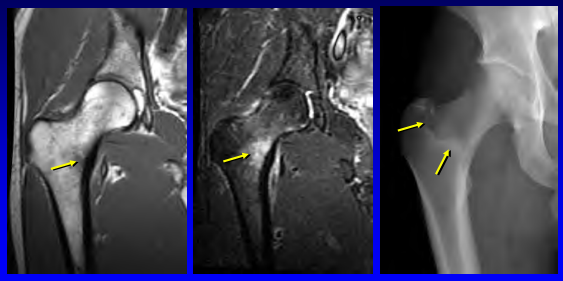
Fracture: bisphosphonate

- To treat osteoporosis: *i.e. Fosamax*
  - Inhibits osteoclasts, may slow bone turnover
- Increased risk of fracture:
  - Average treatment at fracture: 6 years
  - Femur: subtrochanteric, diaphyseal, lateral cortex
- Early sign: periosteal reaction
  - 2% are asymptomatic at early stage
  - Black line: fracture likely progresses

Chen SS et al. AJR 2010; 194:1581

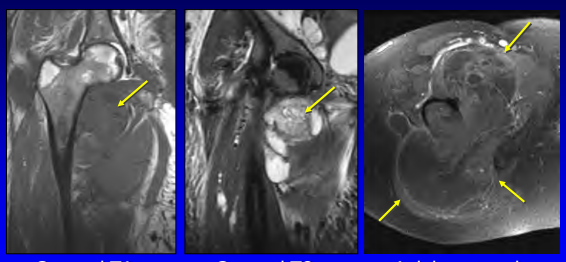
Insufficiency Fracture: bisphosphonate

Femur: fatigue-type stress fracture



T1w T2w Later

Lesser Trochanteric Avulsion: metastasis



Coronal T1w Coronal T2w Axial post-gado

Take Home Points

- Joint: contrast, gradient echo, radiographs
- Imaging for FAI may be unreliable
- Bone marrow edema:
  - Is not early osteonecrosis
  - Is likely from insufficiency fracture
- Insufficiency fracture: MRI is best

Outline:

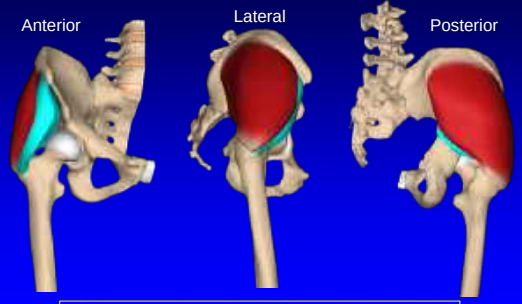
- Hip joint
- Labrum and FAI
- Osteonecrosis
- Fractures
- Greater trochanteric pain syndrome

Greater trochanteric Pain Syndrome:

- Most commonly caused by gluteus minimus and medius tendon abnormalities[1]
- Trochanteric bursitis: uncommon
  - 20% of symptomatic patients[2]
  - Not actually inflamed[3]
  - Not associated with pain[4]

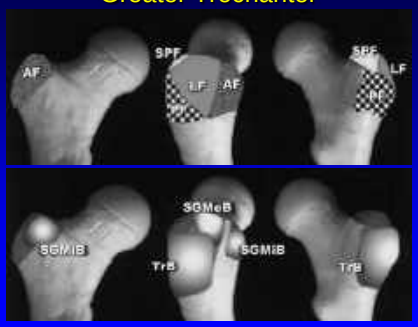
[1]Kong A et al. Eur Rad 2007; 17:1772
[2]Long SS et al. AJR 2013; 201:1083
[3]Sylva F et al. Clin Rheumatol 2008; 14:82
[4]Blankenbaker DG et al. Skeletal Radiol 2008; 37:903

Greater Trochanter: gluteal tendons



Gluteus medius (red) Gluteus minimus (blue)

Greater Trochanter



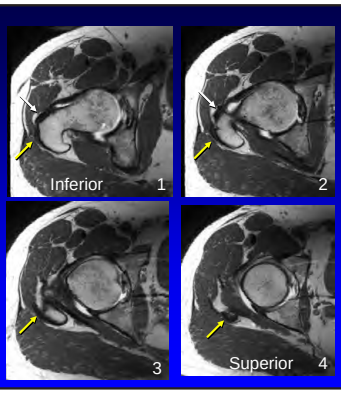
Pfirrmann et al. Radiology 2001; 221:469

Greater Trochanter

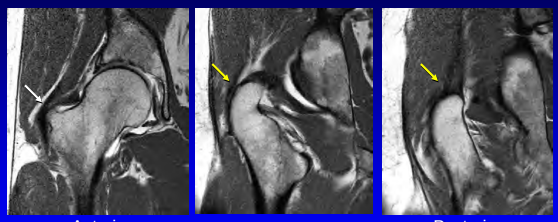
Yellow arrow = gluteus medius

White arrow = gluteus minimus

Axial MRI

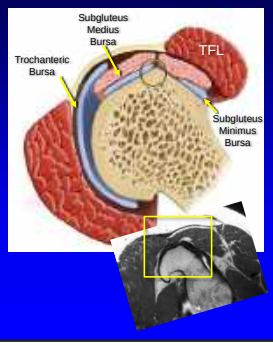


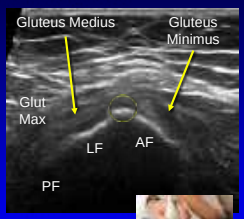
Greater Trochanter



Yellow arrow = gluteus medius
White arrow = gluteus minimus

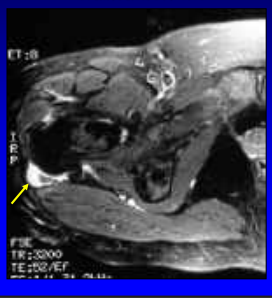
Greater Trochanter

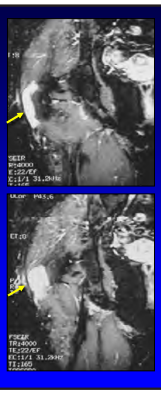




AF: anterior facet
LF: lateral facet
PF: posterior facet

Trochanteric Bursa Distention



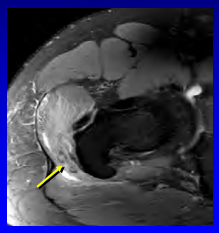


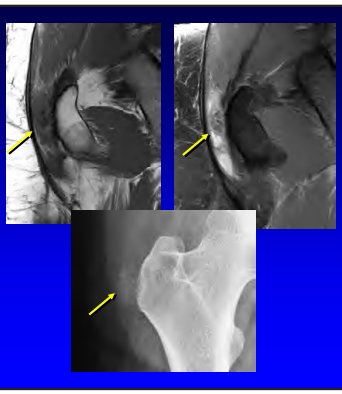
Peritrochanteric Fluid Signal

- Tendon:
  - Gray: tendinosis; Fluid signal: tear
  - Calcific tendinosis
- Bursa
- Diffuse soft tissue: common finding
  - Doesn't correlate with present[1]
  - Likely irrelevant if symmetric

[1]Blankenbaker DG et al. Skeletal Radiol 2008; 37:903

Calcific Tendinosis + Trochanteric Bursitis





Take Home Points

- Joint: contrast, gradient echo, radiographs
- Imaging for FAI may be unreliable
- Bone marrow edema:
  - Is not early osteonecrosis
  - Is likely from insufficiency fracture
- Insufficiency fracture: MRI is best
- Trochanteric bursitis is uncommon

Thank you!

Syllabus on line and other educational material:
www.jacobsonmskus.com

SELF EVALUATION

MR Imaging of the Hip

1. Which of the following is important when evaluating synovial hypertrophy or synovitis?

a. Radiography
b. Gradient echo MR imaging
c. Intra-venous gadolinium contrast MR imaging
d. All of the above.

2. T/F - Imaging for femoroacetabular impingement can be unreliable.

3. T/F - Bone marrow edema can be a precursor to osteonecrosis of the femoral head.

4. T/F - CT is an ideal imaging method in evaluation for insufficiency fracture of the hip in an osteoporotic patient.

5. T/F - The most common cause for greater trochanteric pain syndrome is gluteal tendinopathy.

Answer Key: 1. D, 2. T, 3. F, 4. F, 5. T

FACULTY

Kevin C. McGill, MD, MPH, RMSK, MRMD

Kevin C. McGill, MD, MPH, RMSK, MRMD is an Associate Professor of Musculoskeletal Imaging and the Director of Musculoskeletal Interventions in the Department of Radiology and Biomedical Imaging. Dr. McGill is certified in musculoskeletal sonography (RMSK) and is also a certified Magnetic Resonance Medical Director (MRMD). He also serves as the Chair of the Musculoskeletal Sonography Examination Assessment Committee for the Alliance for Physician Certification and Advancement and Chair of the Online Educational Resources Committee of the International Skeletal Society (ISS) (https://radiologycorelectures.org/msk/).

His research efforts have resulted in multiple publications as well as presentations at national and international conferences. His research interests include diagnostic/therapeutic musculoskeletal ultrasound, image-guided procedures, sports medicine, and oncologic imaging. Dr. McGill serves on committees for multiple professional organizations including the Radiological Society of North America (RSNA). He is Co-Chair of the Pipeline Outreach Committee for the Society of Skeletal Radiology (SSR).

You may contact Dr. McGill with your questions or comments at Kevin.Mcgill@ucsf.edu.

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Musculoskeletal Radiology
UCSF Department of Radiology & Biomedical Imaging

Ultrasound of the Hip

OBJECTIVES

- HIP ULTRASOUND ★
  - ANTERIOR
  - LATERAL
  - POSTERIOR
- HIP ARTHROPLASTY

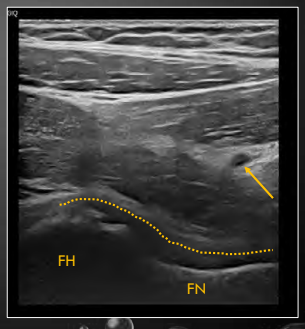
NORTH STAR

- ULTRASOUND LANDMARK
- EASILY IDENTIFIED ON PHYSICAL EXAM AND ULTRASOUND
- ORIENTATION RELATIVE TO OTHER STRUCTURES

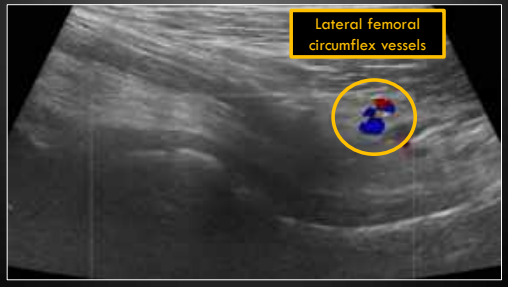
★
- Osseous
- Superficial
- Consistent

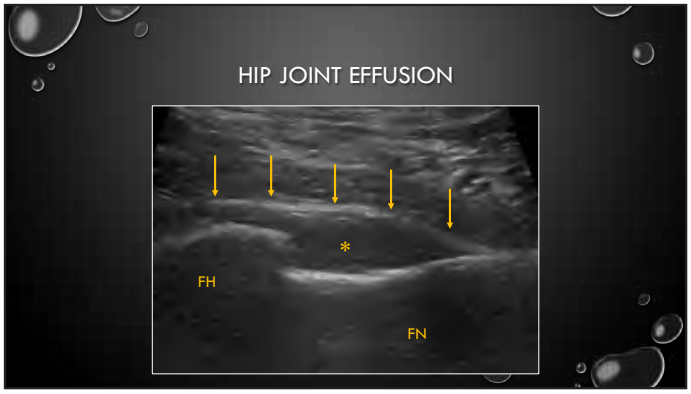
ANTERIOR HIP

Häggström, Mikael (2014). "Medical gallery of Mikael Häggström 2014". *WikiJournal of Medicine* **1** (2). DOI:10.15347/wjm/2014.008



Photos Courtesy of Deanna Hammond, RMSKS

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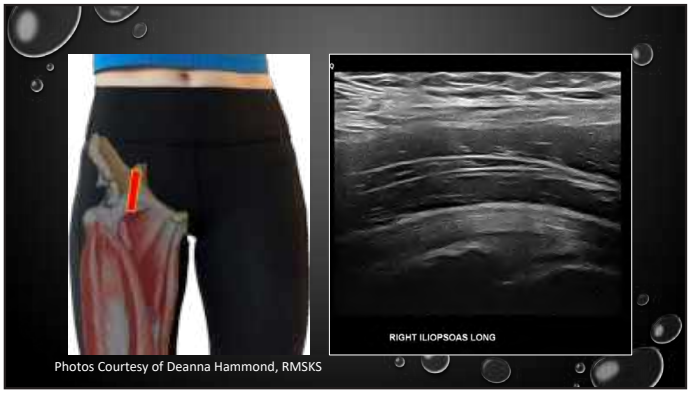
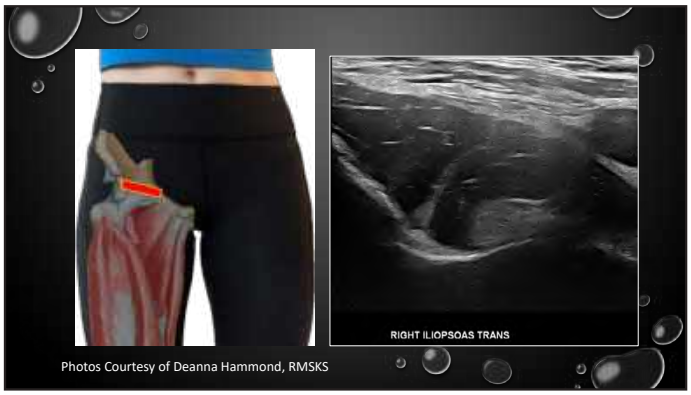
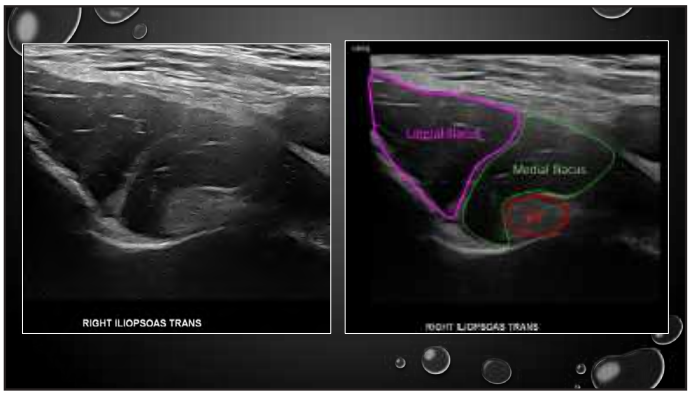
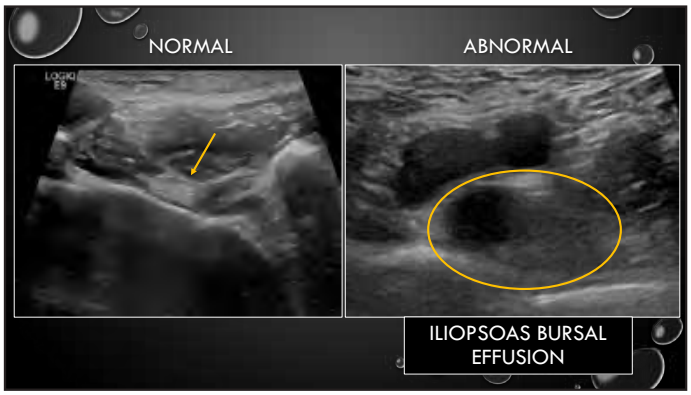
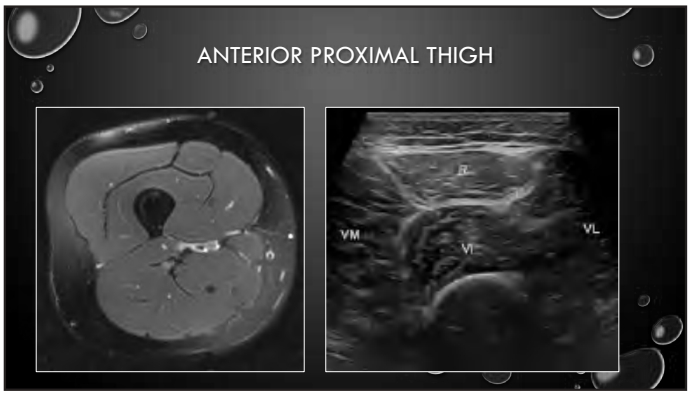
FH
FN


RIGHT ILIOPSOAS LONG
Photos Courtesy of Deanna Hammond, RMSKS

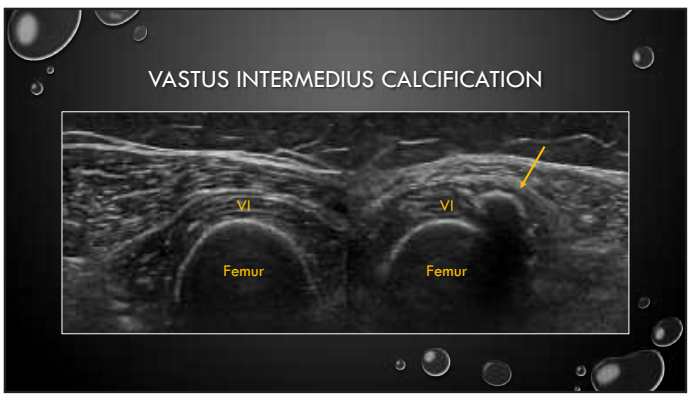

RIGHT ILIOPSOAS TRANS
Photos Courtesy of Deanna Hammond, RMSKS

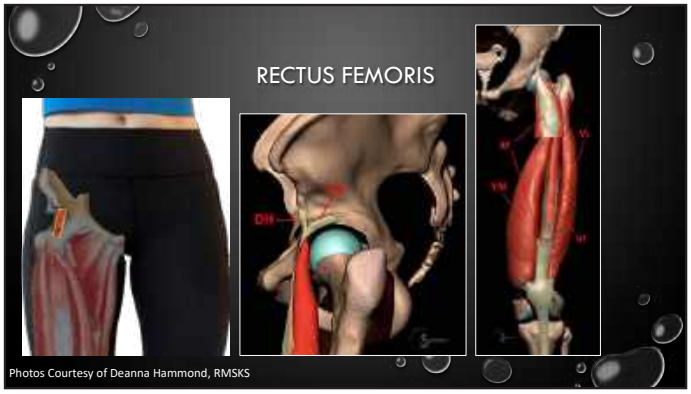

RIGHT ILIOPSOAS TRANS
Medial Rectus

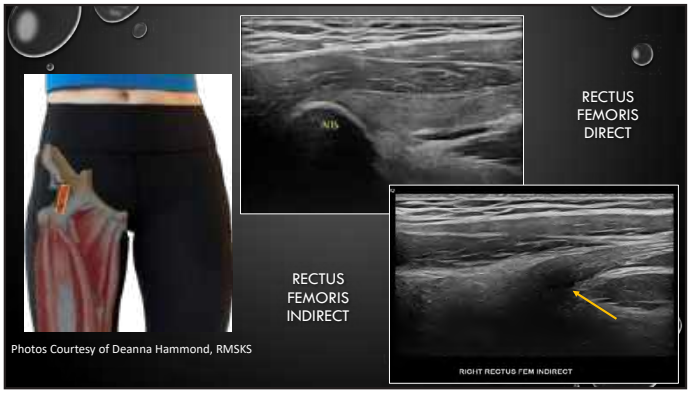

NORMAL
ABNORMAL
ILIOPSOAS BURSAL EFFUSION

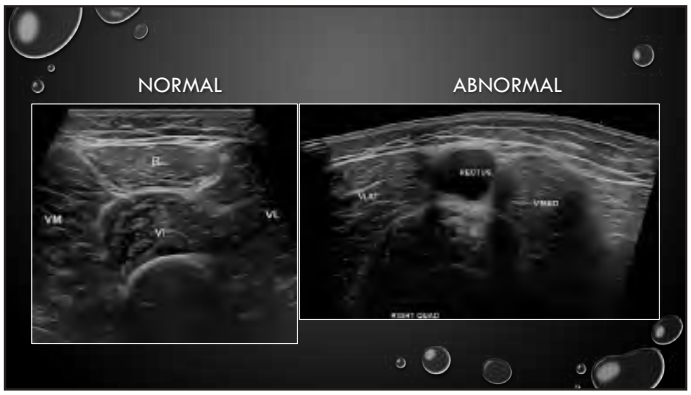

ANTERIOR PROXIMAL THIGH
VM
VI
VL

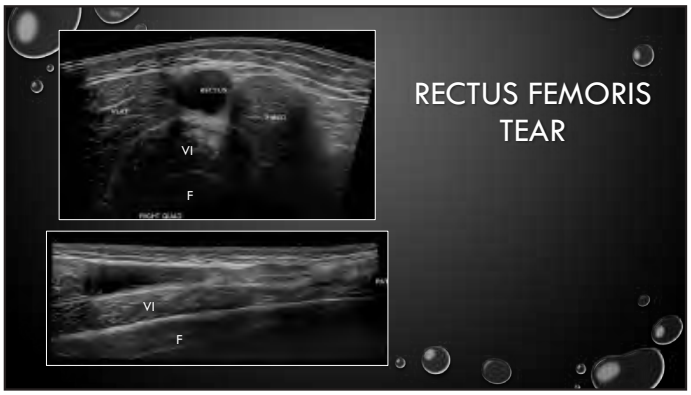

ANTERIOR PROXIMAL THIGH
VM
R
VI
VL


VASTUS INTERMEDIUS CALCIFICATION
VI
VI
Femur
Femur


RECTUS FEMORIS
Photos Courtesy of Deanna Hammond, RMSKS

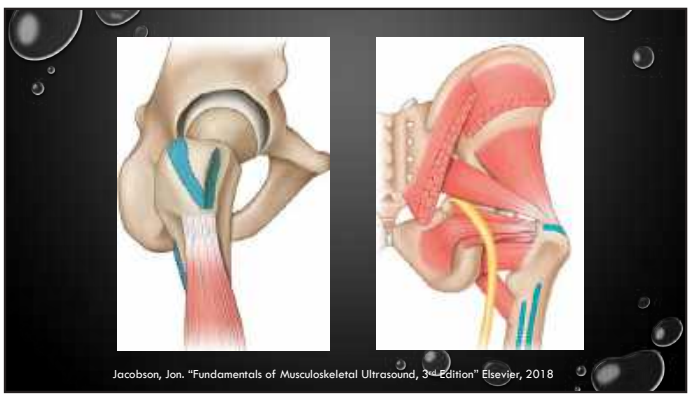

RECTUS FEMORIS DIRECT
RECTUS FEMORIS INDIRECT
Photos Courtesy of Deanna Hammond, RMSKS


NORMAL
ABNORMAL
VM
VI
VL


RECTUS FEMORIS TEAR
VI
F
VI
F


PAT
VI
FEMUR
RIGHT RECTUS LONG AXIS STUMP MID THIGH


LATERAL HIP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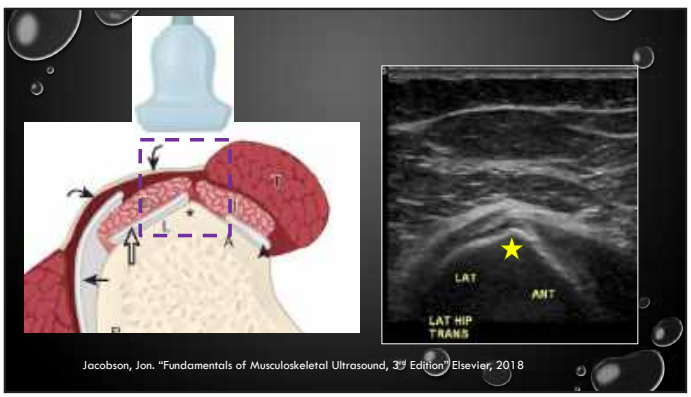
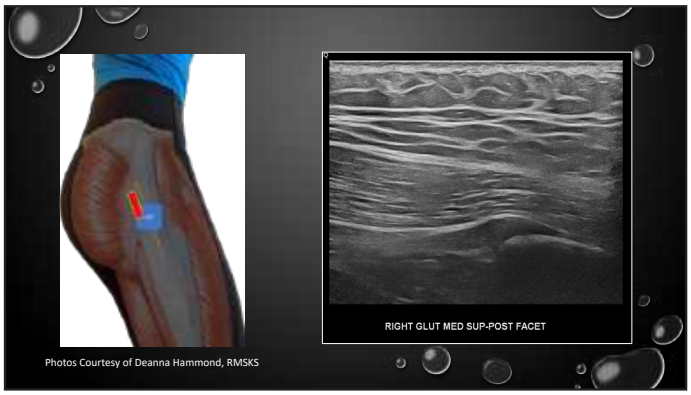
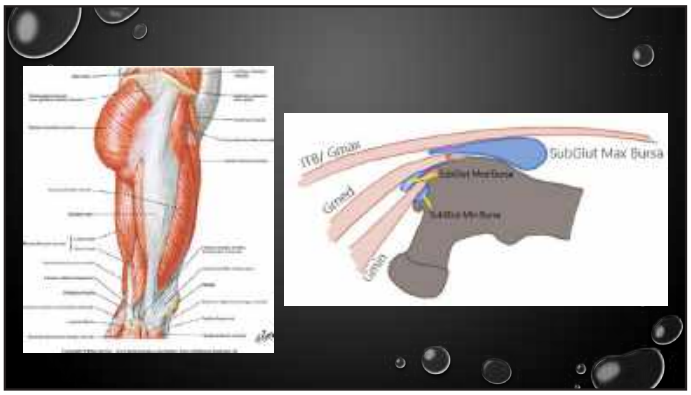

LAT
ANT
LAT HIP TRANS
Jacobson, Jon. "Fundamentals of Musculoskeletal Ultrasound, 3rd Edition" Elsevier, 2018

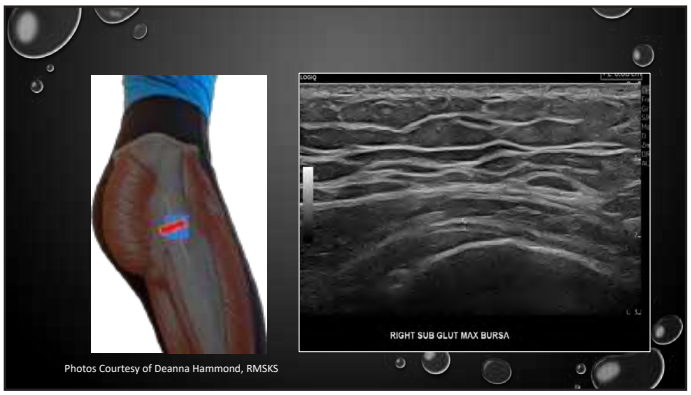

RIGHT GLUT MIN
Photos Courtesy of Deanna Hammond, RMSKS

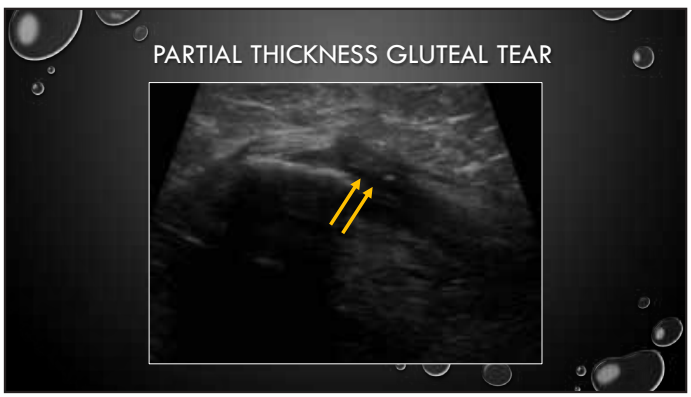

RIGHT GLUT MED LAT FACET
Photos Courtesy of Deanna Hammond, RMSKS


RIGHT GLUT MED SUP-POST FACET
Photos Courtesy of Deanna Hammond, RMSKS


SubGlut Max Bursa


Photos Courtesy of Deanna Hammond, RMSKS


RIGHT SUB GLUT MAX BURSA
Photos Courtesy of Deanna Hammond, RMSKS


PARTIAL THICKNESS GLUTEAL TEAR


PARTIAL THICKNESS GLUTEAL TEAR

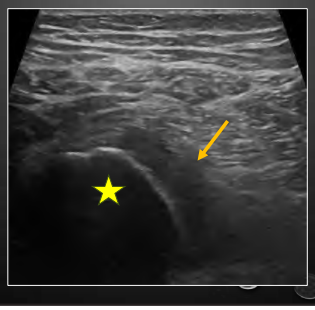
POSTERIOR HIP

Jacobson, Jon. "Fundamentals of Musculoskeletal Ultrasound, 3rd Edition" Elsevier, 2018

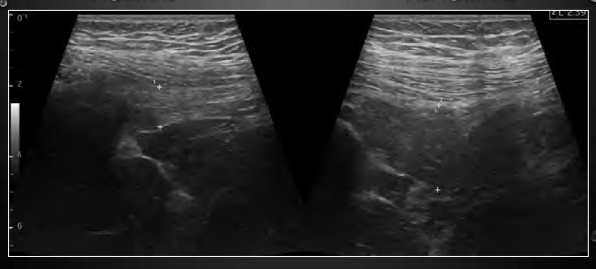
Photos Courtesy of Deanna Hammond, RMSKS

Photos Courtesy of Deanna Hammond, RMSKS

R/O HAMSTRING TEAR

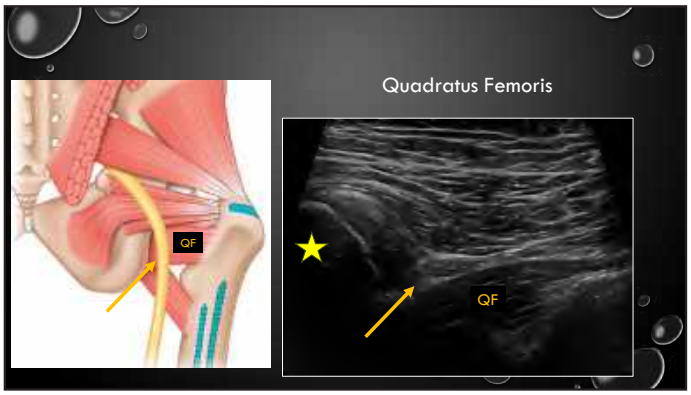


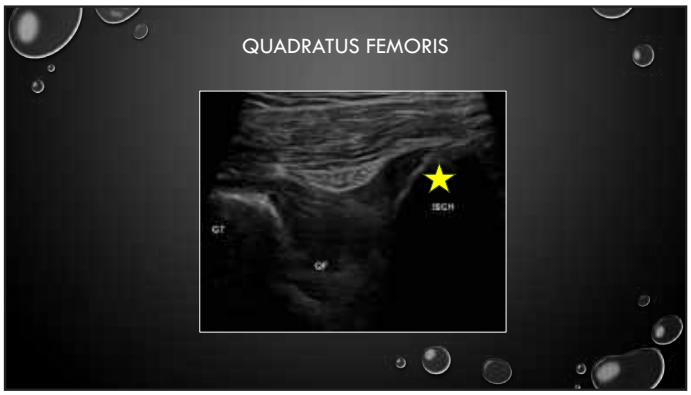
NORMAL ABNORMAL



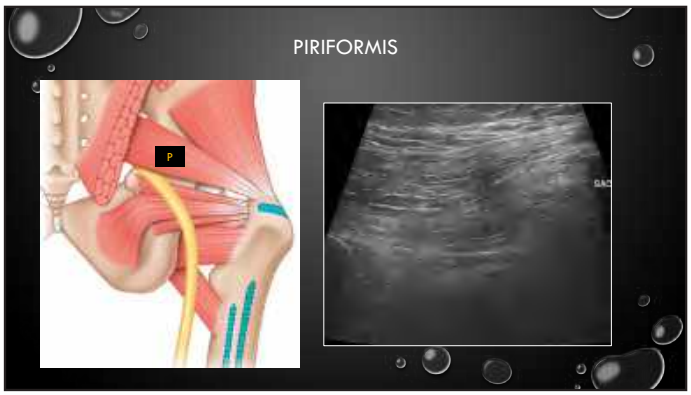

R/O HAMSTRING TEAR
BF
SMT

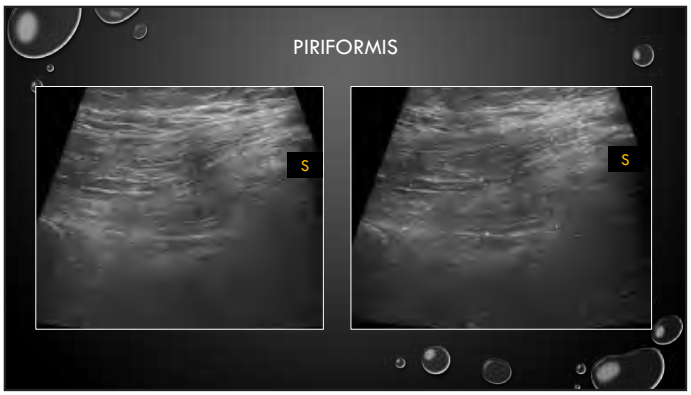

BICEPS FEMORIS HEMATOMA

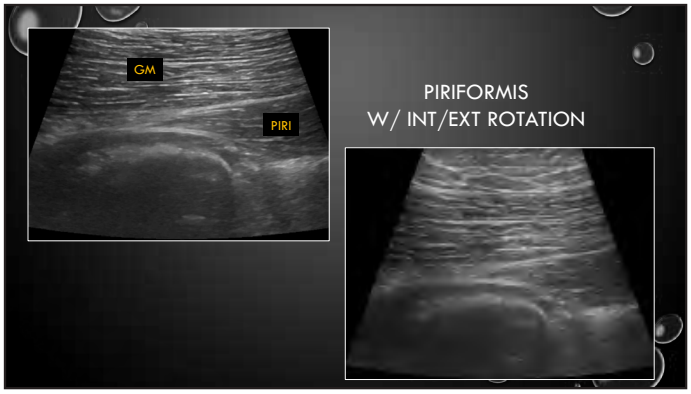

Quadratus Femoris
QF
QF

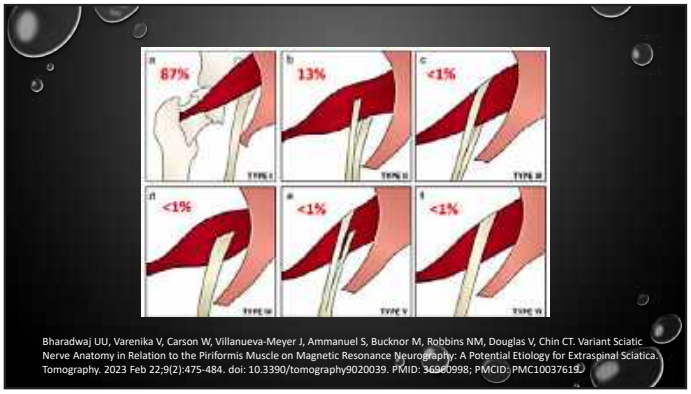

QUADRATUS FEMORIS
ISCH
GT
QF


Ischiofemoral Impingement Syndrome: Clinical and Imaging/Guidance Issues with Special Focus on Ultrasonography


PIRIFORMIS
P


PIRIFORMIS
S
S


GM
PIRI
PIRIFORMIS
W/ INT/EXT ROTATION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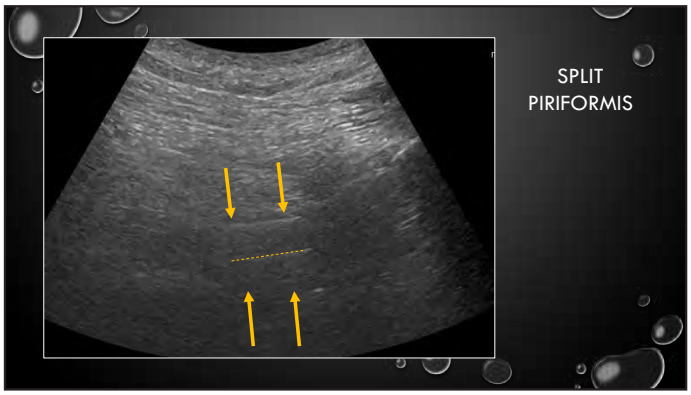
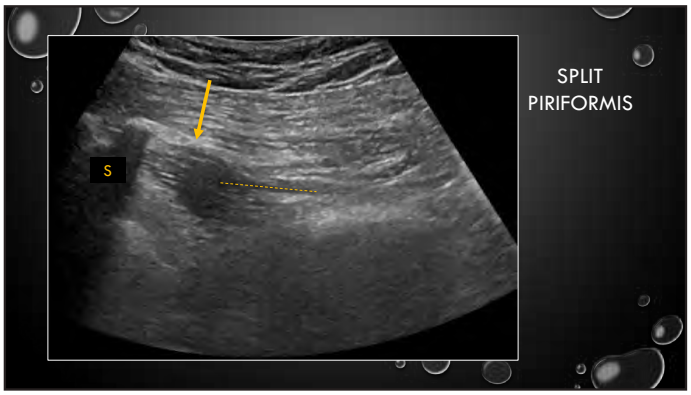
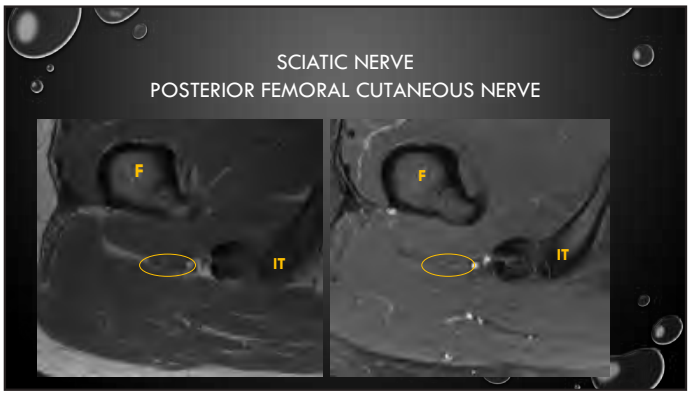
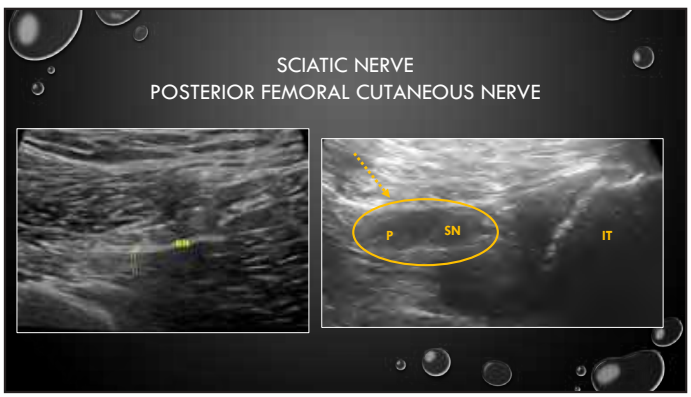
Bharadwaj UU, Varenika V, Carson W, Villanueva-Meyer J, Ammanuel S, Bucknor M, Robbins NM, Douglas V, Chin CT. Variant Sciatic Nerve Anatomy in Relation to the Piriformis Muscle on Magnetic Resonance Neurography: A Potential Etiology for Extraspinal Sciatica. Tomography. 2023 Feb 22;9(2):475-484. doi: 10.3390/tomography9020039. PMID: 36980998; PMCID: PMC10037619


SPLIT
PIRIFORMIS


S
SPLIT
PIRIFORMIS


SPLIT
PIRIFORMIS


SCIATIC NERVE
POSTERIOR FEMORAL CUTANEOUS NERVE
F
IT
F
IT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POSTERIOR FEMORAL CUTANEOUS NERVE
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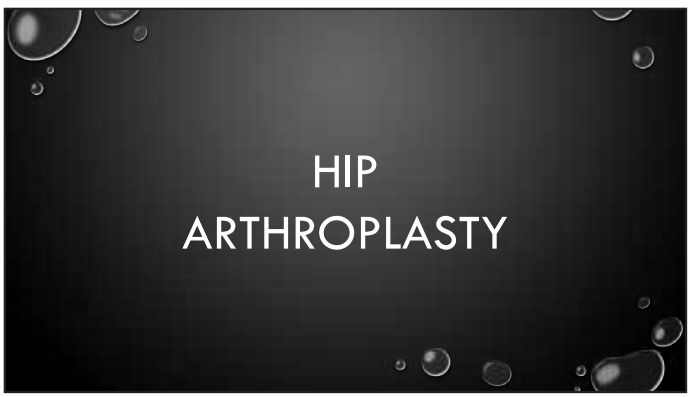

HIP
ARTHROPLASTY

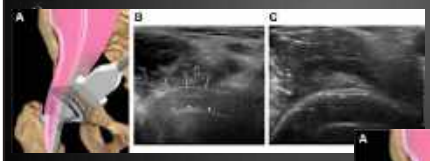
ULTRASOUND IN HIP ARTHROPLASTY

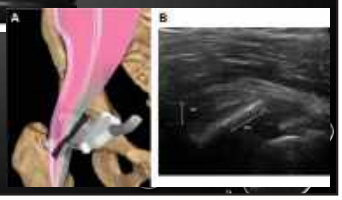
- EFFUSION
- ILIOPSOAS TENDON
- GLUTEAL TENDON

EFFUSION

- EASY TO IDENTIFY WITH ULTRASOUND
- CHECK PRIOR TO ASPIRATION

ILIOPSOAS TENDINOPATHY

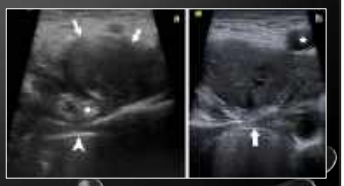




Ultrasound in Total Hip Replacement

ILIOPSOAS TENDINOPATHY

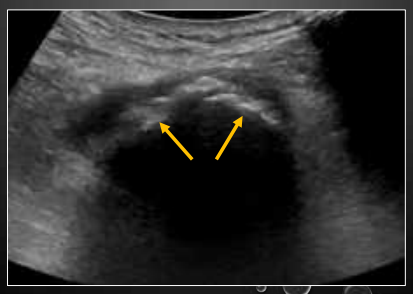
- ILIOPSOAS TENDINOPATHY IS COMMON FOLLOWING HIP ARTHROPLASTY
- BURSAL EFFUSION
- SYNOVIAL THICKENING



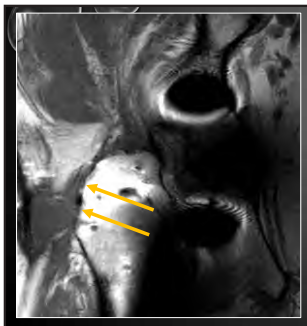
GLUTEAL TENDINOPATHY

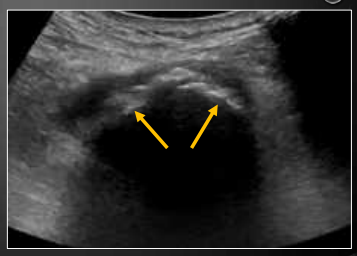
- COMMON FOLLOWING THA
- GLUTEAL TENDON TEARS

FULL THICKNESS GLUTEAL TEAR



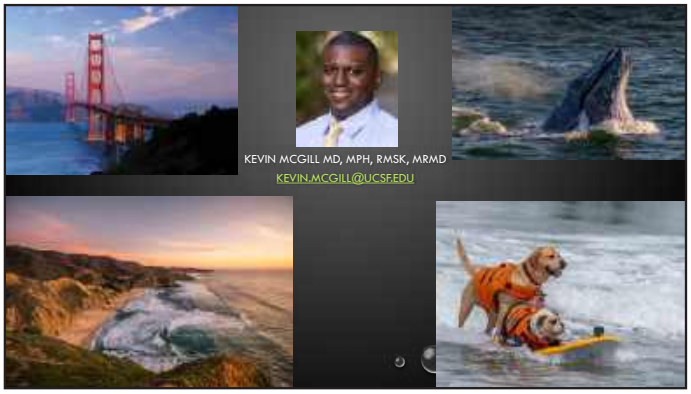
FULL THICKNESS GLUTEAL TEAR





SUMMARY

- HIP ULTRASOUND ★
  - ANTERIOR – HIP, ILIOPSOAS
  - LATERAL – TROCHANTERIC BURSA
  - POSTERIOR – HAMSTRING, QF, PIRIFORMIS
- HIP ARTHROPLASTY
  - EFFUSION
  - ILIOPSOAS BURSA
  - GLUTEAL TENDONS



KEVIN MCGILL MD, MPH, RMSK, MRMD
KEVIN.MCGILL@UCSF.EDU

SELF EVALUATION

Ultrasound of the Hip

True/False

1. When planning an ultrasound guided hip aspiration, it is important to identify the location of medial circumflex artery.

2. On ultrasound of the proximal thigh the muscle deep to the rectus femoris is the sartorius.

3. When evaluating the posterior hip with ultrasound with the patient prone, the hip is typically flexed to help visualize the piriformis.

4. The origin of the piriformis is obscured by shadowing from the sacrum

5. Ischiofemoral syndrome is caused by compression of the piriformis.

Answer Key: 1. F, 2. F, 3. F, 4. T, 5. F

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Imaging Evaluation of Bone Tumors and Tumor-like Lesions

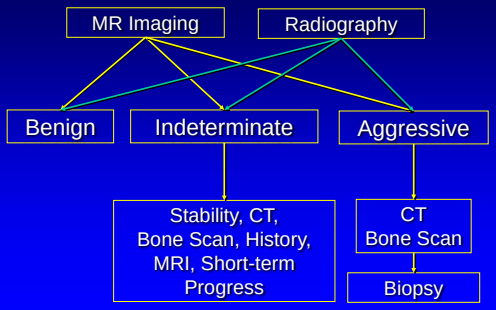
Objectives

- Review algorithm for the work-up of solitary bone lesions
  - Starting point: MRI and radiograph
- Characteristic imaging features of specific bone lesions
- Determine which lesions require biopsy

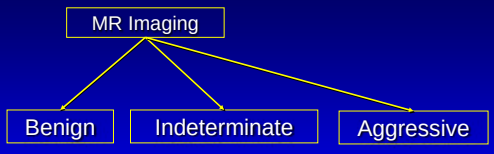
Take Home Points

- Radiography:
  - Essential: benign versus other
- MRI: sensitive but not specific
  - Contrast: only describes cyst versus solid
- CT: matrix mineralization characterization
- Bone scan / PET: global picture, activity

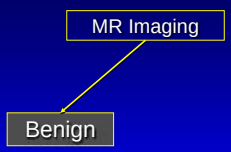
SOLITARY BONE LESION



SOLITARY BONE LESION

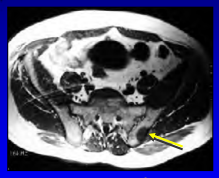


SOLITARY BONE LESION



MRI: Solitary Bone Lesion

- A lesion cannot be labeled benign by MRI unless pathognomonic
  - Malignancy may not appear aggressive
- MRI: sensitive but not specific
- Many lesions are indeterminate
- If considering tumor, need radiograph to further characterize



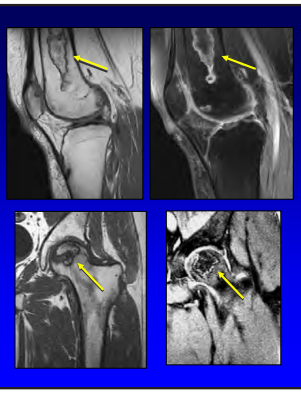
Metastasis

Benign Bone Lesions on MRI: No biopsy indicated

- Osteonecrosis
- Fracture
- Fibrous cortical defect
- Avulsive cortical irregularity
- Enchondroma: *see pitfall*

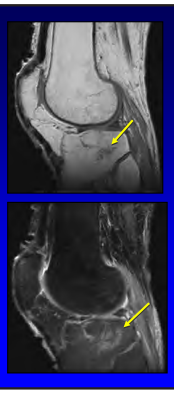
Osteonecrosis

- Bone infarct (metaphysis) and avascular necrosis (epiphysis)
- Geographic low signal rim
- Variable internal signal
- Double line sign:
  - High signal (T2w) or enhancing rim on inner surface of rim



Bone Injury and Fracture

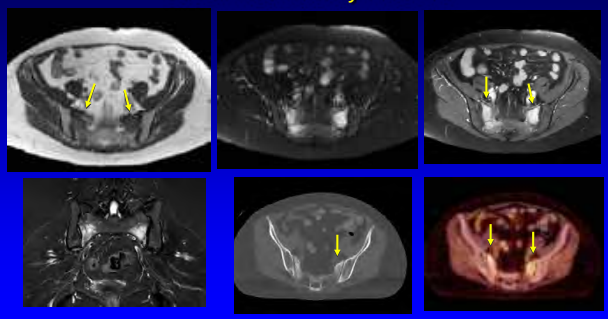
- Increased fluid signal: non-specific
- Reactive edema:
  - Usually not replace fat
  - If unclear: get CT
  - Evaluate for lytic process
- Look for fracture line:
  - Low T1, variable T2 signal



Stress Fracture

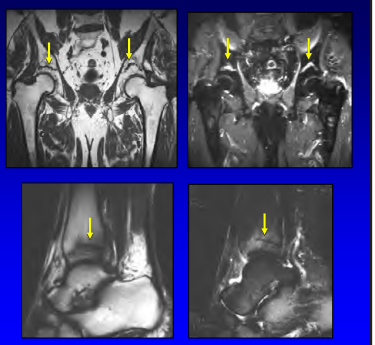
- Insufficiency: normal stress, abnormal bone
  - Sacrum, pubic rami, pelvis, tibia, calcaneus
- Fatigue: abnormal stress, normal bone
  - Metatarsal shaft, femoral neck
- Imaging: often non-specific
  - Hot bone scan, abnormal PET, enhancement
- MRI: fracture line, location, distribution, configuration

Sacral Insufficiency Fracture



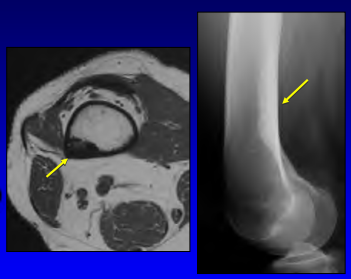
Stress Fracture Lines

- Sacrum: sagittal, parallel to SI joint
- Pubic rami
- Acetabulum: superior, transverse
- Ischium: sagittal
- Tibia: transverse



Non-ossifying Fibroma

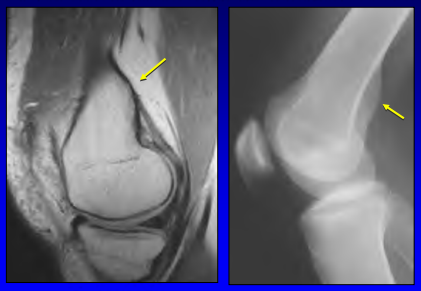
- Metaphyseal
  - Later: diaphyseal
- Long bone
- Cortical based (endosteal)



Avulsive Cortical Irregularity

- Periosteal or juxtacortical desmoid
- Medial gastrocnemius and adductor magnus insertions
- Erosion or bone proliferation
- Possible soft tissue and marrow edema
- No enhancing mass

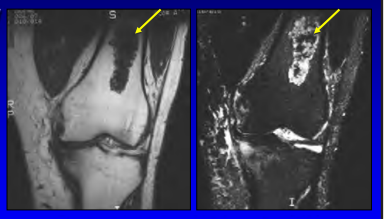
Avulsive Cortical Irregularity: healed



Sagittal T1w

Enchondroma

- Lobular, high signal T2w images
- Chemical shift artifact
- Possible low signal mineralized matrix
- Cortical thinning < 2/3 thickness
- No aggressive features
  - Soft tissue mass, etc.

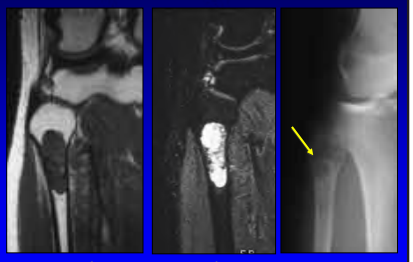


RadioGraphics 1998; 18:1213

Enchondroma: pitfall

- If symptomatic (and no fracture):
  - Consider atypical cartilaginous tumor (low grade chondrosarcoma)
  - Biopsy

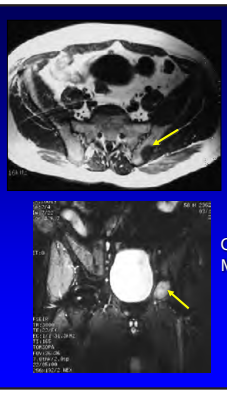
Atypical Cartilaginous Tumor



Coronal T1w Coronal T2w

Rule: Solitary Bone Lesion

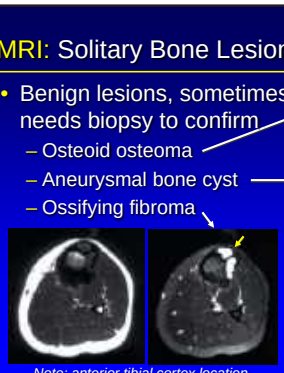
- If lesion is symptomatic or hot on bone scan:
  - May not be benign
  - Complication of a benign lesion
    - Fracture, malignant degeneration
- Must correlate with radiography
  - Benign vs. malignant



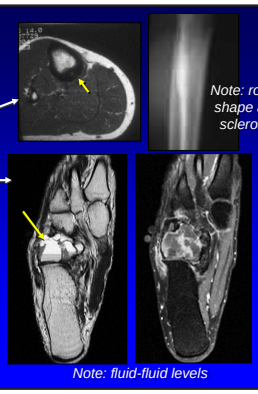
Lung Carcinoma Metastasis

MRI: Solitary Bone Lesion

- Benign lesions, sometimes needs biopsy to confirm
  - Osteoid osteoma
  - Aneurysmal bone cyst
  - Ossifying fibroma



Note: anterior tibial cortex location



Note: round shape and sclerosis

Note: fluid-fluid levels

SOLITARY BONE LESION

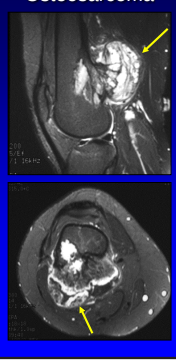
MR Imaging

Benign Aggressive

MRI: Solitary Bone Lesion

- Aggressive
  - Ill defined
  - Surrounding high T2w signal
  - Cortical destruction
  - Soft tissue mass
- If considering tumor, need radiograph to further characterize

Osteosarcoma



Lymphoma: tibia

Axial T1w Axial T2w Gadolinium

Note: extra-osseous soft tissue mass with relatively normal cortex

Ewing Sarcoma: ilium

Note: extra-osseous soft tissue mass with relatively normal cortex

Chondrosarcoma:
Malignant Transformation of Osteochondroma

Coronal T1w

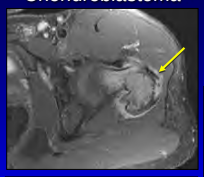
Coronal T2w

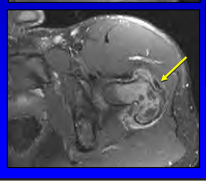
Note osteochondroma (open arrow)

MRI: Pitfall

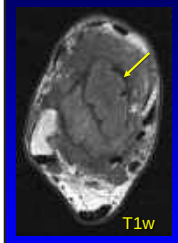
- Some low grade or benign lesions are associated with soft tissue edema
  - Chondroblastoma
  - Osteoblastoma
  - Osteoid osteoma
  - Any lesion with fracture
  - Infection

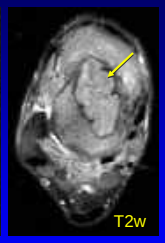
Chondroblastoma

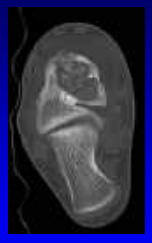




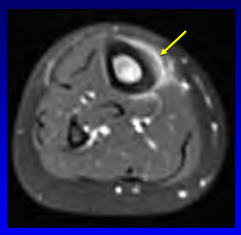
Osteoblastoma



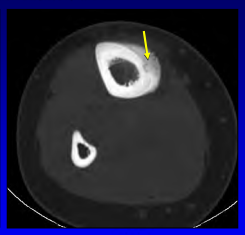




Osteoid Osteoma



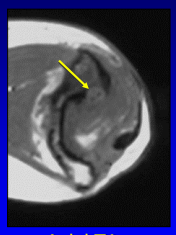
Axial T1w post-gado



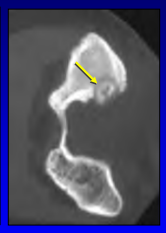
CT

Teaching Point
CT is excellent for identification of mineralized nidus

Osteoid Osteoma: intra-articular

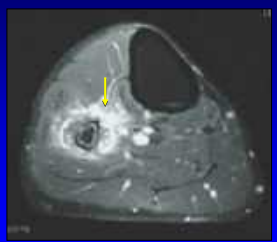


Axial T1w



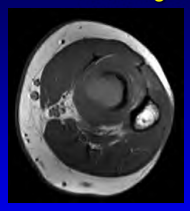
Sagittal T1w post-gado

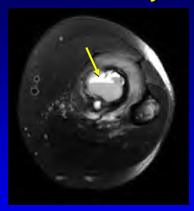
Pathologic Fracture: enchondroma

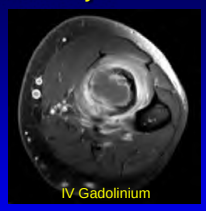


Axial T1w post IV Gado

Pathologic Fracture: aneurysmal bone cyst







Teaching Point
Expansile bone lesion with fluid-fluid levels and NO enhancing soft tissue mass = ABC

MRI: Solitary Bone Lesion

- Aggressive
- Report:
  - Osseous extent and skip lesion
  - Soft tissue extension
  - Intra-articular extension
  - Neurovascular involvement
  - Necrotic areas after gadolinium administration

Osteosarcoma

T1w T2w

SOLITARY BONE LESION

MR Imaging

Benign | Indeterminate | Aggressive

- Indeterminate
  - Does not fit into either benign or aggressive categories
  - Not symptomatic

SOLITARY BONE LESION

Radiography

Benign | Indeterminate | Aggressive

Radiography: Solitary Bone Lesion

- Primary question:
  Joint process or bone process?
  - Joint process:
    - Arthritis
    - Synovial proliferative disorder
  - Bone process:
    - Tumor, infection

Plasmacytoma: scapula

Subchondral Cyst: intra-articular gas

SOLITARY BONE LESION

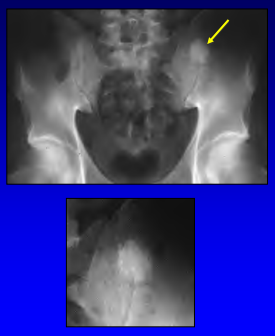
Radiography

Benign

- If lytic:
  - Well-defined + sclerotic border = benign
  - Well-defined, non-sclerotic border = indeterminate
  - Ill-defined border: aggressive

Radiography: Solitary Bone Lesion

- Benign - *sclerotic*:
  - Uniformly dense
  - Irregular shape
  - Typically not round
  - Spiculated border = Bone Island (enostosis)



Radiography: Solitary Bone Lesion

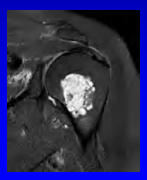
- Benign - *sclerotic*:
  - Serpiginous sclerotic border
  - Geographic
  - No endosteal scalloping
  - Smoke-like appearance
  - Osteonecrosis

Coronal T1w

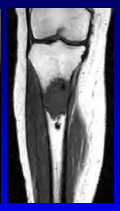
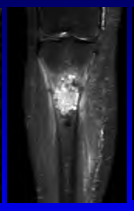
Radiography: Solitary Bone Lesion

- Benign - *sclerotic*:
  - Lobular contours
  - Rings and arcs = chondroid
  - Little endosteal scalloping
  - No aggressive features
  - Enchondroma: must be asymptomatic





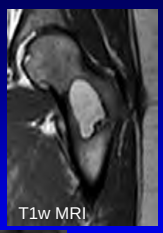
Dedifferentiated Chondrosarcoma

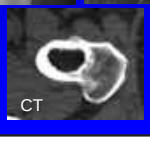




Post-contrast

Radiography: Solitary Bone Lesion

- Benign - *lucent*:
  - Sclerotic border
  - Intertrochanteric or calcaneal
  - Lucent center: fat
    - Requires CT or MRI to confirm
  - Intra-osseous Lipoma



T1w MRI


CT

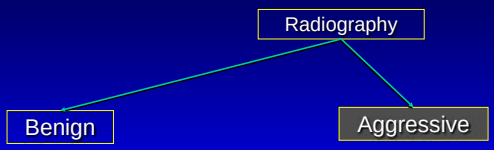
Radiography: Solitary Bone Lesion

- Benign - *lucent*:
  - Sclerotic border
  - Endosteal location*
  - Metaphyseal
  - Later: diaphyseal and sclerotic
  - Non-ossifying Fibroma


Radiography: Solitary Bone Lesion

- Benign - *lucent*:
  - Sclerotic border
  - Metaphyseal
  - Fallen fragment sign from pathologic fracture
  - MRI: confirms cyst
  - Unicameral Bone Cyst

SOLITARY BONE LESION



Radiography: Solitary Bone Lesion

- Aggressive
  - Ill defined
  - Permeative
  - Wide zone of transition
  - Aggressive periostitis

Lymphoma


Renal Cell Carcinoma Metastasis

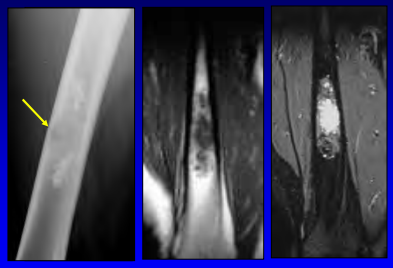

Metastasis: unknown primary

11 ga. Bone Biopsy

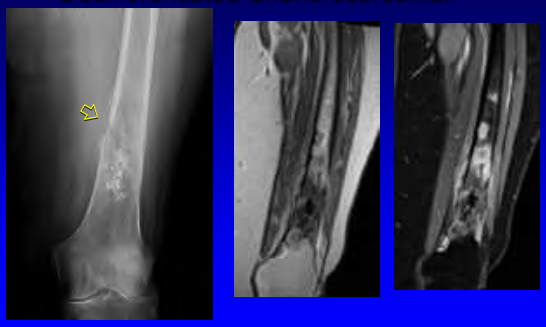
Chondrosarcoma

- Pain
- Deep scalloping >2/3 cortical thickness
- Cortical destruction
- Soft tissue mass
- Periosteal reaction
- Uptake bone scan > anterior iliac crest
- > 5-6 cm in size

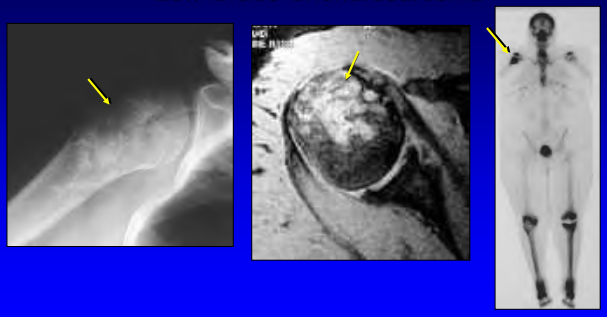
Radiographics 1998; 18:1213



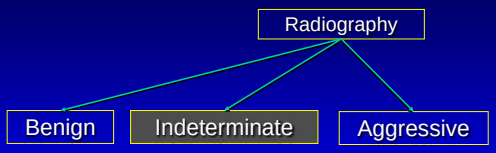
Dedifferentiated Chondrosarcoma:



Low Grade Chondrosarcoma



SOLITARY BONE LESION

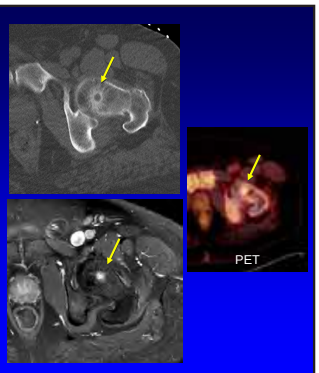


Radiography: Solitary Bone Lesion

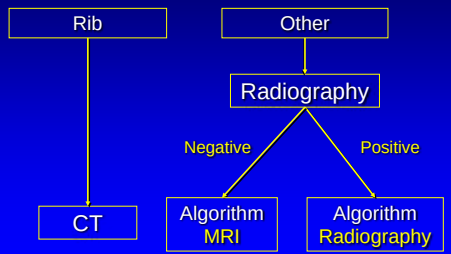
- Indeterminate
  - Does not fit into either benign or aggressive categories
  - If pain: consider aggressive
  - Consider MRI with gadolinium: cyst versus solid
  - Consider biopsy

Radiography: Solitary Bone Lesion

- Indeterminate - *lucent*:
  - Ill-defined sclerotic border
  - Not specific for a benign etiology
  - Consider further imaging: MRI- cyst versus solid
  - Metastasis



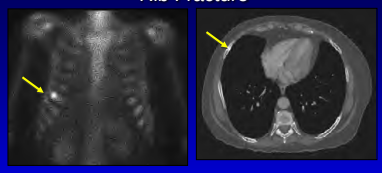
Bone Scan: Solitary Bone Uptake



Solitary Bone Lesion: Bone Scan

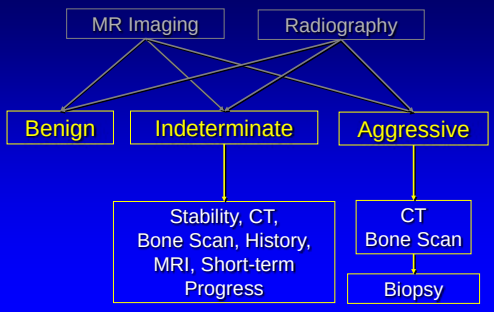
- Rib
  - Get thin section CT
- Benign
  - Old fracture
  - Fibrous dysplasia (ground glass)
- Aggressive
  - Biopsy

Rib Fracture

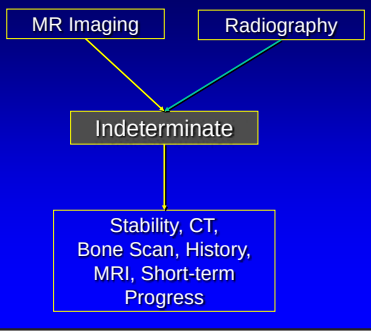


Plasmacytoma

SOLITARY BONE LESION



SOLITARY BONE LESION



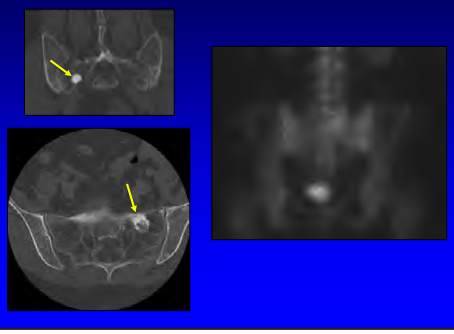
Solitary Bone Lesion: Indeterminate Lesion

- Prior imaging
  - To document stability
- Additional history
  - If painful, may need to biopsy
- Bone scan (or PET)
  - To determine if uptake

Fibrous Dysplasia or Benign Fibro-osseous Lesion

Teaching Point
Uptake on bone scan equal or less than iliac crest = benign

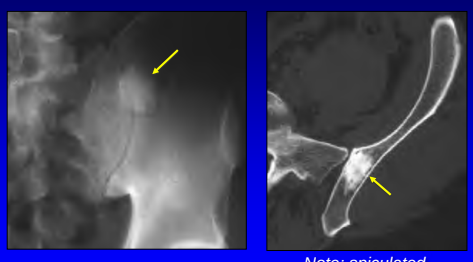
Benign Fibroosseous Lesions



Solitary Bone Lesion: Indeterminate Lesion

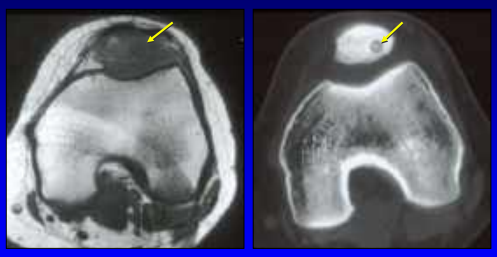
- CT
  - To further characterize
- MRI (if lesion found on radiograph)
  - To determine if pain is from another source (meniscus)
- Consider short-term progress (6 - 8 weeks) or biopsy

Bone Island: CT



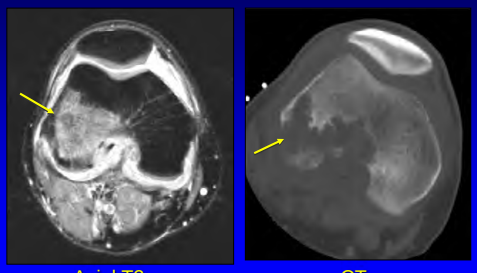
Note: spiculated margins on CT

Osteoid Osteoma



Axial T1w CT

Fungal Infection



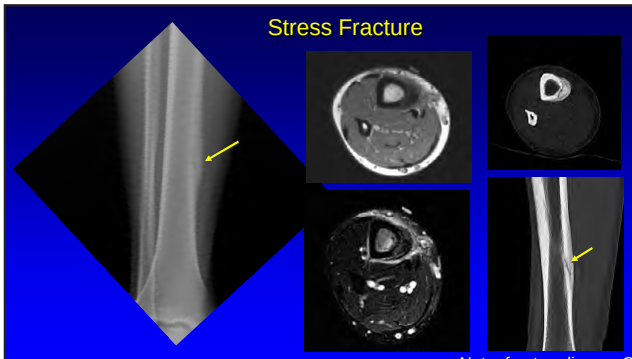
Axial T2w CT

Intraosseous Lipoma: pathologic fracture

CT

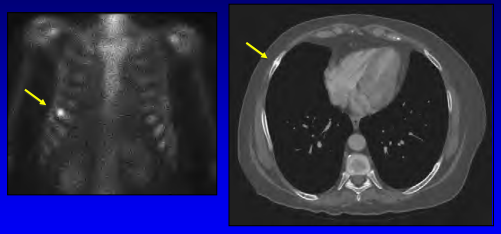
Note: fat attenuation on CT

Stress Fracture



Note: fracture line on CT

Rib Fracture



SOLITARY BONE LESION

MR Imaging

Radiography

Aggressive

CT
Bone Scan

Biopsy

Solitary Bone Lesion: Aggressive Lesion

- Bone scan:
  - Multiplicity (differential)
  - Safest site of biopsy
  - Which site to biopsy (area of increased uptake)
- CT: safest route of biopsy
- MRI: extent

Breast Carcinoma Metastasis: ilium

Renal Cell Carcinoma Metastasis

Take Home Points

- MRI:
  - Sensitive but non-specific
  - Gadolinium: cyst versus solid
  - Radiographic correlation essential
- Radiography and CT:
  - Sclerotic well-defined border: benign
  - Characterize mineralization
- Bone / PET scan: activity

Thank you!

Syllabus online and other educational material:
www.jacobsonmskus.com

SELF EVALUATION

Imaging Evaluation of Bone Tumors and Tumor-like Lesions

True/False

1. A well-defined bone lesion on MRI with aggressive features may be malignant

2. A chondroid bone lesion without aggressive features on imaging but with symptoms should be considered malignant until proven otherwise.

3. A lytic bone lesion with well-defined and sclerotic borders is benign.

4. A sclerotic bone lesion that is oval demonstrating a spiculated border is diagnostic for an enostosis or bone island.

5. A bone lesion with uptake on bone scan that is less than the anterior iliac crest favors a benign etiology.

Answer Key: 1. T, 2. T, 3. T, 4. T, 5. T

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Imaging of Musculoskeletal Infection

Objectives:

1. Understand mechanism of musculoskeletal infection
2. Recognize imaging findings of musculoskeletal infection
3. Differentiate osteomyelitis from neuropathic joint

Outline:

- Mechanisms
- Soft tissue infection
- Septic arthritis
- Osteomyelitis
  - Neuropathic joint
  - Discitis

Mechanisms:

- Hematogenous
  - Children, intravenous drug users
- Contiguous source
  - Diabetic ulcer
- Direct implantation
  - Penetrating injury
  - Surgery

Infection: hematogenous

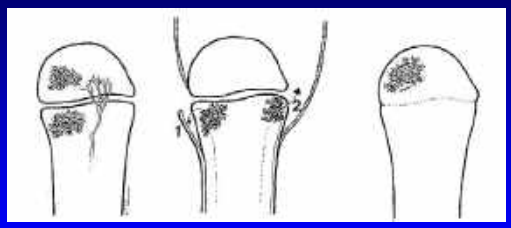
- Abscess (pyomyositis)
- Septic bursitis
- Septic arthritis
  - Acromioclavicular, sternoclavicular
  - Sacroiliac
- Osteomyelitis
  - Vascular patterns differ with age

Normal Vascular Patterns

Infant Child >1 year Adult

From: Ortho Clin North Am 1998; 29:41

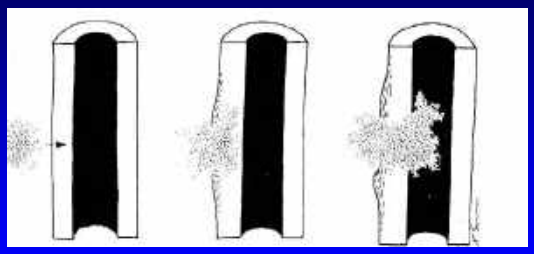
Sites of Hematogenous Osteomyelitis



Infant Child >1 year Adult

From: Ortho Clin North Am 1998; 29:41

Osteomyelitis: Contiguous Source



From: Ortho Clin North Am 1998; 29:41

Osteomyelitis: Direct Implantation

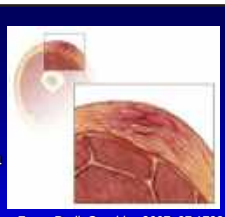
Retained Cat Tooth

Outline:

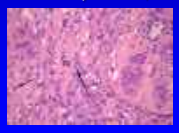
- Mechanisms
- Soft tissue infection
- Septic arthritis
- Osteomyelitis
  - Neuropathic joint
  - Discitis

Cellulitis

- Acute inflammation:
  - Dermis, subdermis
  - Erythema, warmth, edema
- Cause: disruption of skin
  - *Staph. Aureus*
  - *Strep. pyogenes*
- Susceptible:
  - Vascular disease
  - Indwelling objects



From: RadioGraphics 2007; 27:1723



From: Skeletal Radiol 2010 in print

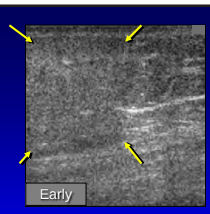
Cellulitis

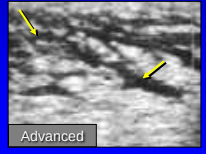
- Radiography and CT:
  - Soft tissue swelling
  - Increased density

Cellulitis: ultrasound

- Early (<3 days):
  - Thick subcutaneous tissues, increase echogenicity
- Advanced:
  - Distorted, anechoic channels
- Severe, advanced:
  - Fluctuating purulent fluid
  - Guided aspiration: efficacy similar to surgery
- Late: abscess formation

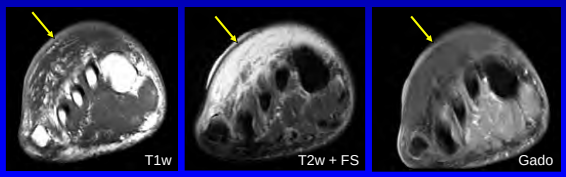
J Ultrasound Med 2000; 19:743





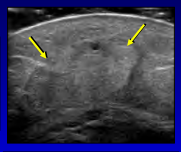
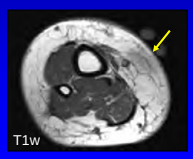
Cellulitis

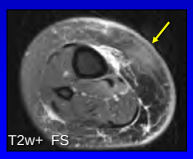
- MRI:
  - Abnormal fluid signal
  - Isolated: subcutaneous tissues

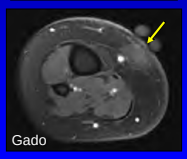


Differential Diagnosis

- Fat necrosis
  - Pain, palpable, focal
  - Thigh, women
  - No erythema
  - Normal WBC

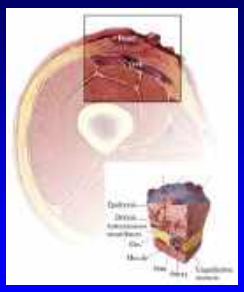




J Ultrasound Med 2008; 27:1751

Necrotizing Fasciitis

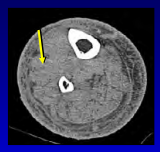
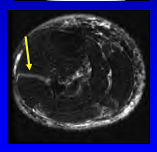
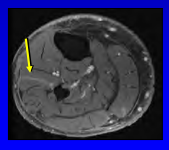
- Infection:
  - Into deep fascia: progressive
  - Necrosis: subcutaneous
- Gas-forming:
  - Anaerobes, aerobic gram negative
- Life threatening emergency
  - 70 – 80% mortality if delayed diagnosis




From: RadioGraphics 2007; 27:1723

Necrotizing Fasciitis

- Deep fascia
  - Thick, enhancing
  - Non-specific
- Gas:
  - Radiography, CT
  - MRI: signal void
  - US: echogenic, dirty shadow
- Muscle abscesses

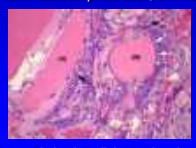





RadioGraphics 2004; 24:1472

Abscess

- *Staph. aureus*: 77%
- Direct spread or hematogenous
- Usually one muscle:
  - Quads > gluteal > iliopsoas
- Pyomyositis: bacterial
  - Common: HIV

From: RadioGraphics 2007; 27:1723



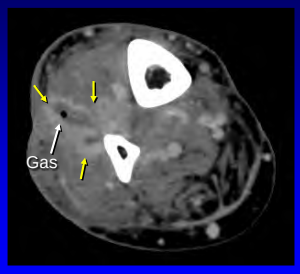
From: Skeletal Radiol 2010 in print

Abscess

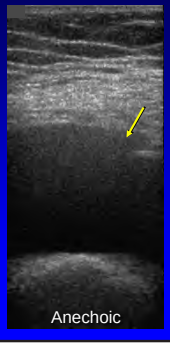
- CT:
  - Fluid collection + ring enhancement
- Ultrasound:
  - Fluid: hypoechoic to hyperechoic
  - May appear solid
- MRI:
  - Fluid signal + ring enhancement
  - T1w: high signal rim*

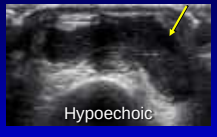
Radiology 1995; 197:279

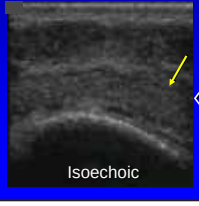
Abscess: Radiography and CT

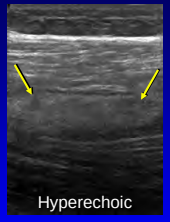



Abscess: ultrasound



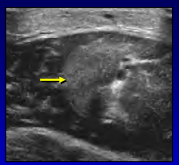


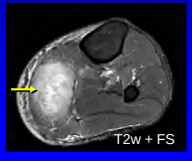


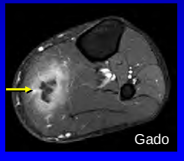


- Dynamic compression
- Through-transmission

MRI Abscess: calf



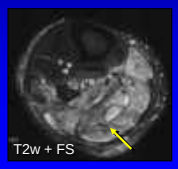



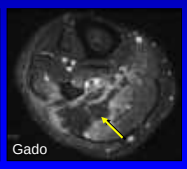


Differential Diagnosis

- Diabetic muscle infarction
- Imaging:
  - Not homogeneous fluid signal
  - Relatively normal muscle architecture
- History:
  - Diabetes
  - Long standing)
  - Normal WBC
- Thigh > calf

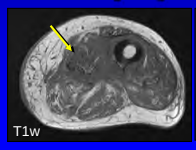
AJR 2000; 174:165

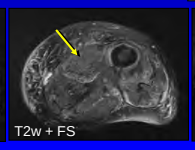


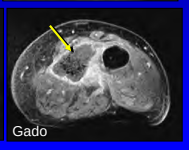


Differential Diagnosis

- Retained foreign body
  - Surgical material
  - Gossypiboma
  - Looks like hetergeneous fluid
  - Low signal gas on MRI







AJR 2000; 174:165

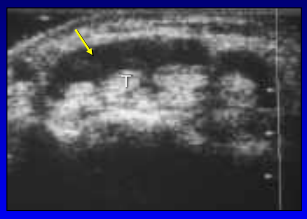
Infective Tenosynovitis

- Uncommon
- Puncture, bite: hand, foot
- Hand: anatomy
  - Flexor tendon sheaths:
    - Thumb connects to little finger
  - Extensors: separate sheaths
- Imaging:
  - Fluid distention: complex
  - Synovitis

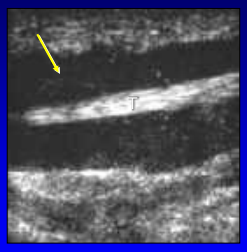
Dorsal

Palmar

Tenosynovitis

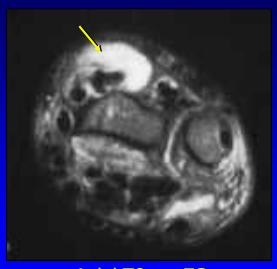


Wrist: dorsal



Foot: dorsal

Infective Tenosynovitis: wrist



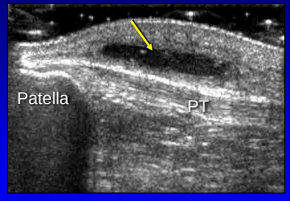
Axial T2w + FS

Axial post-gad

Septic Bursitis

- Direct inoculation
- Olecranon & prepatellar
- Spread from joint
- Radiography:
  - Swelling, possible gas
- Ultrasound / MRI:
  - Fluid collection in expected location of a bursa
  - Possible gas

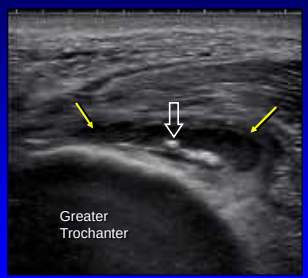
Prepatellar Bursitis



Sagittal

Axial

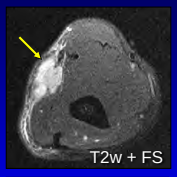
Trochanteric Bursa: infection + gas

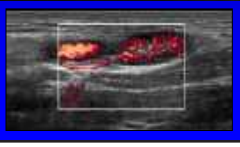


Cat scratch disease = infection

- Animal scratch: usually a cat
  - Bartonella henselae
- Child or adolescent:
  - Most common
- Elbow:
  - Lymphadenopathy
  - Epitrochlear lymph node (medial)

Epitrochlear Lymph Nodes: hyperplastic





Outline:

- Mechanisms
- Soft tissue infection
- Septic arthritis
- Osteomyelitis
  - Neuropathic joint
  - Discitis

Septic Arthritis

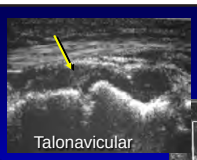
- Hematogenous:
  - *S. aureus* > *Streptococcus*
- Usually large joint
- Also, joints with acronyms
  - ACJ, SCJ, SIJ
  - Small vessels, slow flow
  - Increased risk of infection
- Irreversible joint damage:
  - 48 hours

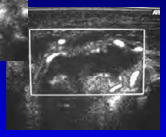
Septic Arthritis

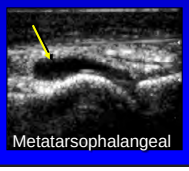
- Radiography / CT:
  - Periarticular osteopenia
  - Joint space widening
    - Acute lax joint, chronic infection
  - Uniform joint space narrowing
  - Indistinct subchondral bone plate
  - Erosions
  - Bone destruction

Septic Arthritis

- Ultrasound:
  - Joint effusion:
    - Variable echogenicity
    - Anechoic to echogenic
  - Hyperemia:
    - Lack of flow does not exclude infection*
  - Synovial thickening
  - Guided aspiration



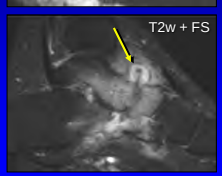




RadioGraphics 1999; 19:1585
*AJR 1998; 206:731

Septic Arthritis

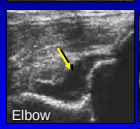
- MRI:
  - Synovial enhancement (98%)
  - Perisynovial edema (84%)
  - Adjacent marrow edema (84%)
  - Joint effusion:
    - 91% of large joints
    - 54% of small joints
  - Synovial thickening (22%): atypical infection



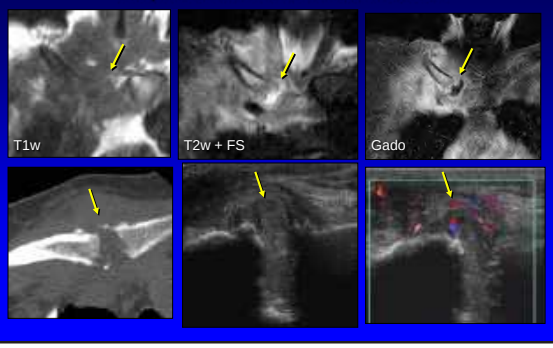
AJR 2004; 182:119

Joint Recesses:

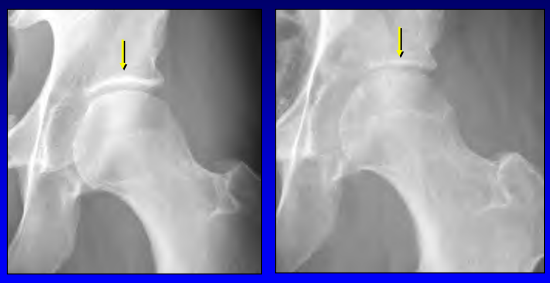
- Shoulder: biceps, posterior
- Elbow: posterior
- Wrist: dorsal
- Hip: anterior femoral neck
- Knee: superior, medial, lateral to patella
- Ankle: anterior
- MCP, MTP: dorsal recesses



Septic Joint: sternoclavicular

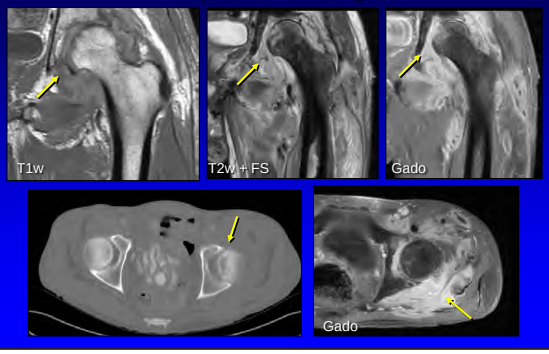


Septic Joint: fungal



10 days later

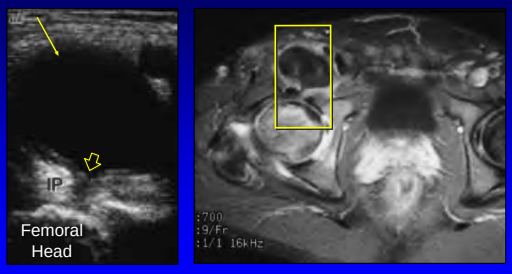
Septic Joint: fungal



Septic Arthritis: diagnosis

- Joint aspiration:
  - Fluoroscopic or ultrasound-guided
- Prior to fluoroscopic aspiration:
  - Must have cross-sectional imaging
  - Exclude overlying bursa or abscess
  - Avoid contamination of a sterile joint by passing needle through overlying bursa
  - Screen for post-operative fluid collections

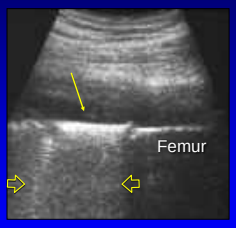
Iliopsoas Bursal Fluid



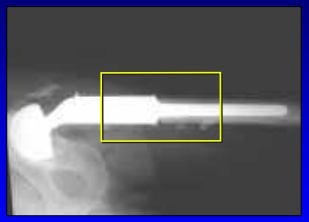
Axial

T1w post-gadolinium

Hip Arthroplasty: infection



Coronal



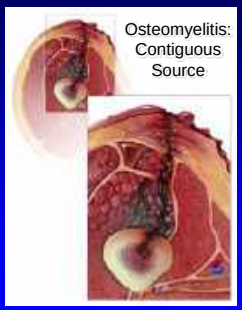
Radiograph

Outline:

- Mechanisms
- Soft tissue infection
- Septic arthritis
- Osteomyelitis
  - Neuropathic joint
  - Discitis

Osteomyelitis

- Staphylococcus aureus
  - HIV: atypical Mycobacteria
- Blood cultures:
  - Only positive in 50% (hematogenous)
- Radiographs:
  - Abnormal after 14 – 21 days
- Serology:
  - ESR elevated
  - WBC: often elevated
  - Fever: variable



From: RadioGraphics 2007; 27:1723

Osteomyelitis: mechanism

- Hematogenous:
  - Infection begins in medullary space of bone
  - Spreads out from bone
  - Children, intravenous drug users, septic
- Contiguous source:
  - Soft tissue abnormality (ulcer) extends to bone
- Direct implantation
  - Surgery (2%), cat bite, puncture wound

Osteomyelitis: acute versus chronic

- Acute:
  - Bone destruction
  - Periostitis: only in children (loose periosteum)
- Chronic:
  - Extensive periostitis, sclerosis
  - Brodie abscess
  - Sequestrum, cloaca, involucrum

Osteomyelitis: adult versus child

- Adult:
  - Often direct spread: ulcer
  - Periostitis: only when subacute / chronic
- Child:
  - Hematogenous
  - Metaphyseal equivalent (100%)*
    - Single bone (63%), contiguous bones (37%)*
    - Subperiosteal abscess: early finding**
    - Periostitis: early sign (acute)
  - Adjacent soft tissue abscess (55%)*

*AJR 2007; 189:867
**Pediatr Radiol 1996; 26:291

Acute Osteomyelitis: *Radiography*

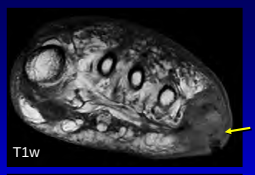
- If ulcer:
  - Look at adjacent bone
  - Early: discontinuous cortex
  - Later: bone destruction
  - Periostitis: not a feature
- If no ulcer:
  - Look for permeative appearance of bone
- Up to 3 weeks to identify

Follow-up

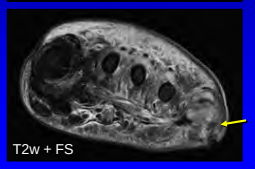
Acute Osteomyelitis: *MRI: criteria*

- If ulcer:
  1. Extends from ulcer to bone
  2. Cortex disrupted
  3. T1w: low signal
  4. T2w: high signal
  5. Contrast: + enhancement

*More criteria, higher likelihood of osteomyelitis



T1w



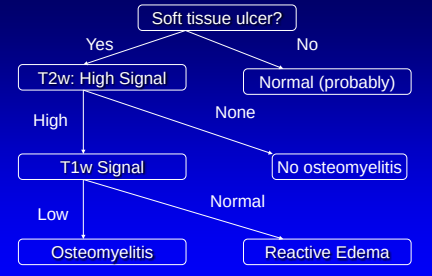
T2w + FS

Osteomyelitis: MRI

- Inversion recovery and T2w fat saturation:*
  - Highest sensitivity for osteomyelitis (not specific)
  - Highest negative predictive value
- T1-weighted images:**
  - Adds specificity
  - If high T2w and normal T1w: reactive edema
- MRI unenhanced:
  - 98% sensitivity, 75% specificity***

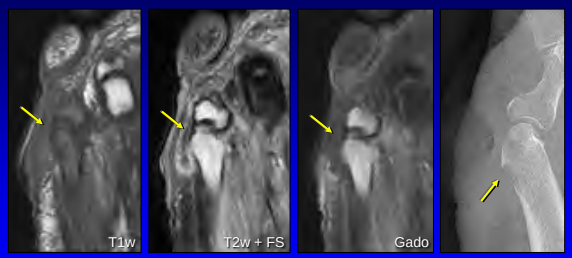
*Radiology 1998; 207:625
**AJR 2005; 185:386
***Radiology 1991; 180:533

Osteomyelitis: adult diabetic

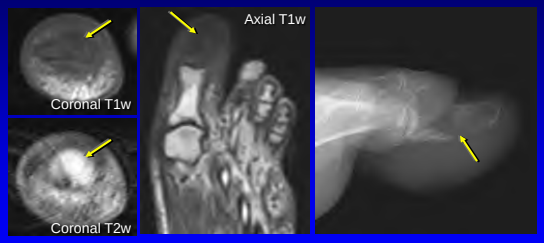


*Gadolinium not needed for osteomyelitis diagnosis

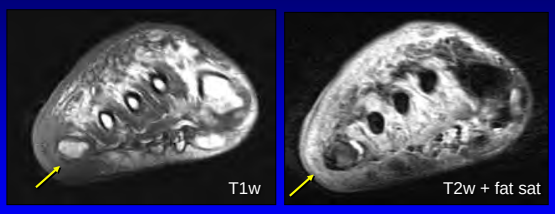
Osteomyelitis: 5th metatarsal



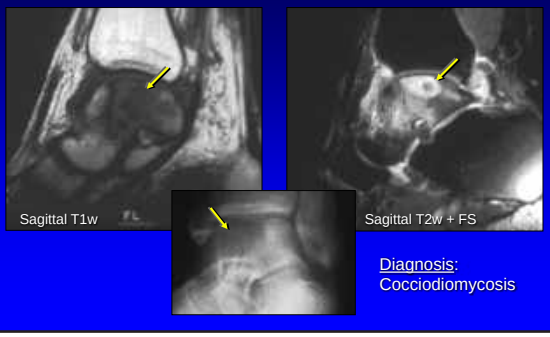
Osteomyelitis: 1st distal phalanx



Reactive Edema

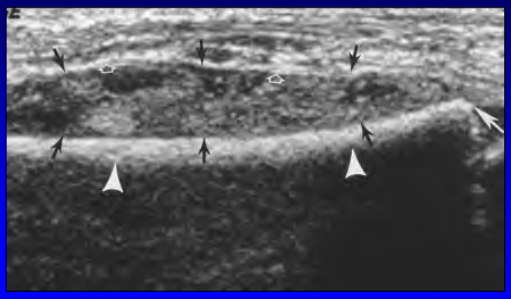


Osteomyelitis: hematogenous

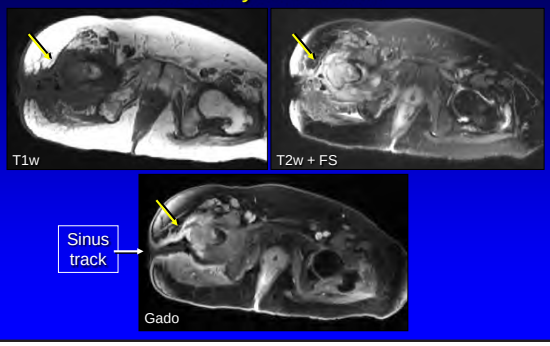


Diagnosis:
Cocciodiomycosis

Subperiosteal Abscess: tibia



Osteomyelitis: femur

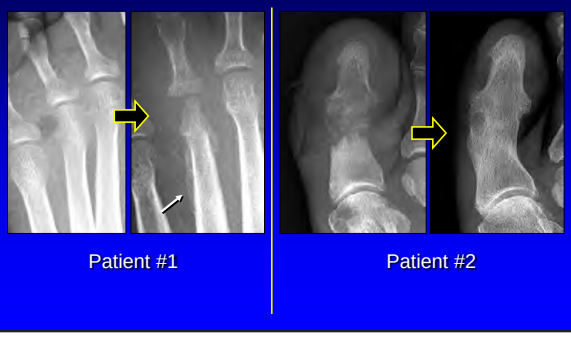


Osteomyelitis: chronic

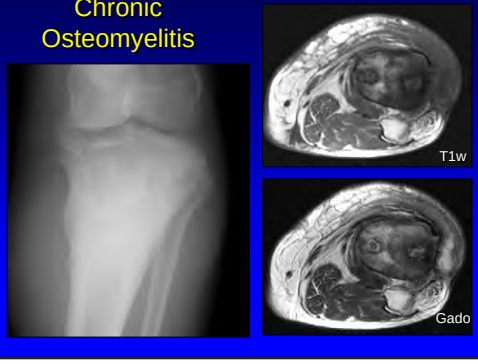
- Radiography:
  - Remodeled, sclerotic, lucent
  - Exuberant periostitis
- CT:
  - Sequestrum:
  - Scan without and with contrast
- MRI:
  - Less fluid signal
  - Brodie's abscess

*Radiology 1998; 207:625
**AJR 2005; 185:386
***Radiology 1997; 203:849

Chronic Osteomyelitis



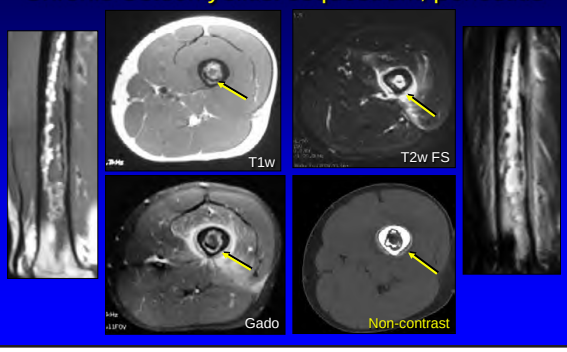
Chronic Osteomyelitis

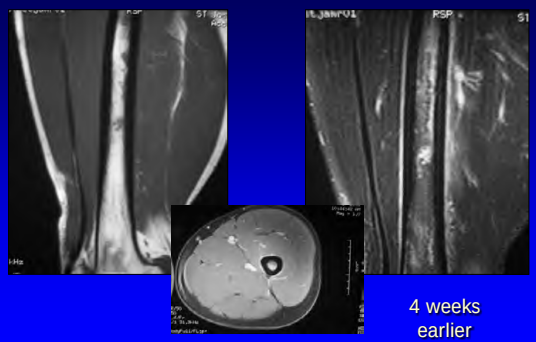


Osteomyelitis: chronic

- Terminology:
  - Brodie abscess: chronic abscess of bone with surrounding fibrosis/sclerosis
  - Sequestrum: dead bone separated from normal bone
  - Cloaca: passage into bone leading to cavity and sequestrum
  - Involucrum: envelope of new bone surrounding sequestrum

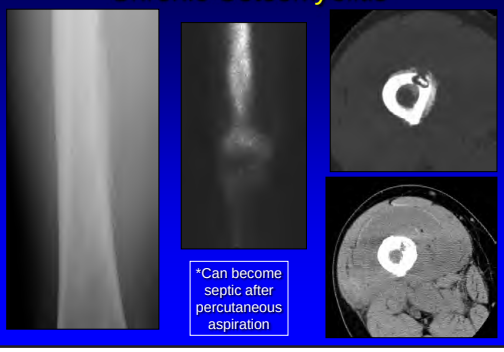
Chronic Osteomyelitis: sequestrum, periostitis





4 weeks earlier

Chronic Osteomyelitis



*Can become septic after percutaneous aspiration

Neuropathic Foot

- Loss of proprioception and deep sensation
- Relaxation, hypotonia
- Recurrent injury
- Malalignment
- Joint destruction and disorganization
- Location: determined by disease
  - Diabetes: lower extremity, esp. midfoot
  - Syrinx: upper extremity, spine

Neuropathic Foot

- Bone marrow edema:
  - High T2w
  - T1w: variable, often normal
- No adjacent ulcer
- Multiple joints: esp. midfoot
  - Osteomyelitis: 5th MT > 1st MT > calcaneus
- Subluxation

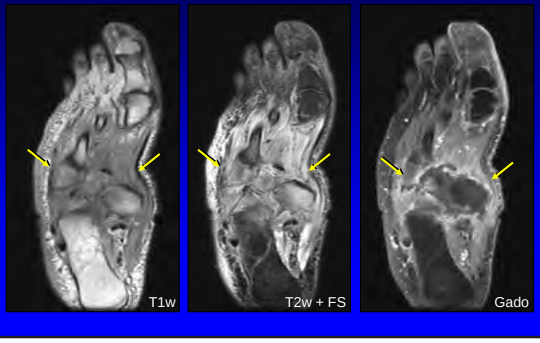
Radiology 2002; 224:649

Neuropathic Foot vs Osteomyelitis

- Absence of ulceration:
  - Osteomyelitis unlikely: no need for MRI*
- Other findings: exclude infection:
  - Location: midfoot
  - Thin rim enhancement of effusion
  - Subchondral cysts, intra-articular bodies
- Findings: superimposed infection**
  - Sinus track, abnormal soft tissues, fluid collection
  - Diffuse abn marrow: low T1, high T2, +enhancement

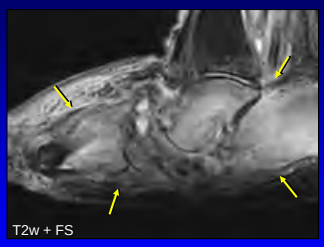
*J Am Coll Radiol 2008; 5:881
**Radiology 2006; 238:622

Neuropathic Foot

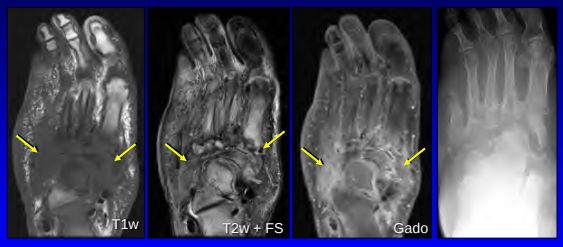


Neuropathic Foot

Neuropathic Foot

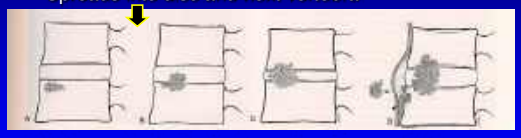


Neuropathic Foot



Discitis

- Adult:
  - Begins subchondral bone: anterolateral
  - Spreads into disc and next vertebra



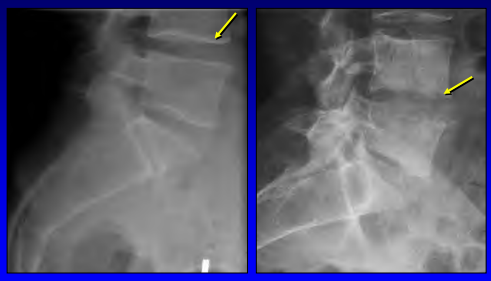
- Child: may begin in disc (usually < 7 years old)
  - Annulus fibrosus: vascular / lymphatic supply up to 20 years

Discitis: acute

- Radiography:
  - Ill-defined endplate
  - Possible disc space narrowing
  - Focal lucency: anterior subchondral bone
- MRI:
  - Endplates: fluid signal
  - Disc: fluid signal
    - May not be uniform
  - Paraspinal abscesses: TB

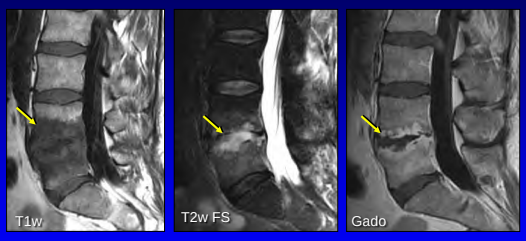
Sem Musculoskel Radiol 2004; 8:215

Discitis: acute



1 year earlier

Discitis: acute



Differential Diagnosis

- Degenerative changes:
  - Modic 1: fluid signal
  - Modic 2: fat signal
  - Modic 3: low signal
- Signal of disc: helpful
  - If low: degeneration
  - If high: suspect infection

Note low signal of disc

Discitis: chronic

- Radiographs / CT:
  - Ill-defined endplates
  - Sclerotic
- MRI:
  - Improvement in fluid signal

Take Home Points:

- Osteomyelitis: adult
  - Look at bone adjacent to ulcer
  - Radiograph: loss of cortical line
  - MRI:
    - High T2, low T1 = osteomyelitis
    - High T2, normal T1 = reactive edema
- Osteomyelitis: child
  - Subperiosteal abscess, periostitis

Take Home Points:

- Neuropathic joint:
  - No ulcer: osteomyelitis rare
- Septic hip or shoulder:
  - Screen soft tissues with cross-sectional imaging before fluoroscopic aspiration

Thank you!

Syllabus online and other educational material:
www.jacobsonmskus.com

SELF EVALUATION

Imaging of Musculoskeletal Infection

True/False

1. Ultrasound assessment of a joint effusion can accurately predict if the fluid is infection.

2. Intravenous gadolinium is required for the diagnosis of osteomyelitis on MRI?

3. Regarding the foot of a diabetic patient, in the absence of a puncture wound or prior surgery, the absence of a soft tissue ulcer essentially excludes osteomyelitis.

4. A soft tissue abscess on ultrasound can appear anechoic, hypoechoic, isoechoic, or hyperechoic.

5. The use of intravenous gadolinium is very important when evaluating soft tissue infection to accurately identify an abscess or sinus track.

Answer Key: 1. F, 2. F, 3. T, 4. T, 5. T

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E-mail: jon.jacobson.rad@gmail.com

MR Imaging of the Ankle and Foot

Outline:

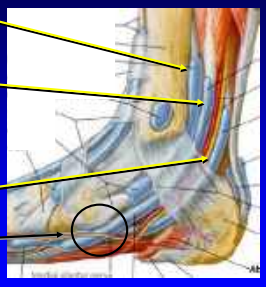
- Trauma
  - Tendon, Ligament, Bone, Neuropathic
- Infection and Inflammation
- Developmental anomalies
- Tumors and Tumor-like Abnormalities

Anterior Tendons

- Tibialis anterior:
  - 1st MT base, medial cuneiform
- Extensor hallucis longus:
  - 1st distal phalanx
- *Anterior tibial artery ⟶ dorsalis pedis*
- Extensor digitorum longus:
  - Proximal + distal digits #2 – 5
  - ✓ Peroneus tertius

Medial Tendons

- Tibialis posterior
  - Navicular > cuneiforms
  - Metatarsals 2 – 4
- Flexor digitorum longus
  - Distal phalanges #2 – 5
- Tibial nerve, artery, veins
- Flexor hallucis longus
  - Base of distal 1st phalanx
  - *Knot of Henry: FHL & FDL

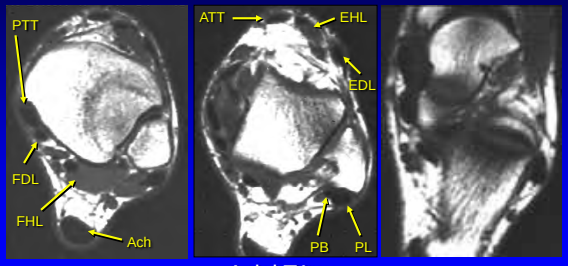


From: Netter's Atlas of Human Anatomy

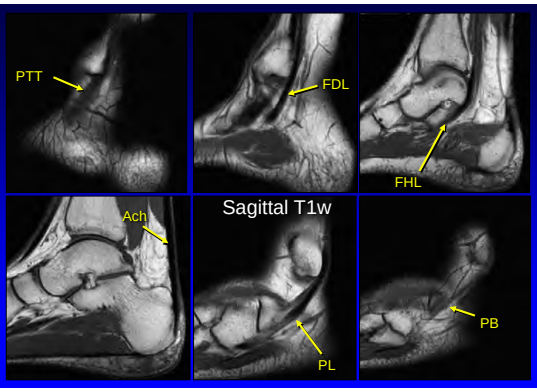
Lateral and Posterior Tendons

- Peroneus brevis:
  - Oval or crescent shaped
  - Inserts of 5th metatarsal
- Peroneus longus
  - Plantar 1st MT base
  - Medial cuneiform
- Achilles:
  - Calcaneus

Ankle Tendons



Axial T1w



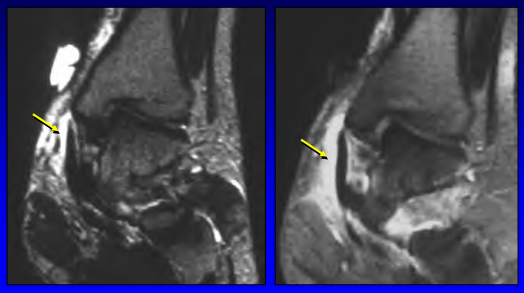
Sagittal T1w

Suggested Classification System

- Tenosynovitis: paratenon inflammation
- Tendinosis: tendon degeneration
- Tendon tear
  - Partial-thickness
  - Full-thickness tear: incomplete or complete

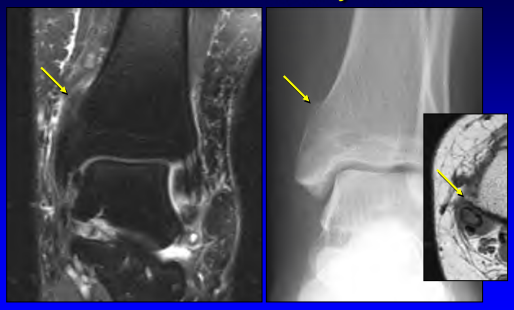
Khoury NJ et al.
MRI of posterior tibial tendon dysfunction
AJR 1996; 167:675

Tenosynovitis: tibialis posterior tendon



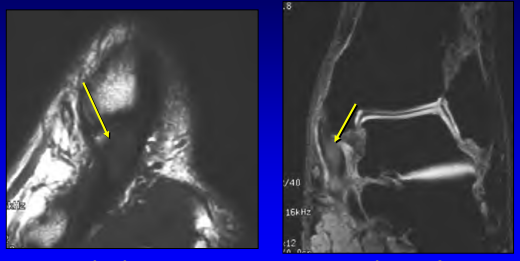
Coronal T2w | Coronal T1w post-gado

Periostitis: PTT Tenosynovitis



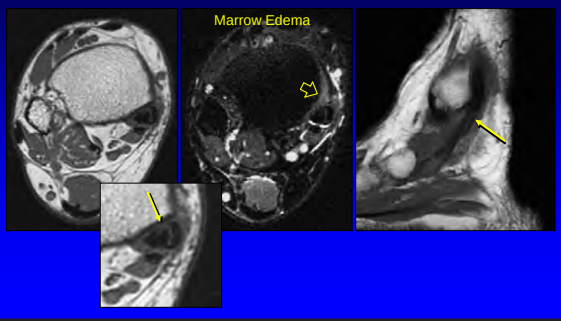
Sagittal PDw | Coronal T2w

Tendinosis: tibialis posterior tendon

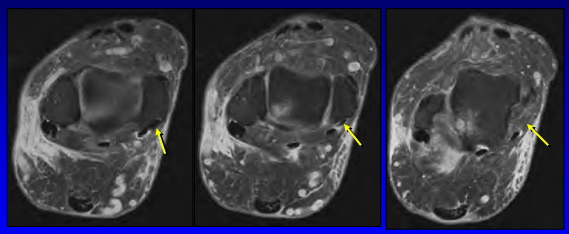


Sagittal T1w | Coronal T1w fat sat

Longitudinal Split: tibialis posterior



Tibialis Posterior Tendon: full-thickness tear

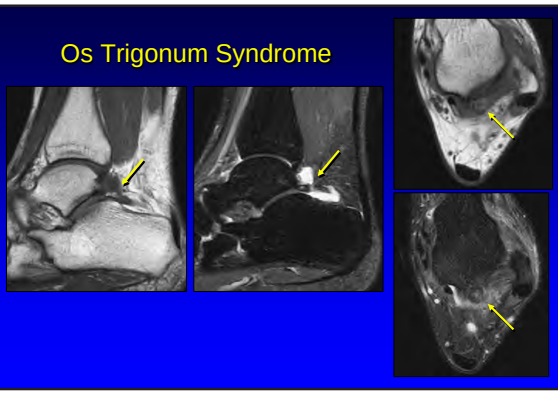


Os Trigonum Syndrome

- Os trigonum: ossicle
  - Posterior to lateral process of talus
- MR findings:
  - Edema: os trigonum or lateral process
  - Fragmentation
  - Posterior recess fluid
  - FHL tendon sheath fluid

Bureau. Radiology 2000; 215:497

Os Trigonum Syndrome



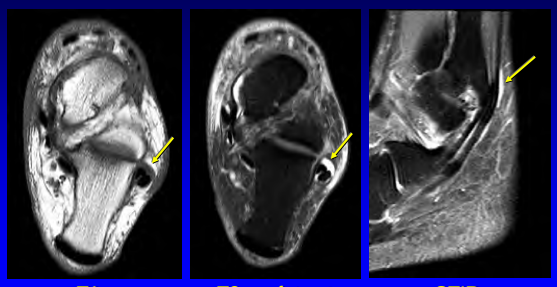
Peroneal Tendon Pathology:

Retrospective: 40 patients with surgery:

- 88% peroneus brevis tear
- 37% peroneus brevis + longus tears
- 33% low lying peroneus brevis muscle
- 20% tendon subluxation
- 13% peroneus longus tear

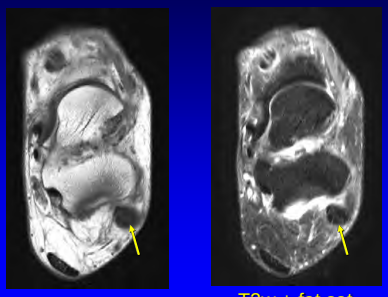
J Foot Ankle Surg 2003; 42:250

Tenosynovitis: MRI



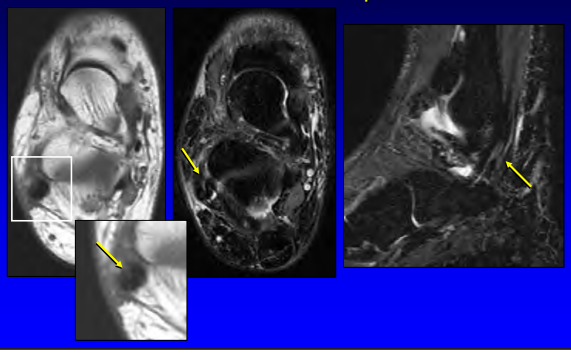
T1w T2w + fat sat STIR

Tendinosis: MRI

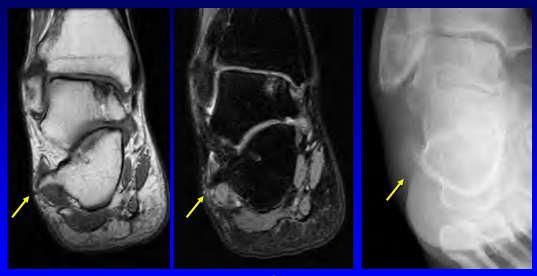


T1w T2w + fat sat

Peroneus Brevis Split

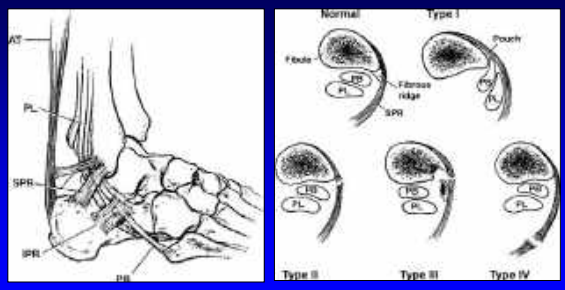


Hypertrophic Peroneal Tubercle + Tear



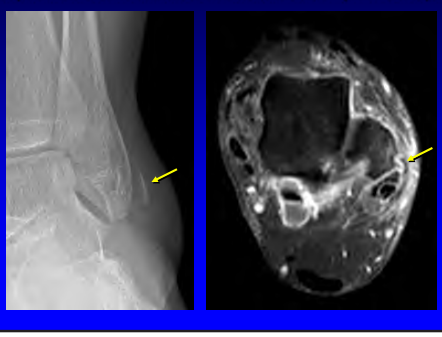
Coronal T1w Coronal T2w

Peroneal Retinaculum



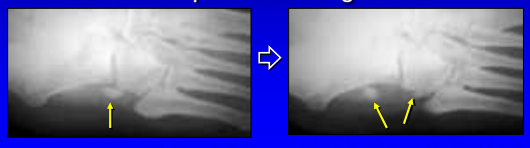
Rosenberg et al. AJR 2003; 181:1551

Superior Retinaculum Avulsion (+ PB split)



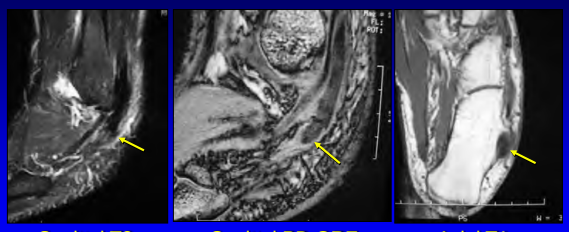
Os Peroneum Fracture:

- Interval fragmentation or fracture
- Contraction + compression on cuboid
- Separation: > 6 mm (unlike bipartite)
- Associated: peroneus longus tear



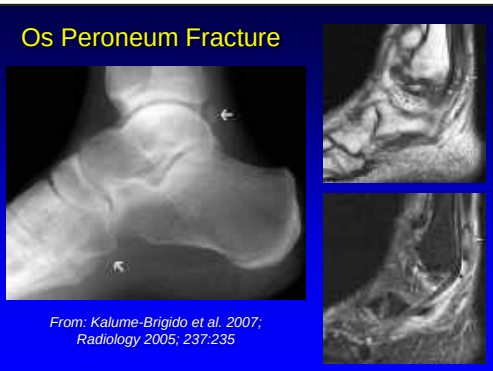
Kalume-Brigido et al. 2007; Radiology 2005; 237:235.

Os Peroneum Fracture



Sagittal T2w | Sagittal PD GRE | Axial T1w

Os Peroneum Fracture

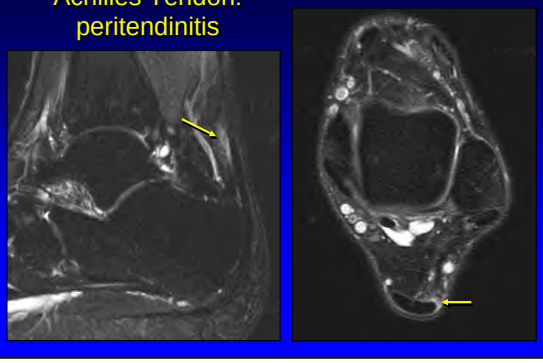


From: Kalume-Brigido et al. 2007; Radiology 2005; 237:235

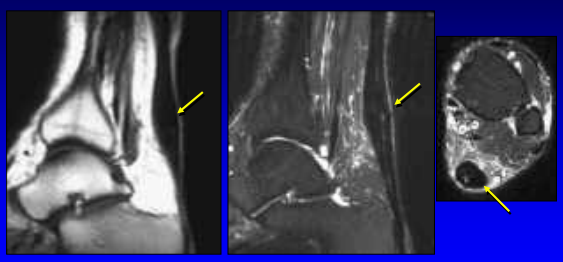
Achilles Tendon:

- 2 – 6 cm proximal to insertion
  - Tendinosis
  - Full-thickness tear
- Calcaneal attachment
  - Tendinosis, tear
  - Haglund Syndrome

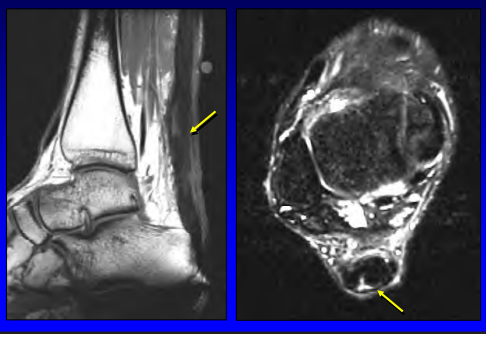
Achilles Tendon: peritendinitis



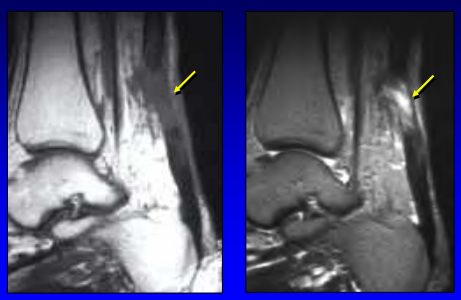
Achilles Tendon: tendinosis



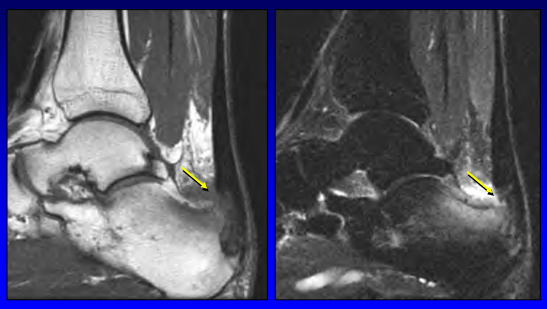
Achilles Tendon: partial-thickness tear



Achilles Tendon: full-thickness tear



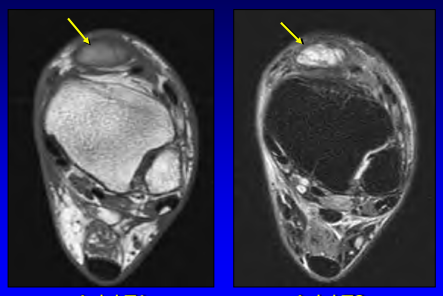
Achilles Tendon: partial-thickness tear



Tibialis Anterior Tendon:

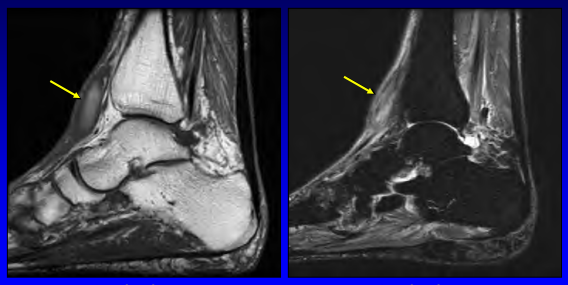
- At tibiotalar joint
  - Tendinosis
  - Full-thickness tear
- First cuneiform and 1st MT base
  - Avulsion
- Significant retraction, pseudotumor appearance

Tibialis Anterior Tendon Avulsion



Axial T1w | Axial T2w

Tibialis Anterior Tendon Avulsion

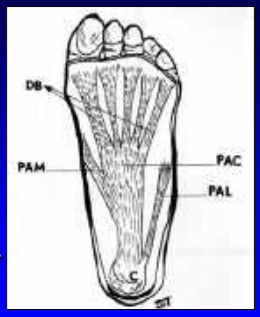


Sagittal T1w | Sagittal T2w

Tibialis Anterior Tendon Avulsion

Plantar Fascia or Aponeurosis:

- 3 components:
  - Medial cord
  - Lateral cord
  - Central cord
    - Most important
    - Fibers envelop flexor digitorum brevis



RadioGraphics 2000; 20:181

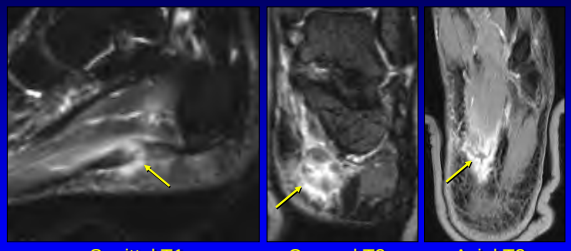
Plantar Fasciopathy

- Central cord, proximal
- Tight heel cord, repetitive injury
- Degenerative, tendinosis-like, tear
- MRI: thickened, fluid signal

Sagittal T2w

Yu. Skeletal Radiol 2000; 29:491

Plantar Fascia Complete Tear



Sagittal T1w | Coronal T2w | Axial T2w

Outline:

- Trauma
  - Tendon, Ligament, Bone, Neuropathic
- Infection and Inflammation
- Developmental anomalies
- Tumors and Tumor-like Abnormalities

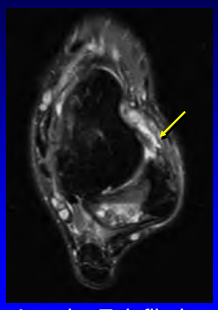
From: Netter's Atlas of Human Anatomy

Trauma: *ligament*

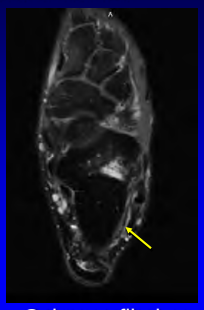
- Lateral:
  - Anterior talofibular: isolated tear in 66%
  - Calcaneofibular
    - 20% calcaneofibular + anterior talofibular
  - Posterior talofibular: dislocation
  - Anterior tibiofibular: high ankle sprain

Helgason. Radiol Clin N Am 1998; 36:729

Lateral Ligament Tears

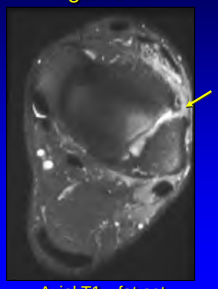


Anterior Talofibular



Calcaneofibular

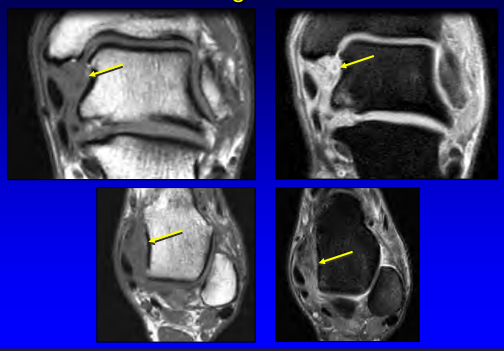
Tear: anterior tibiofibular ligament



Axial T1w fat-sat

Maisonneuve Injury

Deltoid Ligament Tear

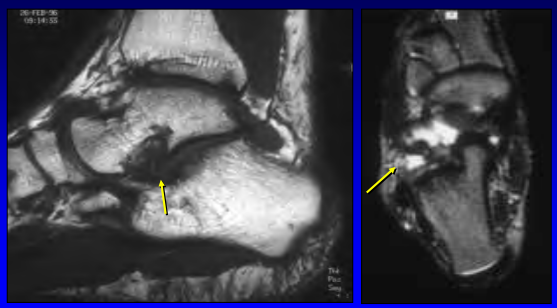


Sinus Tarsi Syndrome

- Cervical and interosseous ligaments
  - 3 roots of inferior extensor retinaculum
- MR findings:
  - Partial or complete tear of ligaments
  - Fat replaced on T1w images
  - Low or high signal on T2w images

Lektrakul. Radiology 2001; 219:802

Sinus Tarsi Syndrome



Outline:

- Trauma
  - Tendon, Ligament, Bone, Neuropathic
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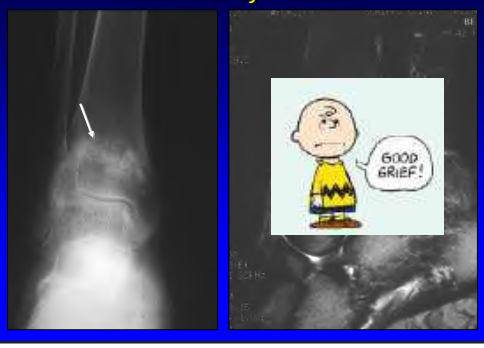
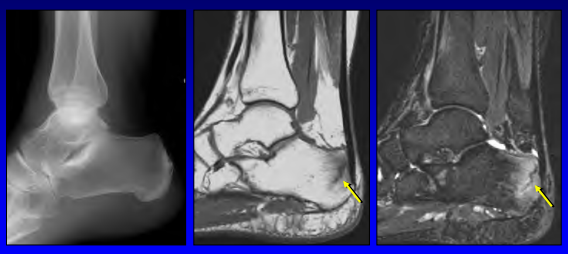
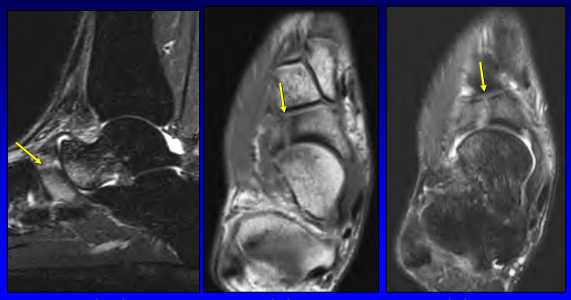
Insufficiency Fracture



Insufficiency Fracture: calcaneus

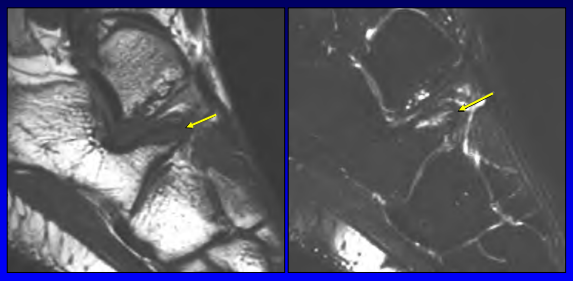


Fatigue Fracture: navicular



Sagittal T2w | Axial PDw | Axial T2w

Fracture: anterior process of calcaneus



Sagittal T1w | Sagittal STIR

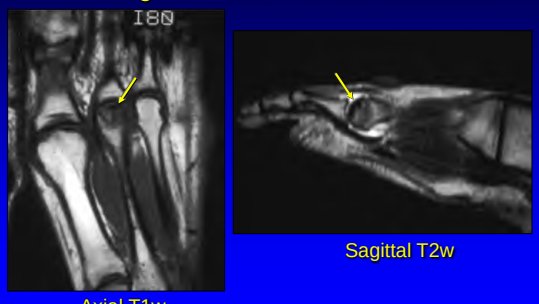
Fracture: anterior process of calcaneus

Freiberg Disease

- Collapse, osteonecrosis, fissures
- 2nd or 3rd MT head
- Women, adolescence, high heels
- MRI:
  - Marrow edema, joint effusion
  - Collapse

Yu. RadioGraphics 2001; 21:1425

Freiberg Disease: 2nd metatarsal head

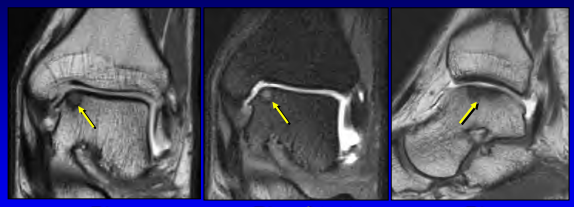


Axial T1w | Sagittal T2w

Talar Dome Osteochondral Abnormality:

- Associated with other ankle injuries
- Can be a subtle finding
- Appearances:
  - Bone marrow edema
  - Cartilage abnormality
  - Osteochondral defect with loose body

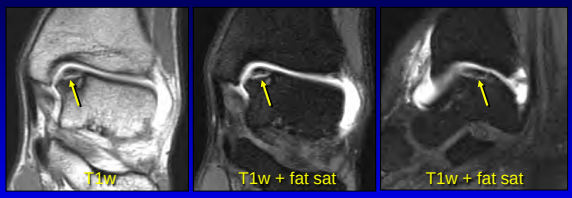
Osteochondral Abnormality: stable



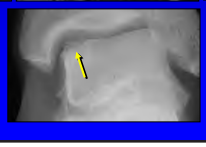
T1w | T1w + fat sat | T1w

Post- Intraarticular Gadolinium

Osteochondral Abnormality: unstable



Post-Intraarticular Gadolinium

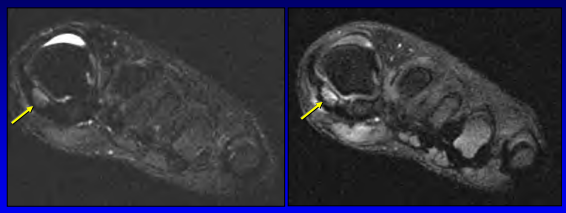


Hallux Sesamoid Stress Changes:

- 1st metatarsophalangeal joint
- Repetitive trauma: spectrum
  - Bone marrow edema
  - Fracture
  - Reactive soft tissues abnormalities
- "Sesamoiditis"- not an accurate term

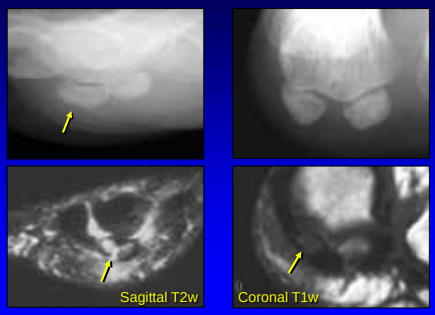
Ashman. RadioGraphics 2001; 21:1425

Marrow Edema

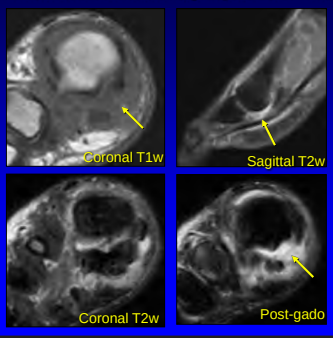


Coronal T2w | Coronal post-gado

Hallux Sesamoid Fracture



"Plantar Plate" Injury: Turf Toe



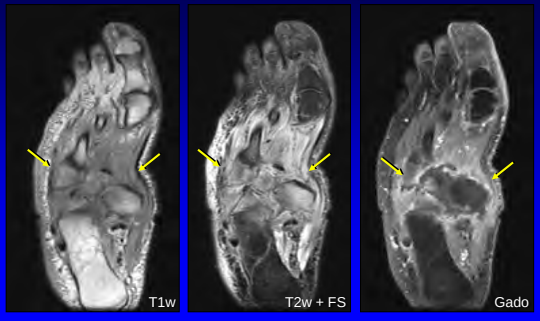
Ashman. RadioGraphics 2001; 21:1425

Yao. AJR 1994; 163:641

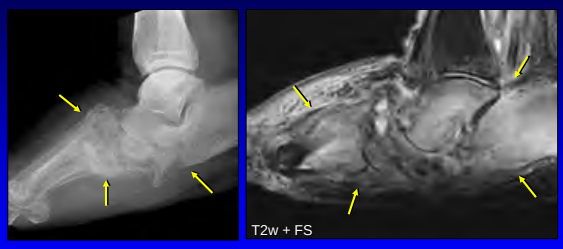
Outline:

- Trauma
  - Tendon, Ligament, Bone, Neuropathic
- Infection and Inflammation
- Developmental anomalies
- Tumors and Tumor-like Abnormalities

Neuropathic Foot



Neuropathic Foot



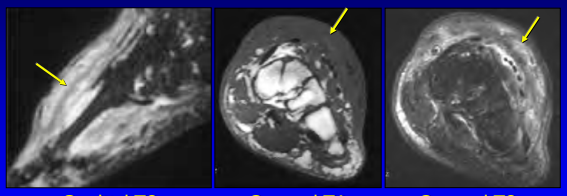
Outline:

- Trauma
  - Tendon, Ligament, Bone, Neuropathic
- Infection and Inflammation
- Developmental anomalies
- Tumors and Tumor-like Abnormalities

Infection: *predicted by route*

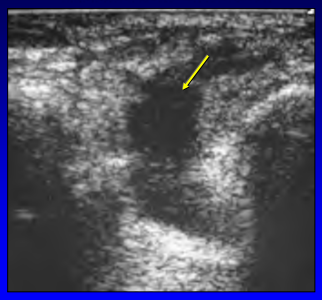
- Direct spread:
  - Ulceration (diabetic), penetrating injury
  - Soft tissue infection, osteomyelitis
- Hematogenous spread:
  - Children, intravenous drug abusers
  - Septic joint, osteomyelitis

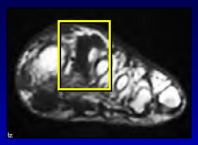
Cellulitis



Sagittal T2w | Coronal T1w | Coronal T2w

Abscess: forefoot

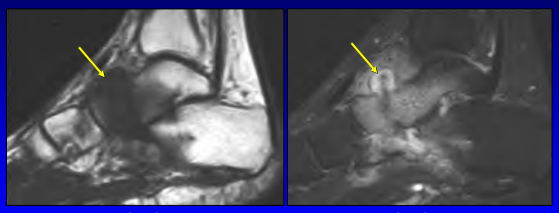




Sagittal T1w

Coronal post-gado

Septic Joint: talonavicular

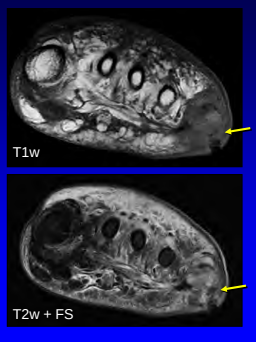


Sagittal T1w | Sagittal T2w

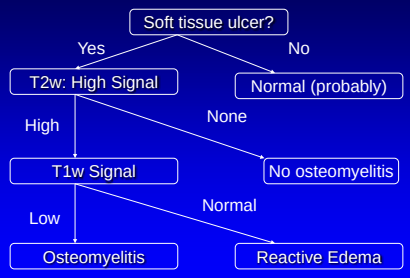
Acute Osteomyelitis: *MRI: criteria*

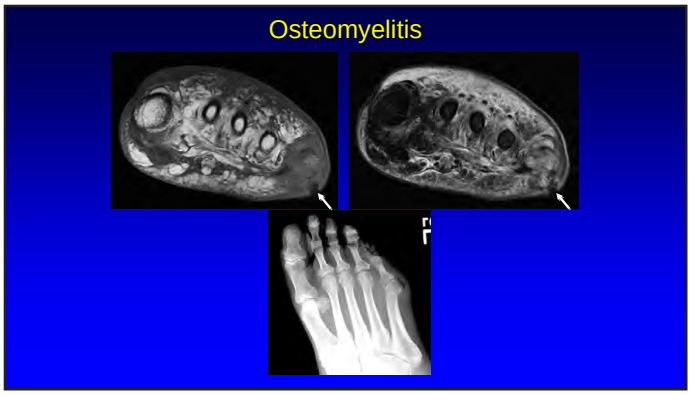
- If ulcer:
  1. Extends from ulcer to bone
  2. Cortex disrupted
  3. T1w: low signal
  4. T2w: high signal
  5. Contrast: + enhancement

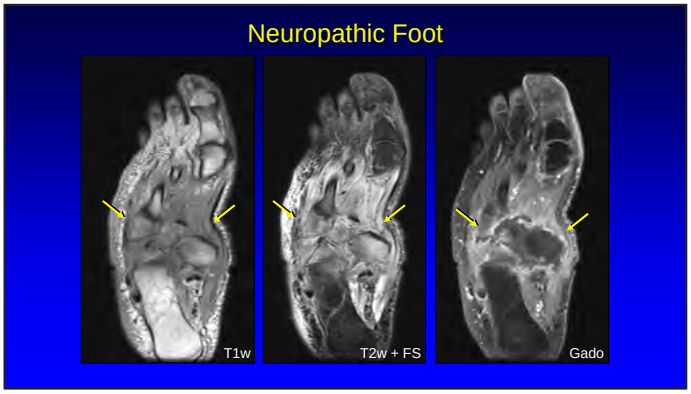
*More criteria, higher likelihood of osteomyelitis

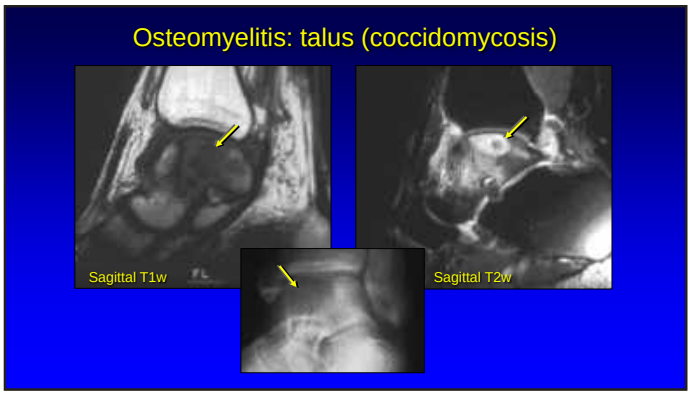


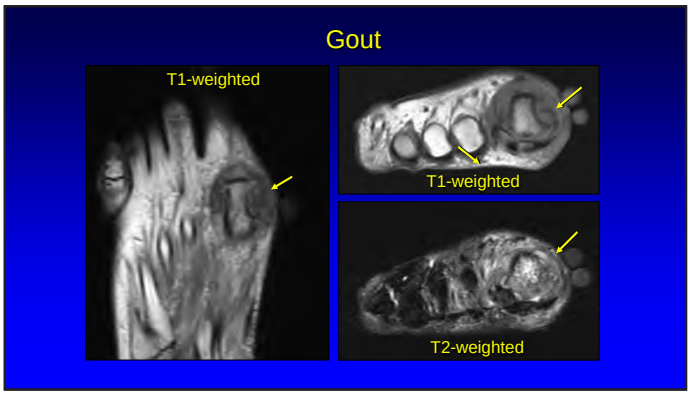
Osteomyelitis: diabetic foot

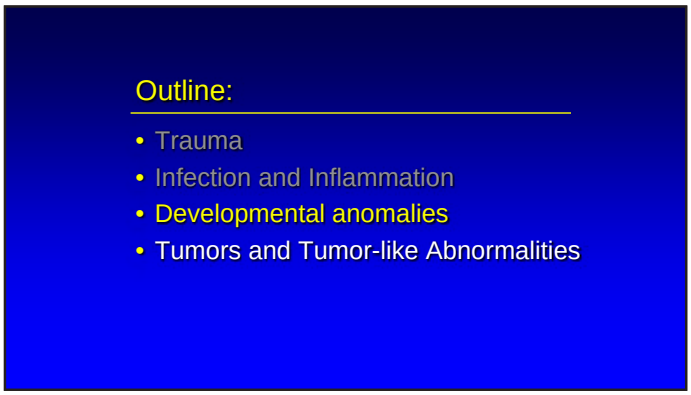


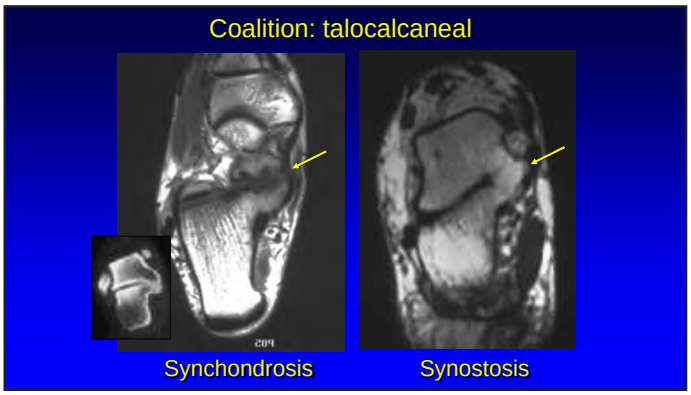

Osteomyelitis

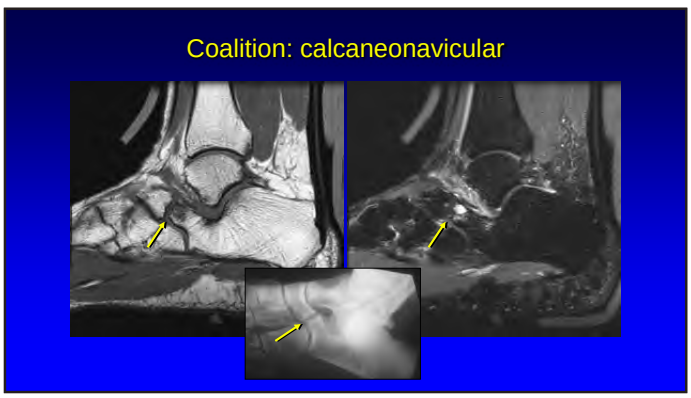

Neuropathic Foot
T1w
T2w + FS
Gado

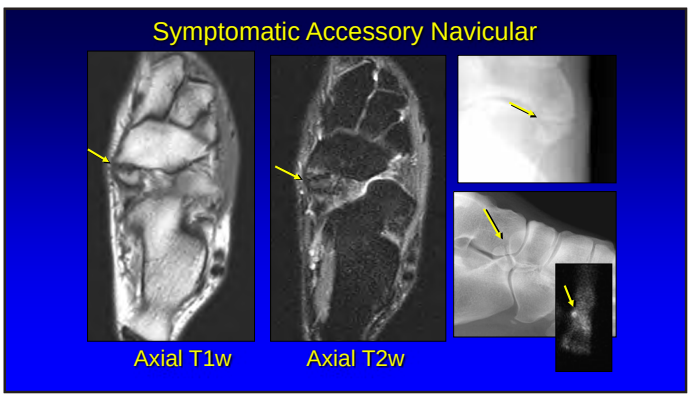

Osteomyelitis: talus (coccidomycosis)
Sagittal T1w
Sagittal T2w


Gout
T1-weighted
T1-weighted
T2-weighted

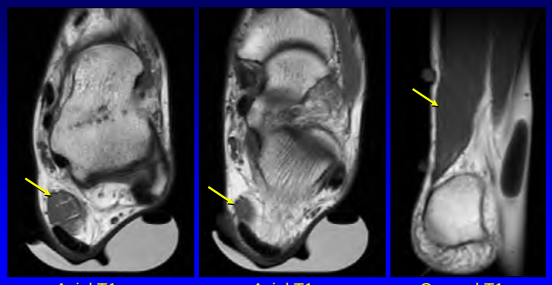

Outline:
• Trauma
• Infection and Inflammation
• Developmental anomalies
• Tumors and Tumor-like Abnormalities


Coalition: talocalcaneal
Synchondrosis
Synostosis


Coalition: calcaneonavicular

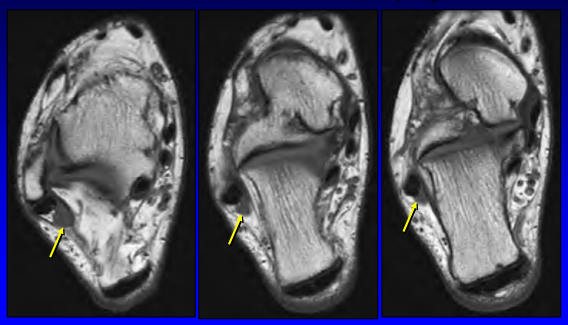

Symptomatic Accessory Navicular
Axial T1w
Axial T2w

Accessory Soleus Muscle

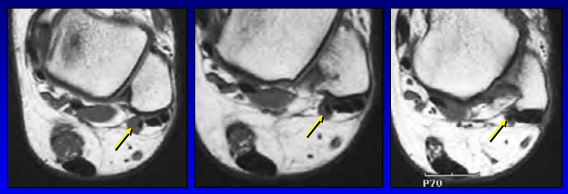


Axial T1w | Axial T1w | Coronal T1w

Peroneus Brevis: low lying



Peroneus Quartus



Outline:

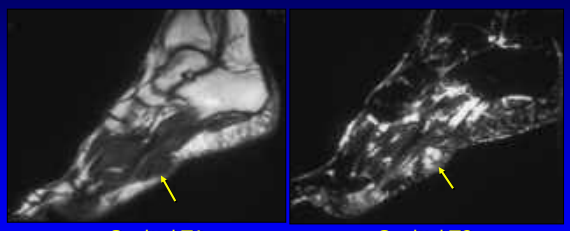
- Trauma
- Infection and Inflammation
- Developmental anomalies
- Tumors and Tumor-like Abnormalities

Plantar Fibromatosis:

- Fibroblastic proliferation
- At plantar fascia and subcutaneous fat
  - May invade plantar and dorsal
- High recurrence rate: 60 – 100%
- MRI: variable signal, +enhancement

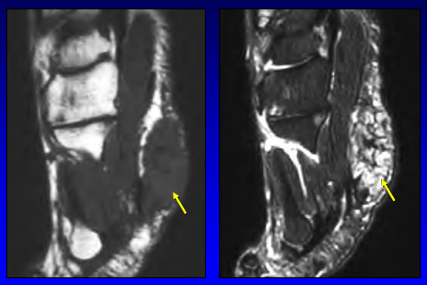
Yu. Skeletal Radiol 2000; 29:491

Plantar Fibromatosis



Sagittal T1w | Sagittal T2w

Plantar Fibromatosis



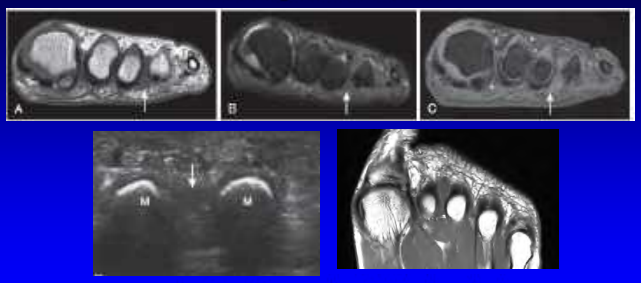
Sagittal T1w | Sagittal T2w

Interdigital Neuroma:

- Digital nerve entrapment
- Edema, fibrosis, necrosis
- MRI: coronal
  - T1w: low signal, *best sequence
  - T2w: low signal
  - Gadolinium: minimal enhancement

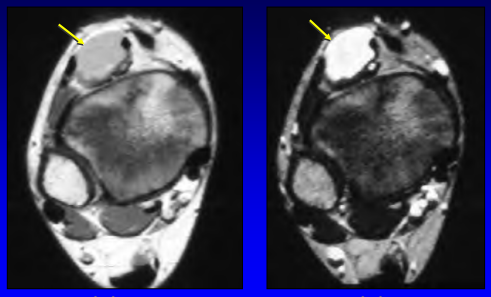
Zanetti. AJR 1997; 168:529

Interdigital Neuroma



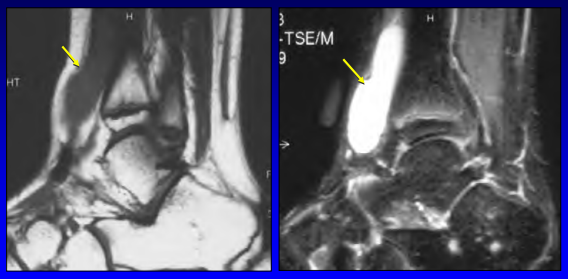
Note: location of neuroma located plantar extending beyond metatarsal heads

Synovial Sarcoma



Axial PDw | Axial T2w

Synovial Sarcoma



Sagittal T1w | Sagittal T2w

"Cyst" on non-contrast MRI or US

- History: Infection? — Yes → Abscess
- History: Infection? — No → Multilocular? — Yes → Ganglion, Paralabral cyst, Parameniscal cyst
- Multilocular? — No → Location of Bursa? — Yes → Anatomic bursa, Adventitious bursa
- Location of Bursa? — No → Dark Rim Sign? — Yes → *History of trauma or surgery*, Hematoma/Seroma
- Dark Rim Sign? — No → Myxoid tumor, Synovial Sarcoma

Take Home Points

- Tendons:
  - Specific locations
  - Avulsion fractures: radiography
- Osteomyelitis: low T1w, high T2w
- Neuropathic: midfoot, no ulcer
- Fibromatosis: heterogeneous signal
- Synovial sarcoma: looks like a cyst

Thank you!

Syllabus on line and other educational material:
www.jacobsonmskus.com

SELF EVALUATION

MR Imaging of the Ankle and Foot

True/False

1. Proximal migration of an os peroneum fracture fragment indicates peroneus longus tendon tear.

2. Joint fluid or intra-articular contrast extending beneath a talar dome osteochondral fragment indicates that the fragment is unstable.

3. In the diagnosis of neuropathic osteoarthropathy, midfoot location and absence of soft tissue ulcer are characteristic.

4. When evaluating for infection, high T2 and normal T1 marrow signal are diagnostic for osteomyelitis.

5. The final diagnosis of a non-specific soft tissue cyst on MRI is acceptable.

Answer Key: 1. T, 2. T, 3. T, 4. F, 5. F

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Musculoskeletal Radiology
UCSF Department of Radiology & Biomedical Imaging

Ultrasound of the Ankle

OBJECTIVES

1. REVIEW THE NORMAL APPEARANCE OF ANKLE LIGAMENTS ON ULTRASOUND
2. DISCUSS COMMON INJURY PATTERNS
3. DESCRIBE IMAGING TECHNIQUES TO IMPROVE IDENTIFICATION OF ANKLE LIGAMENT INJURIES

OBJECTIVES

- COMMON ANKLE LIGAMENT INJURIES
  - LATERAL COLLATERAL LIGAMENTS
  - SYNDESMOSIS
  - DELTOID LIGAMENT

Babler F, Gaetke-Udager K, Crawford EA, Yablon CM. Imaging of soccer injuries in adolescent female athletes. Skeletal Radiol. 2024 Mar 13. doi: 10.1007/s00256-024-04625-z

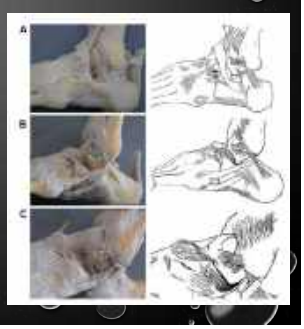
LATERAL COLLATERAL LIGAMENT COMPLEX

LATERAL COLLATERAL LIGAMENT COMPLEX (LCLC)

- PRIMARILY RESIST INVERSION
- ANTERIOR TALOFIBULAR LIGAMENT
- CALCANEOFIBULAR LIGAMENT
- POSTERIOR TALOFIBULAR LIGAMENT

LCLC ANATOMIC VARIATION

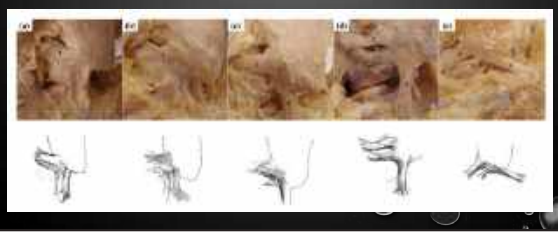
- ANTERIOR TALOFIBULAR LIGAMENT
  - 1-3 BUNDLES
  - 1 (10.6%), 2 (80.3%), 3 (9.1%)



Anatomic Measurement and Variability Analysis of the Anterior Talofibular Ligament and Calcaneofibular Ligament of the Ankle

LCLC ANATOMIC VARIATION

- CALCANEOFIBULAR LIGAMENT
  - VARIABLE ORIGIN

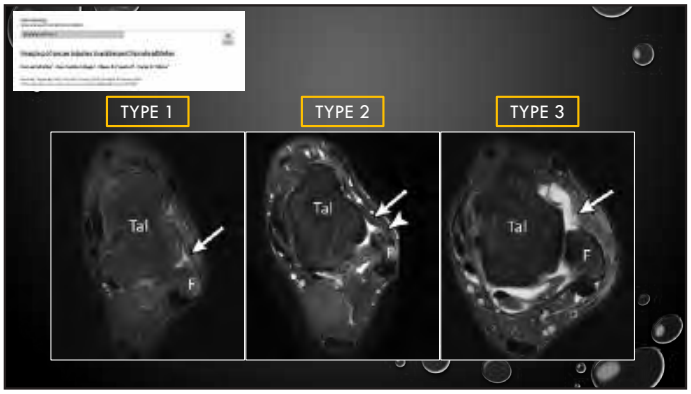


ANTERIOR TALOFIBULAR LIGAMENT

ANTERIOR TALOFIBULAR LIGAMENT

- ANTERIOR LATERAL MALLEOLUS => LATERAL TALUS
- RESIST PLANTARFLEXION
- WEAKEST LIGAMENT
  - INVOLVED IN 85% OF SPRAINS

Kim JS, Kim MS, Kim DK, Lee SH. Magnetic Resonance Imaging Characteristics of a Lateral Ligament Injury in Acute Ankle Sprains Among Athletes. Orthop J Sports Med. 2023 Nov 9;11(11):23259671231207688. doi: 10.1177/23259671231207688.



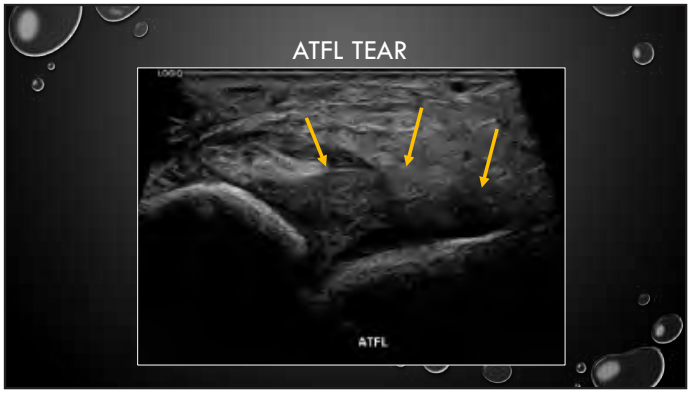
ANTERIOR TALOFIBULAR LIGAMENT

NORTH STAR

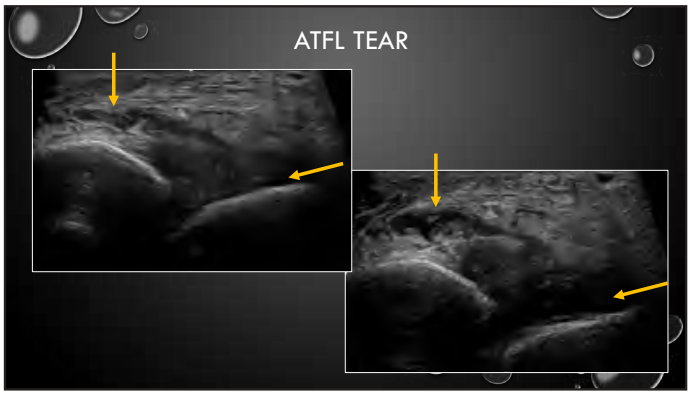
- Osseous
- Superficial
- Consistent

ATFL W/ PLANTARFLEXION

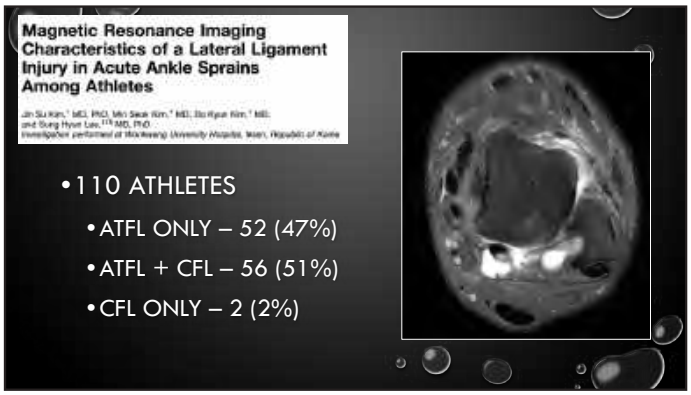
ATFL W/ PLANTARFLEXION – PARTIAL TEAR


ATFL TEAR
ATFL

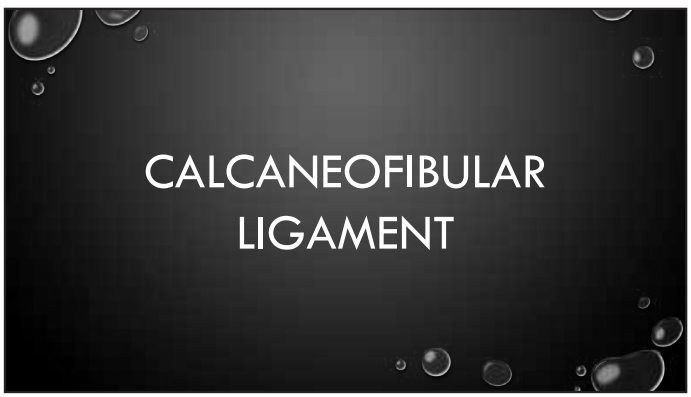

ATFL TEAR

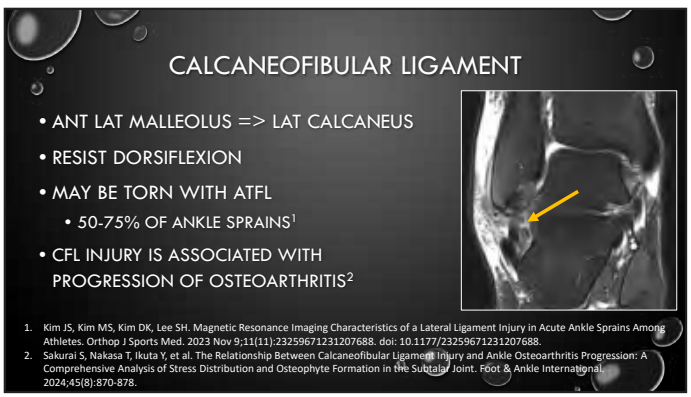

ATFL TEAR


ATFL TEAR

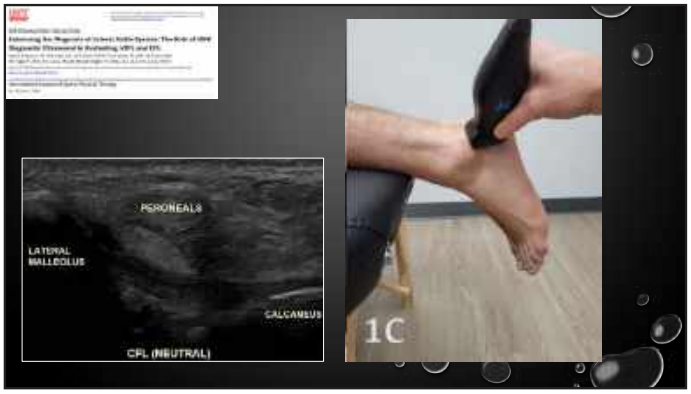

Magnetic Resonance Imaging Characteristics of a Lateral Ligament Injury in Acute Ankle Sprains Among Athletes
•110 ATHLETES
•ATFL ONLY – 52 (47%)
•ATFL + CFL – 56 (51%)
•CFL ONLY – 2 (2%)

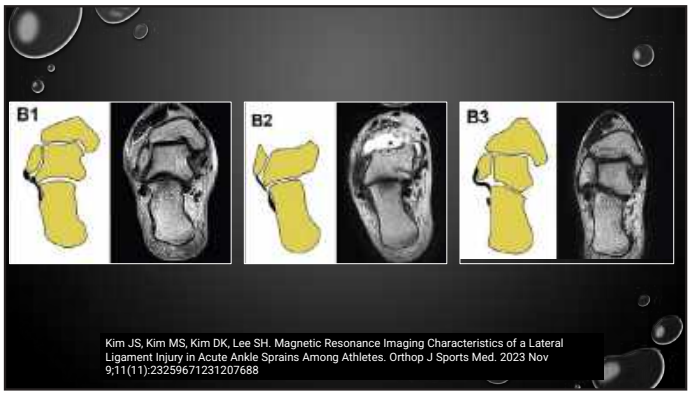

Prevalence and Injury Patterns of CFL Injury in Chronic Lateral Ankle Instability: An Observational Cross-Sectional Study Using Ultrasound
Qianru Li, PhD
Yibin Li, BA
Jieling Shan, BA
Yinghui Hua, PhD
•938 ATHLETES W/ CHRONIC ANKLE INSTABILITY
•450 (48%) W/ ISOLATED ATFL
•408 (44%) W/ ATFL + CFL
•75 (8%) W/ ATFL + TIBIOFIBULAR

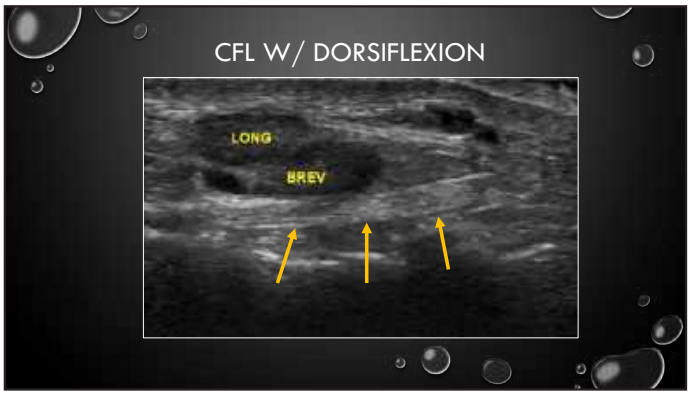

CALCANEOFIBULAR LIGAMENT

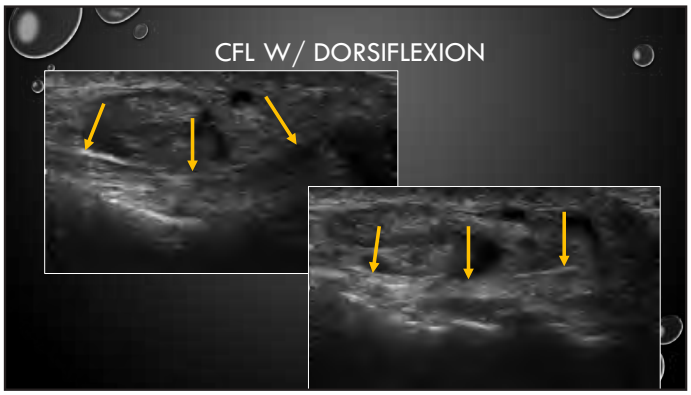

CALCANEOFIBULAR LIGAMENT
• ANT LAT MALLEOLUS => LAT CALCANEUS
• RESIST DORSIFLEXION
• MAY BE TORN WITH ATFL
• 50-75% OF ANKLE SPRAINS[1]
• CFL INJURY IS ASSOCIATED WITH PROGRESSION OF OSTEOARTHRITIS[2]
1. Kim JS, Kim MS, Kim DK, Lee SH. Magnetic Resonance Imaging Characteristics of a Lateral Ligament Injury in Acute Ankle Sprains Among Athletes. Orthop J Sports Med. 2023 Nov 9;11(11):23259671231207688. doi: 10.1177/23259671231207688.
2. Sakurai S, Nakasa T, Ikuta Y, et al. The Relationship Between Calcaneofibular Ligament Injury and Ankle Osteoarthritis Progression: A Comprehensive Analysis of Stress Distribution and Osteophyte Formation in the Subtalar Joint. Foot & Ankle International. 2024;45(8):870-878.


PERONEALS
LATERAL MALLEOLUS
CALCANEUS
CFL (NEUTRAL)
FD
CALC
SUBTALAR JT
CFL (STRESSED)


PERONEALS
LATERAL MALLEOLUS
CALCANEUS
CFL (NEUTRAL)
1C


B1
B2
B3
Kim JS, Kim MS, Kim DK, Lee SH. Magnetic Resonance Imaging Characteristics of a Lateral Ligament Injury in Acute Ankle Sprains Among Athletes. Orthop J Sports Med. 2023 Nov 9;11(11):23259671231207688


CFL W/ DORSIFLEXION
LONG
BREV


CFL W/ DORSIFLEXION


CFL W/ DORSIFLEXION


CFL W/ TEAR?


CFL W/ PARTIAL WIDTH TEAR

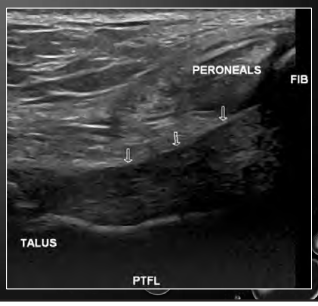
POSTERIOR TALOFIBULAR LIGAMENT

POSTERIOR TALOFIBULAR LIGAMENT

- POSTEROMEDIAL LATERAL MALLEOLUS => LATERAL POSTERIOR TALAR PROCESS
- STRONGEST LIGAMENT
  - <10% OF ANKLE SPRAINS[1]

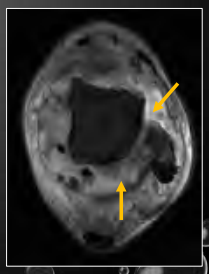
1. Kim JS, Kim MS, Kim DK, Lee SH. Magnetic Resonance Imaging Characteristics of a Lateral Ligament Injury in Acute Ankle Sprains Among Athletes. Orthop J Sports Med. 2022 Nov 9;11(11):23259671231207688. doi: 10.1177/23259671231207688.
2. Fursten T, Platt S. THE INCIDENCE AND SIGNIFICANCE OF POSTERIOR TALOFIBULAR LIGAMENT INJURY ON MAGNETIC RESONANCE IMAGING. Orthop Procs. 2012;94-B(SUPP_XXII):56-56. doi:10.1302/1358-992X.94BSUPP_XXII.BOFAS2010-056

POSTERIOR TALOFIBULAR LIGAMENT

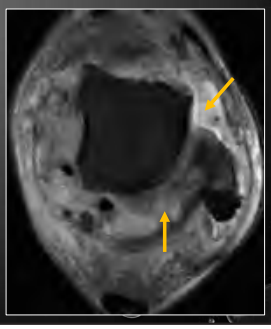


POSTERIOR TALOFIBULAR LIGAMENT

- ANKLE DISLOCATION



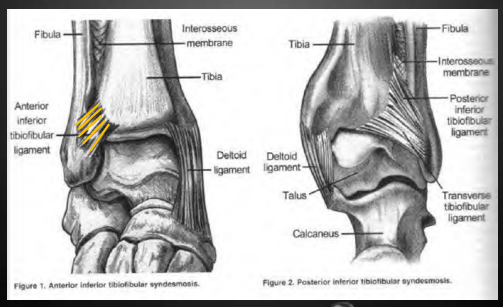
S/P ANKLE DISLOCATION



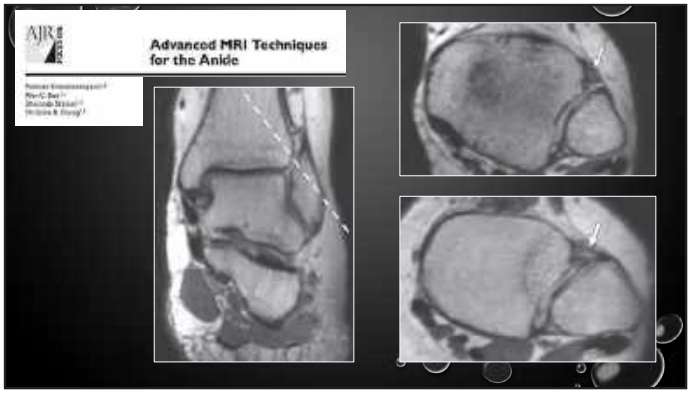
SYNDESMOTIC LIGAMENT COMPLEX

SYNDESMOSIS

- ANTERIOR INFERIOR TIBIOFIBULAR LIGAMENT (AITFL)
- POSTERIOR INFERIOR TIBIOFIBULAR LIGAMENT (PITFL)
- INFERIOR TRANSVERSE TIBIOFIBULAR LIGAMENT (TRTFL)
- INFERIOR INTEROSSEOUS LIGAMENT

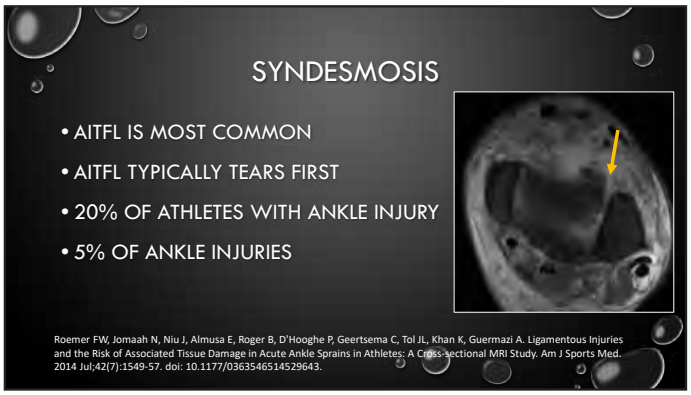


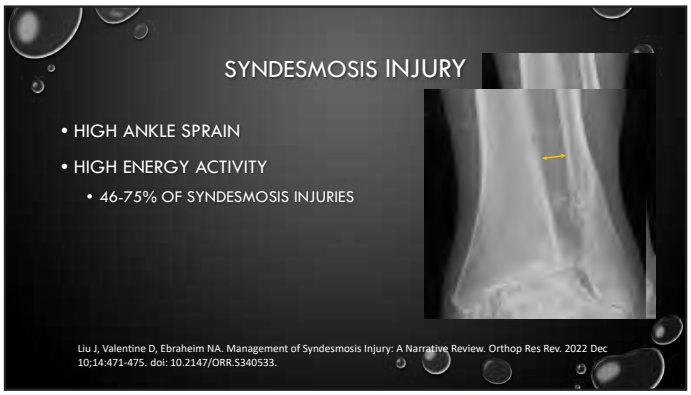
https://www.orthobullets.com/foot-and-ankle/7005/ankle-ligaments

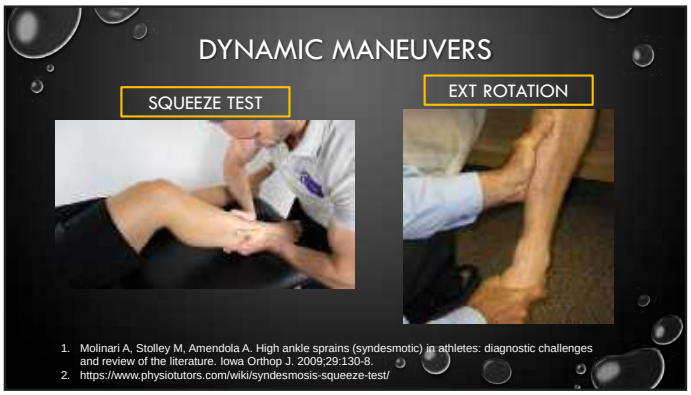

Advanced MRI Techniques for the Anide

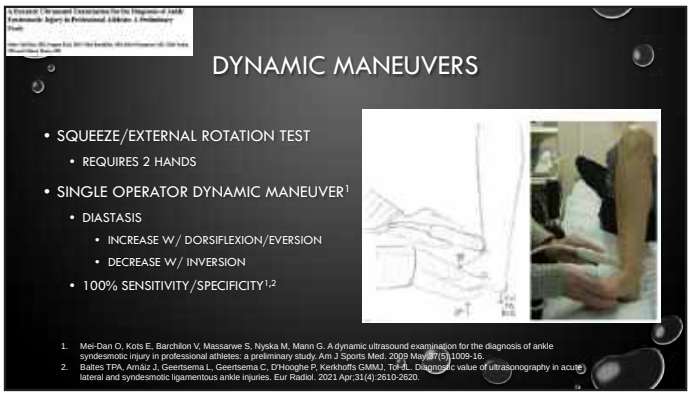

Coronal Oblique Proton Density-Weighted 3D MRI
Axial Oblique Proton Density-Weighted 3D MRI

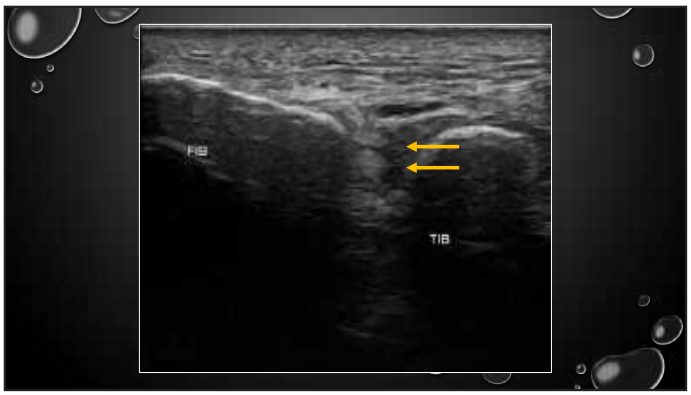

ANTERIOR INFERIOR TIBIOFIBULAR LIGAMENT


SYNDESMOSIS
• AITFL IS MOST COMMON
• AITFL TYPICALLY TEARS FIRST
• 20% OF ATHLETES WITH ANKLE INJURY
• 5% OF ANKLE INJURIES
Roemer FW, Jomaah N, Niu J, Almusa E, Roger B, D'Hooghe P, Geertsema C, Tol JL, Khan K, Guermazi A. Ligamentous Injuries and the Risk of Associated Tissue Damage in Acute Ankle Sprains in Athletes: A Cross-sectional MRI Study. Am J Sports Med. 2014 Jul;42(7):1549-57. doi: 10.1177/0363546514529643.

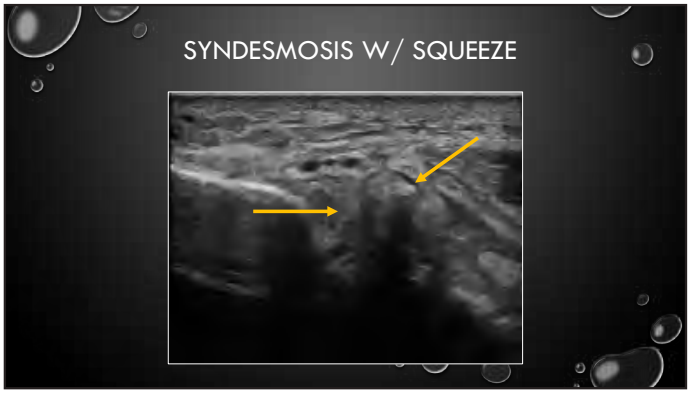

SYNDESMOSIS INJURY
• HIGH ANKLE SPRAIN
• HIGH ENERGY ACTIVITY
• 46-75% OF SYNDESMOSIS INJURIES
Liu J, Valentine D, Ebraheim NA. Management of Syndesmosis Injury: A Narrative Review. Orthop Res Rev. 2022 Dec 10;14:471-475. doi: 10.2147/ORR.S340533.


DYNAMIC MANEUVERS
SQUEEZE TEST
EXT ROTATION
1. Molinari A, Stolley M, Amendola A. High ankle sprains (syndesmotic) in athletes: diagnostic challenges and review of the literature. Iowa Orthop J. 2009;29:130-8.
2. https://www.physiotutors.com/wiki/syndesmosis-squeeze-test/


DYNAMIC MANEUVERS
• SQUEEZE/EXTERNAL ROTATION TEST
• REQUIRES 2 HANDS
• SINGLE OPERATOR DYNAMIC MANEUVER[1]
• DIASTASIS
• INCREASE W/ DORSIFLEXION/EVERSION
• DECREASE W/ INVERSION
• 100% SENSITIVITY/SPECIFICITY[1,2]
1. Mei-Dan O, Kots E, Barchilon V, Massarwe S, Nyska M, Mann G. A dynamic ultrasound examination for the diagnosis of ankle syndesmotic injury in professional athletes: a preliminary study. Am J Sports Med. 2009 May;37(5):1009-16.
2. Baltes TPA, Arnáiz J, Geertsema L, Geertsema C, D'Hooghe P, Kerkhoffs GMMJ, Tol JL. Diagnostic value of ultrasonography in acute lateral and syndesmotic ligamentous ankle injuries. Eur Radiol. 2021 Apr;31(4):2610-2620.


FIB
TIB


FIB
TIB

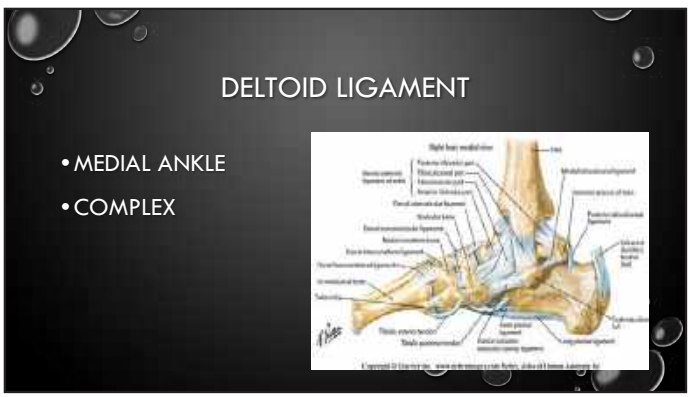

SYNDESMOSIS W/ SQUEEZE


SYNDESMOSIS W/ SQUEEZE


SYNDESMOSIS W/O SQUEEZE


SYNDESMOSIS W/ SQUEEZE


DELTOID
LIGAMENT


DELTOID LIGAMENT
• MEDIAL ANKLE
• COMPLEX

DELTOID LIGAMENT

- MEDIAL STABILIZER
- SUPERFICIAL/DEEP COMPONENTS
- ISOLATED INJURY IS RARE
- 5-15% OF ANKLE SPRAINS[1,2]

1. Mengiardi B, Pfirrmann CW, Vienne P, Hodler J, Zanetti M. Medial collateral ligament complex of the ankle: MR appearance in asymptomatic subjects. Radiology. 2007 Mar;242(3):817-24. doi: 10.1148/radiol.2423060055. Epub 2007 Jan 5. PMID: 17209165.
2. Savage-Elliott I, Murawski CD, Smyth NA, Golanó P, Kennedy JG. The deltoid ligament: an in-depth review of anatomy, function, and treatment strategies. Knee Surg Sports Traumatol Arthrosc. 2013 Jun;21(6):1316-27. doi: 10.1007/s00167-012-2159-3. Epub 2012 Aug 10. PMID: 22878436.

DELTOID LIGAMENT

- FAN SHAPED
- INTERSPERSED FAT
- STRENGTH OF COMPONENTS
  - DEEP > SUPERFICIAL
- VARIABLE SUPERFICIALLY
  - EX. TIBIONAVICULAR - 55%

Perrich KD, Goodwin DW, Hecht PJ, Cheung Y. Ankle ligaments on MRI: appearance of normal and injured ligaments. AJR Am J Roentgenol. 2009 Sep;193(3):687-95. doi: 10.2214/AJR.08.2286. PMID: 19696282.

DELTOID LIGAMENT

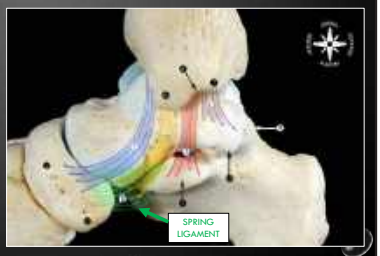
SUPERFICIAL

TIBIONAVICULAR (TNL)

TIBIOSPRING (TSL)

TIBIOCALCANEAL (TCL)

TIBIOTALAR (SPTL)



DELTOID LIGAMENT

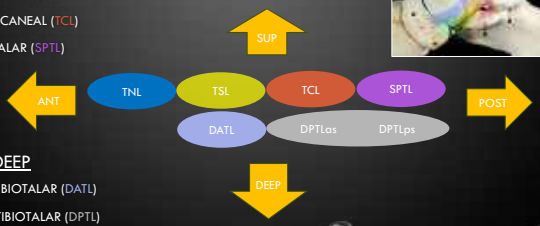
SUPERFICIAL

TIBIONAVICULAR (TNL)

TIBIOSPRING (TSL)

TIBIOCALCANEAL (TCL)

TIBIOTALAR (SPTL)



DEEP

ANTERIOR TIBIOTALAR (DATL)

POSTERIOR TIBIOTALAR (DPTL)

Omodani T, Takahashi K. Ultrasound findings of the deltoid ligament in patients with acute ankle sprains: A retrospective review. J Orthop Sci. 2023 Jul;28(4):843-848. doi: 10.1016/j.jos.2022.05.010. Epub 2022 Jun 9. PMID: 35691876.

ANTERIOR TIBIOTALAR

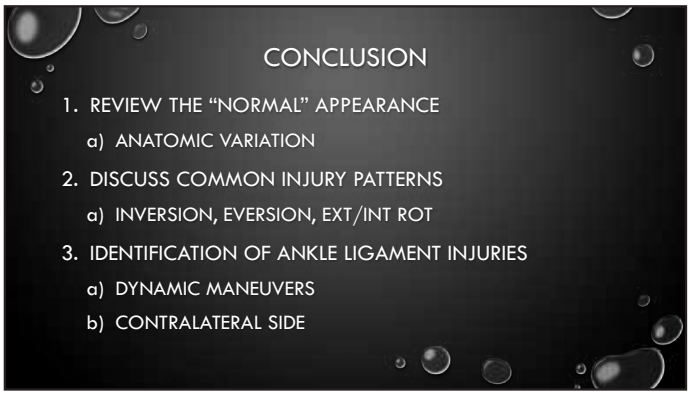
POSTERIOR TIBIOTALAR

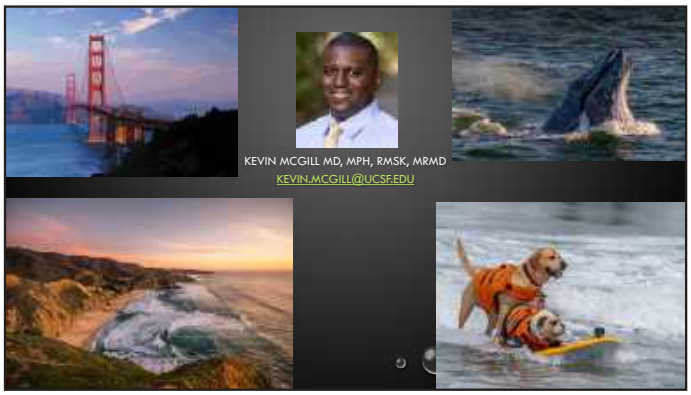
TIBIO-NAVICULAR


TIBIO-CALCANEAL
TIB
CALC
TCL
TIBIO-CALCANEAL LIG


Ultrasound findings of the deltoid ligament in patients with acute ankle sprains: A retrospective review
DEEP POSTERIOR TIBIOTALAR LIGAMENT TEAR
pTTL
POSTERIOR TIBIO-TALAR LIG (DEEP)


SUMMARY
• COMMON ANKLE INJURIES
• LATERAL ANKLE LIGAMENTS
• SYNDESMOSIS
• DELTOID LIGAMENT


CONCLUSION
1. REVIEW THE "NORMAL" APPEARANCE
a) ANATOMIC VARIATION
2. DISCUSS COMMON INJURY PATTERNS
a) INVERSION, EVERSION, EXT/INT ROT
3. IDENTIFICATION OF ANKLE LIGAMENT INJURIES
a) DYNAMIC MANEUVERS
b) CONTRALATERAL SIDE


KEVIN MCGILL MD, MPH, RMSK, MRMD
KEVIN.MCGILL@UCSF.EDU

SELF EVALUATION

Ultrasound of the Ankle

True/False

1. While performing an ankle ultrasound, the ankle may be dorsiflexed to assess integrity of the calcaneofibular ligament.

2. Injury to the deltoid ligament is also known as a high ankle sprain.

3. The Posterior talofibular ligament is the strongest ligament in the lateral collateral ligament complex.

4. The most common configuration of the anterior talofibular ligament is 1 bundle.

5. The superficial components of the deltoid ligament are stronger and are the primary contribution to the integrity of the ligament.

Answer Key: 1. T, 2. F, 3. T, 4. F, 5. F

Jon A. Jacobson, MD FACR
Professor of Radiology
University of California, San Diego Lenox Hill Radiology, NYC
E-mail: jon.jacobson.rad@gmail.com

Imaging of Subtle and Important Fractures: Lower Extremity

Objectives

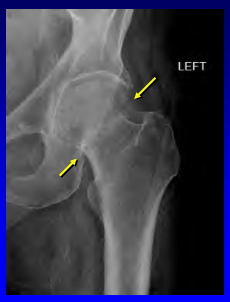
- To recognize subtle fractures
- To identify fractures with hidden implications
- To understand the importance of MRI

Imaging Approach:

- Look for common fractures in characteristic locations
- Specifically look at sites of subtle and important fractures
- Use MRI if negative radiograph and continued symptoms

Femoral Neck Fracture

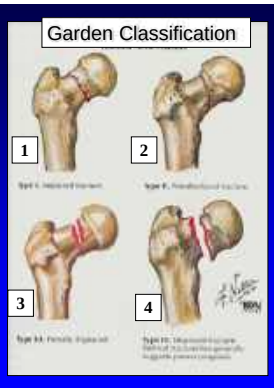

External Rotation

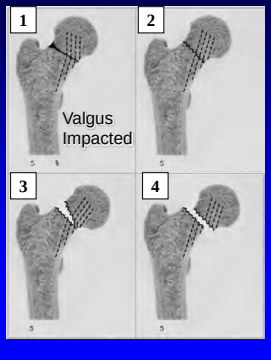


Internal Rotation

Femoral Neck Fracture:

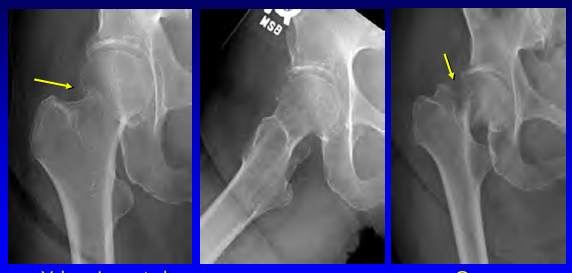
- Internal rotation radiograph essential
- Goal: diagnose non-displaced femoral neck fracture
- Garden Classification: 1 – 4
  - ➢1 & 2: non-displaced ⇨ percutaneous pins
  - ➢3 & 4: displaced ⇨ arthroplasty (risk of AVN)
- With osteopenia, MRI necessary
  - – CT not effective





Femoral Neck Fracture: Garden 1

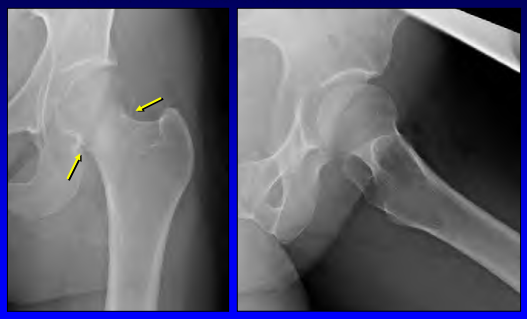
Femoral Neck Fracture: now displaced



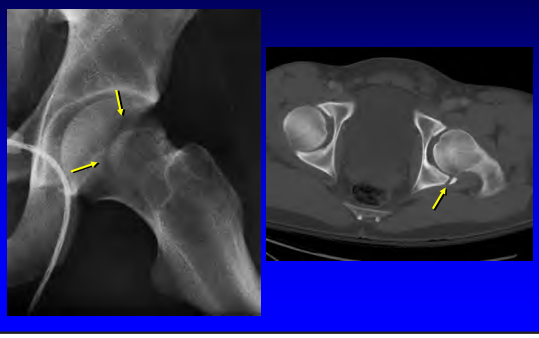
Valgus Impacted Garden 1

Oops

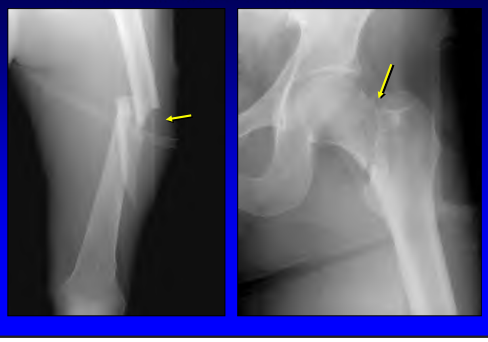
Femoral Neck Fracture: Garden 1



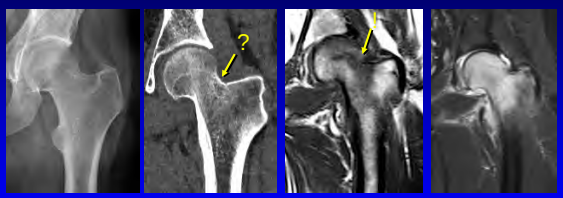
Acetabulum: posterior wall fracture



Femoral Shaft and Neck Fractures

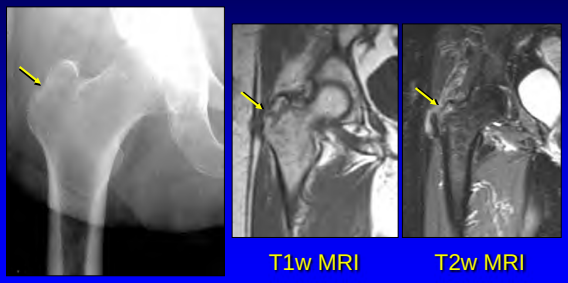


Intertrochanteric Fracture



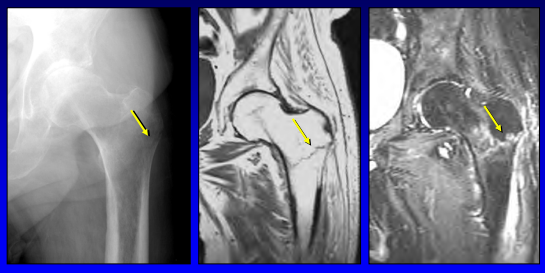
CT T1w T2w

Greater Trochanter Fracture



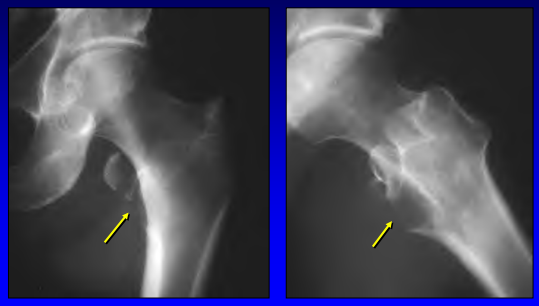
T1w MRI T2w MRI

Subtrochanteric Fracture

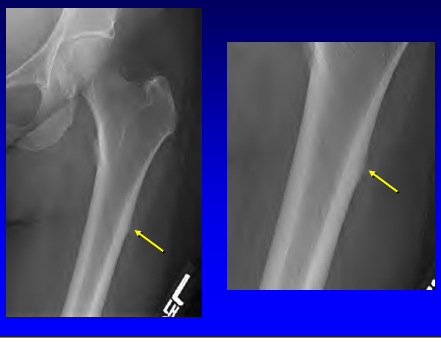


T1w T2w

Metastatic Lung Cancer: avulsion



Insufficiency fracture: bisphosphonate



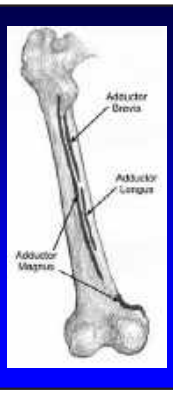
Insufficiency Fracture: bisphosphonate

Bisphosphonate

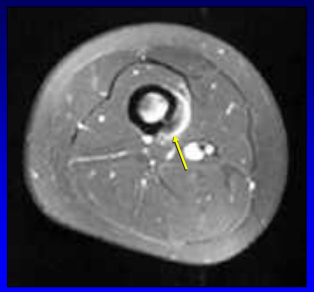
- To treat osteoporosis
  - Inhibits osteoclasts, may slow bone turnover
- Increased risk of fracture:
  - Average treatment at fracture: 6 years
  - Femur: subtrochanteric, diaphyseal, lateral cortex
- Early sign: periosteal reaction
  - 2% are asymptomatic at early stage

AJR 2011; 197:954

Thigh Splints



Coronal T2w



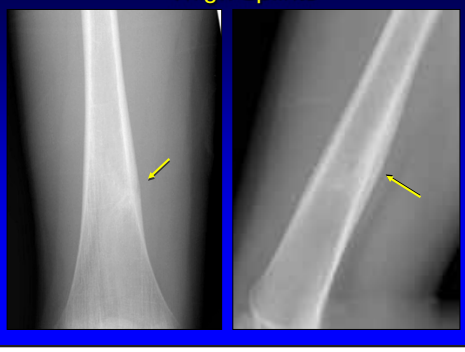
Axial T1w post-gadolinium

Thigh splints

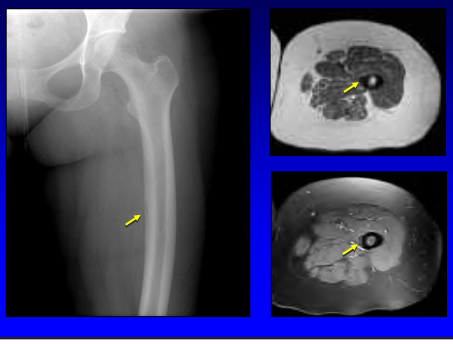
- Adductor insertion avulsion syndrome
- MRI:
  - Edema, enhancement, periostitis
  - May simulate tumor
- Key: location, history
- Fracture line: very helpful

AJR 2001; 177:673

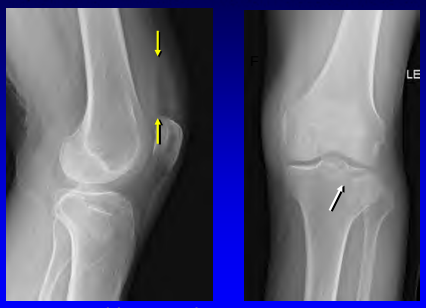
Thigh Splints



Thigh Splints



Lipohemarthrosis + Tibial Plateau Fracture

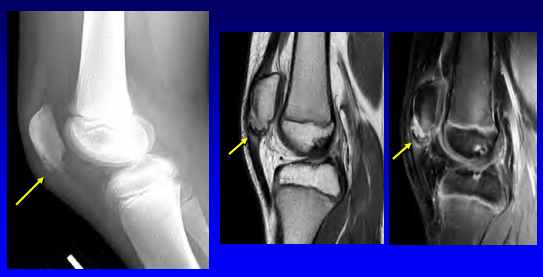


Cross Table Lateral

Lipohemarthrosis

- Intraarticular fat with hemorrhagic effusion
- Indicates occult intra-articular fracture
  - Lateral tibial plateau
- With trauma: lateral knee is supine
  - Cross-table lateral
  - Look for distinct fat-fluid level

Patellar Sleeve Fracture

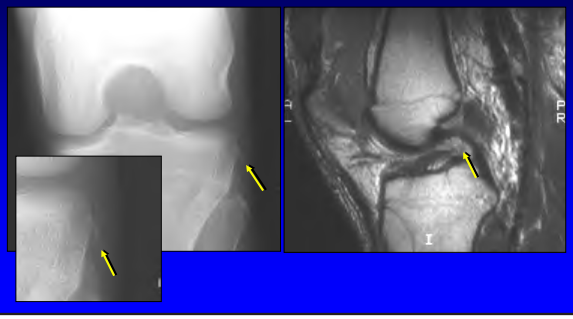


Patellar Sleeve Fracture

- Hyperextension injury: children
- Inferior patella: small bone fragments
- Cartilage avulsion: under-estimated
- Patella alta may be present
- MRI displays full extent of injury

Bates DG et al. Radiology 1994; 193:825

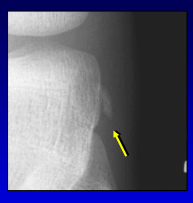
Segond Fracture: ACL Tear



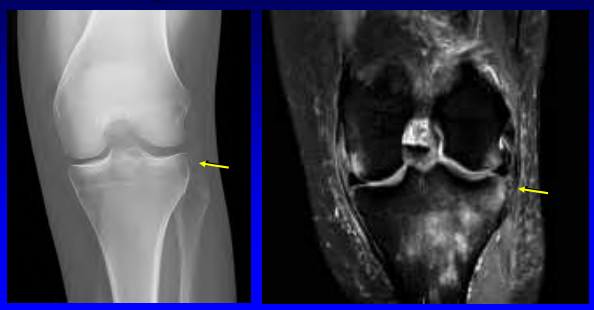
Segond Fracture

- Varus injury
- Avulsion of tibia
  - Lateral capsular ligament
  - Posterior aspect of ITB
- Anterior cruciate ligament tear in 75 – 100%

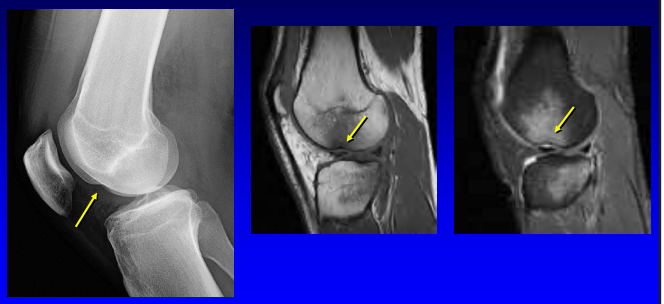
Flores DV et al. Skeletal Radiol 2016; 45:1635



Segond Fracture: ACL Tear

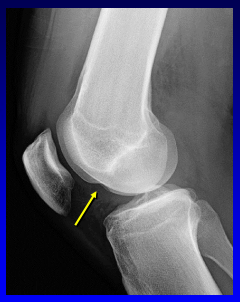


Deep Notch Sign: ACL Tear

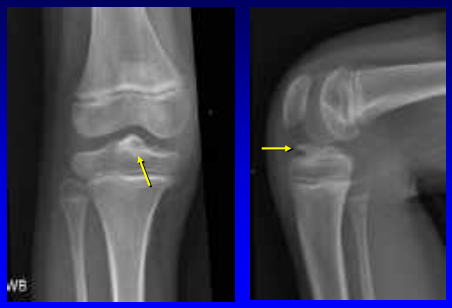


Deep Notch Sign

- Impaction fracture of lateral femoral condyle: valgus injury
- Abnormal if > 1.5 - 2 mm deep
- Associated with ACL tear

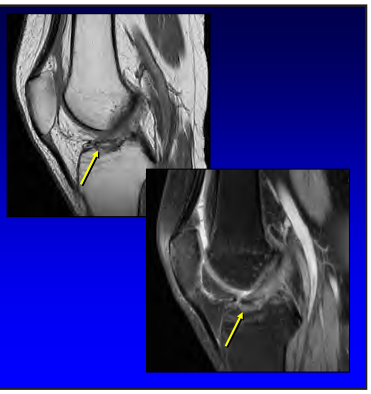


Tibial Eminence Avulsion



Tibial Eminence Avulsion

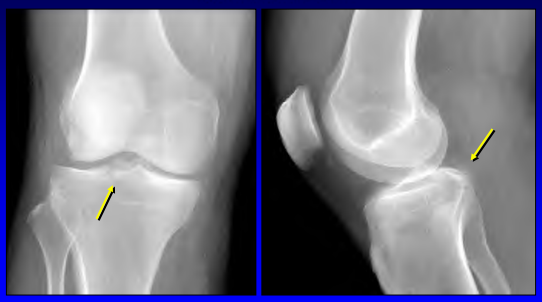
- Hyperextension injury
- Children
- Associated with functional ACL tear



ACL Associated Fractures

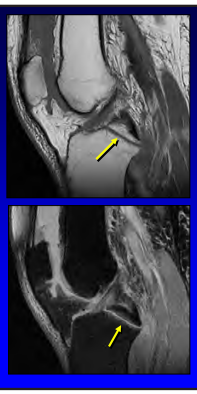
- Segond fracture: varus rotation
- Deep notch sign: valgus rotation
- Tibial eminence avulsion: hyperextension

PCL Avulsion



Posterior Cruciate Avulsion

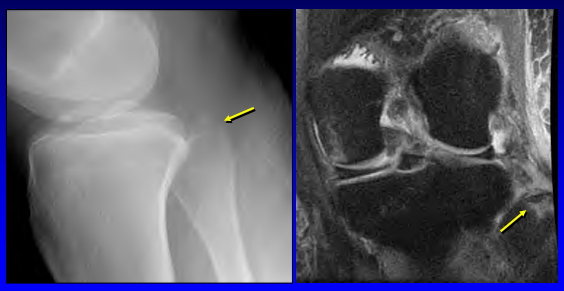
- May be associated with tibial fragment
- Difficult to identify if not true lateral
- Associated with:
  - Anterior cruciate ligament tear
  - Posterolateral corner injury



Arcuate Sign: posterolateral corner injury

Sagittal T1w

Arcuate Sign



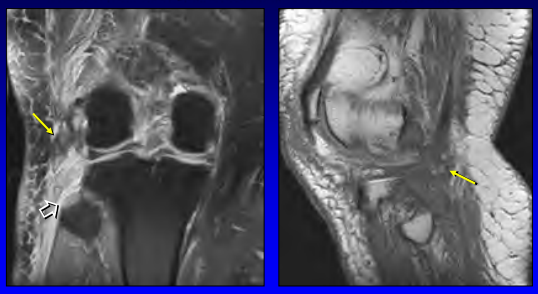
Arcuate Sign

- Popliteofibular and arcuate ligament avulsion
- Insertion: styloid process of fibula
- Indicates posterolateral corner injury
- Uncommon without LCL tear
- Associated PCL tear

Huang et al. AJR 2003; 180:381

LCL + Biceps Femoris Tendon Avulsion

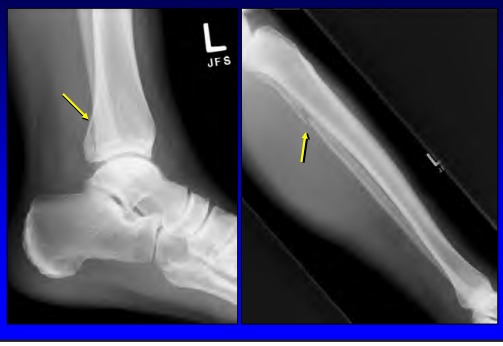
LCL + Biceps Femoris Tendon Avulsion



Axial T1w

Sag Oblique T2w

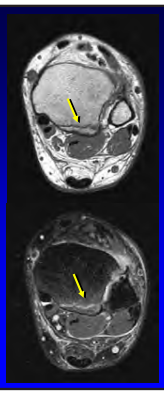
Maisonneuve Fracture



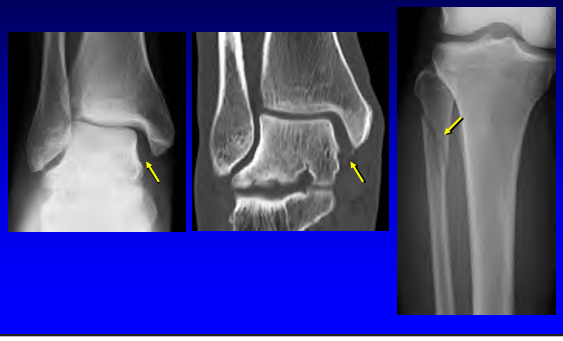
Maisonneuve Fracture:

- High fibula fracture
  - Ankle injury
  - Interosseous membrane injury
- Fibula fracture may not be obvious
- Isolated posterior or medial malleolus fracture: look for fibular fracture

Maisonneuve Fracture



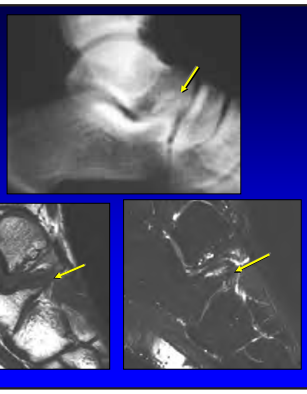
Maisonneuve Fracture



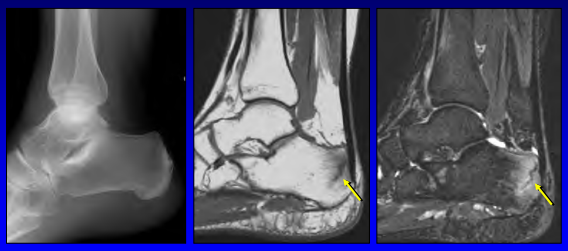
Fracture: anterior process of calcaneus

Anterior Process Fracture

- Insertion of bifurcate ligament
- Often difficult to identify at radiography



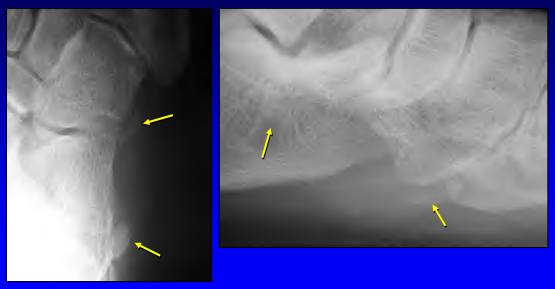
Insufficiency Fracture: calcaneus



Insufficiency Fracture

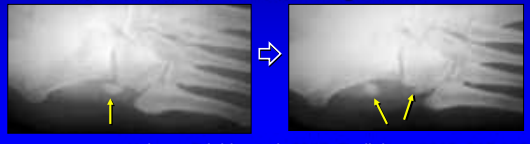
- Trabecular bone: ill-defined linear sclerosis
- Normal stress on abnormal bone: osteopenia
- MRI diagnostic: fracture line

Os Peroneum Fracture



Os Peroneum Fracture:

- Interval fragmentation or fracture
- Contraction + compression on cuboid
- Separation: > 6 mm (unlike bipartite)
- Associated: peroneus longus tear



Kalume-Brigido et al. 2007; Radiology 2005; 237:235

Os Peroneum Fracture

From: Kalume-Brigido et al. 2007; Radiology 2005; 237:235

Avusion Fracture: extensor digitorum brevis

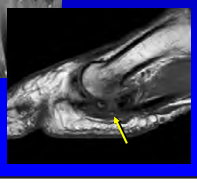

Extensor Digitorum Brevis Tendon

- Lateral surface of calcaneus
- Extensor digitorum brevis origin
- Fracture displaces away from calcaneus
- Only seen on AP view

Sesamoid Fracture



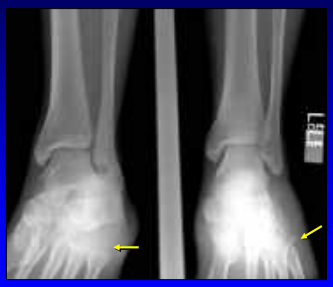
Contralateral Side



Hallux Sesamoid

- 1st metatarsophalangeal joint
- Medial sesamoid: bipartite or tripartite
  - Lateral: uncommonly bipartite
- Well-defined sclerotic margins
- Fracture:
  - Interval fragmentation
  - Separated fragments
  - Non-sclerotic margins

5th Metatarsal Avulsion Fracture




Fifth Metatarsal Fracture

- Peroneus brevis tendon and retinaculum avulsion at 5th metatarsal
- May present after ankle trauma
- All ankle radiographs must include proximal 5th metatarsal!

Fifth Metatarsal Fractures

- Avulsion (I):
  Extends to cuboid
- Jones (II):
  Extends to 4th MT
- Diaphyseal (III):
  Distal to 4th MT articulation

Jones Fracture

Buskova K et al. JBJS Reviews 2021; 9:1

Snowboarder's Fracture



Snowboarder's Fracture

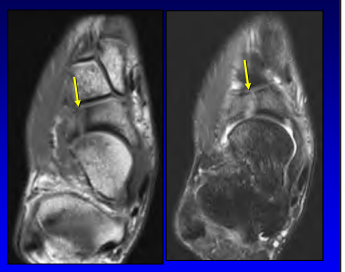
- Lateral process of talus
- 2% of all snowboarding injuries
- Snowboarders: 17x more likely to get this fracture than general population
- Often only seen on anteroposterior ankle radiograph

Melenevsky Y et al. Radiographics 2015; 35:765

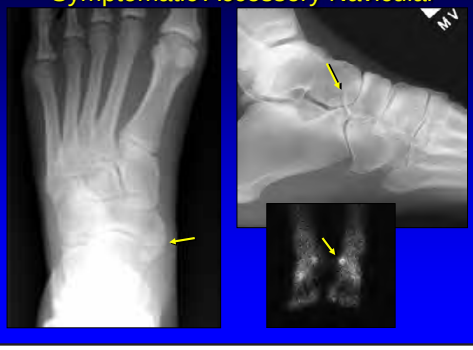
Fatigue Fracture: Navicular

Navicular Stress Fracture

- Abnormal stress on normal bone
- Very characteristic configuration:
  - Linear
  - Sagittal plane
- Only seen on anteroposterior radiograph

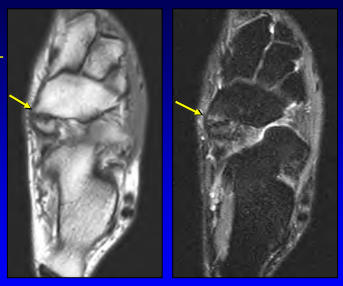


Symptomatic Accessory Navicular



Type 2 Accessory Navicular

- Synchondrosis between accessory and native navicular
- Repetitive injury, synchondrosis injury
- Symptomatic
- MRI: bone marrow edema

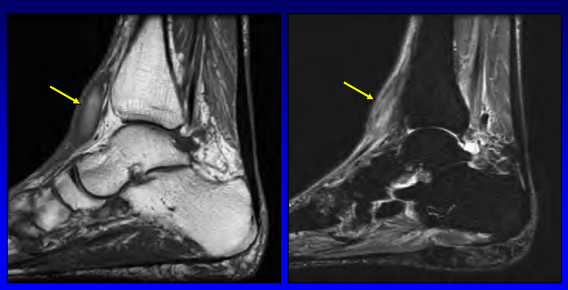


Accessory Navicular:

- Type 1: small ossicle, asymptomatic
- Type 2: triangle shape, immediately adjacent to navicular, symptomatic
- Type 3: fusion with navicular, asymptomatic

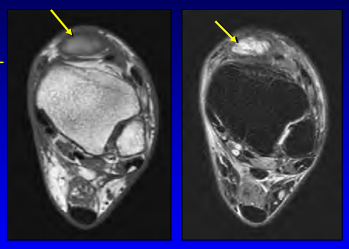
Anterior Tibialis Tendon Avulsion

Anterior Tibialis Tendon Avulsion



Tibialis Anterior Tendon Avulsion

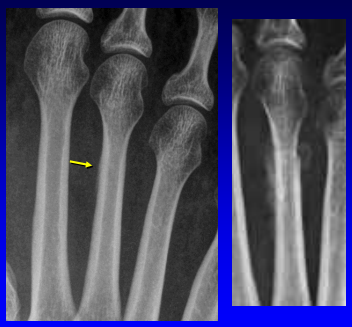
- Inserts of first cuneiform and first metatarsal
- Complete tear: retraction
- May present as soft tissue mass



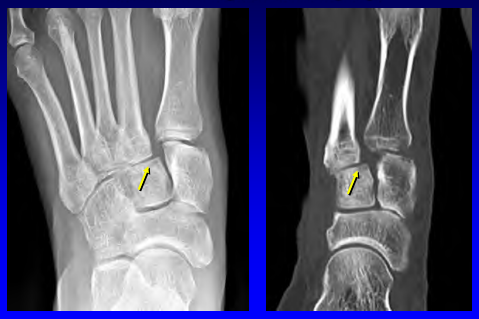
Metatarsal Fatigue Fracture

Metatarsal Stress Fracture

- Abnormal stress, normal bone:
  - March fracture
- Initial: periostitis
- Later: cortical fracture line, callus



Lisfranc Ligament Injury



Radiographs: importance of weight-bearing

Supine

Weight-bearing

Note offset between C2 and M2, which is more obvious with weight-bearing

Radiographs: importance of lateral view

Note dorsal subluxation of MT2 on lateral view (arrow).

Lisfranc Injury:

- Fracture:
  - C1 or MT 2 at Lisfranc ligament
  - Any fracture at TMT joints: get CT
  - Pitfall: os intermetatarseum
- Alignment:
  - Medial MT2 should align with C2
  - Other intertarsal widening
  - Weight-bearing radiographs

Lisfranc Injury: fracture

Pitfall: Os Intermetarseum

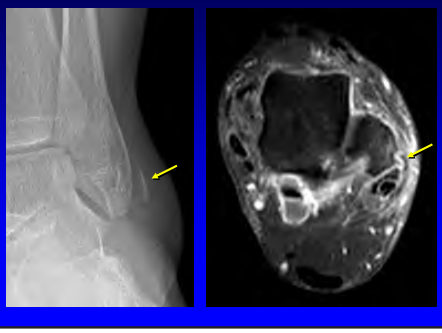
Unlike Lisfranc avulsion:

- Location: distal to Lisfranc ligament between MT1 and 2
- Well-corticated
- Shape: oblong or "torpedo"

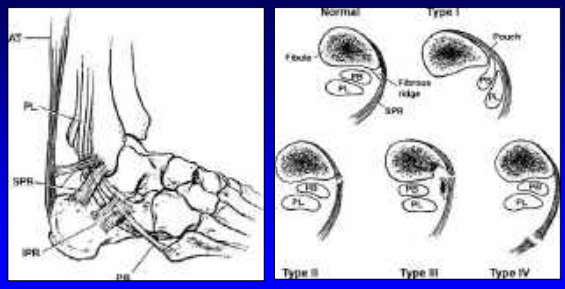
Radiographs: wide intertarsal space

Note asymmetric widened intertarsal space (arrow) and offset at navicular (arrowhead). There is no offset at the 2nd TMT joint.

Superior Retinaculum Avulsion (+ PB split)



Peroneal Retinaculum

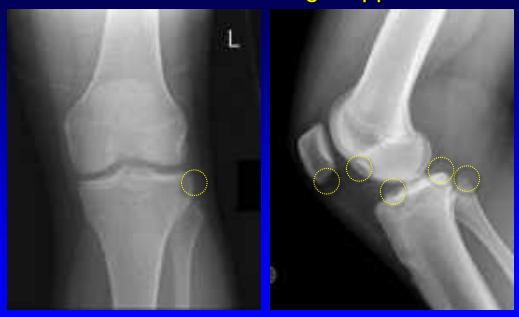


Rosenberg et al. AJR 2003; 181:1551

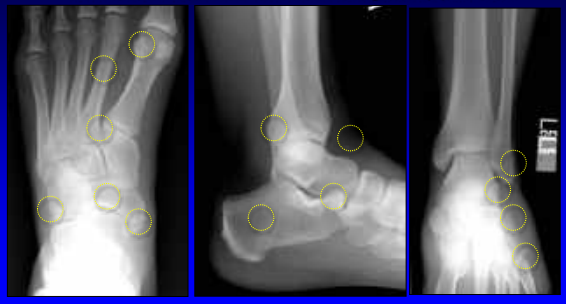
Summary

- Know where common fractures occur
- Look for subtle or important fractures
- Know specific avulsion fractures
- Consider MRI

Knee Fractures: target approach



Ankle / Foot Fractures: target approach



Thank you!

Syllabus online and other educational material:
www.jacobsonmskus.com

SELF EVALUATION

Imaging of Subtle and Important Fractures: Lower Extremity

True/False

1. Regarding femoral neck fractures, angulation of the primary compressive trabeculae is an important finding to diagnose a Garden 1 valgus impacted fracture.

2. In an osteoporotic patient, CT is accurate in the diagnosis of intramedullary insufficiency fractures.

3. Regarding an avulsion fracture on MRI, the resulting soft tissue edema often obscures a small fracture fragment.

4. At the ankle, an isolated posterior malleolus or medial malleolus fracture should raise suspicion for a high fibula or Maisonneuve fracture.

5. The most common imaging feature of a Lisfranc ligament tear is malalignment between the first metatarsal and the medial cuneiform.

Answer Key: 1. T, 2. F, 3. T, 4. T, 5. F

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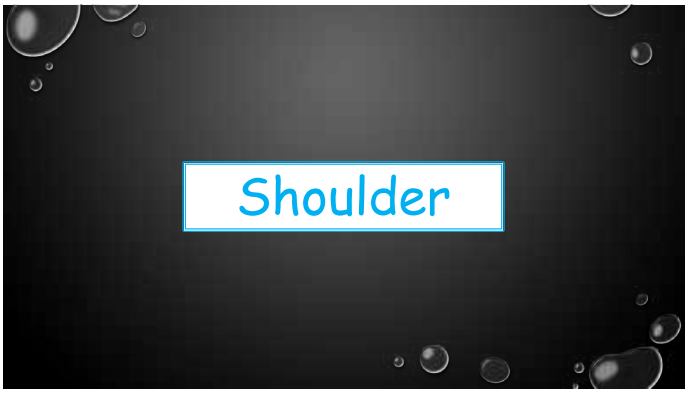
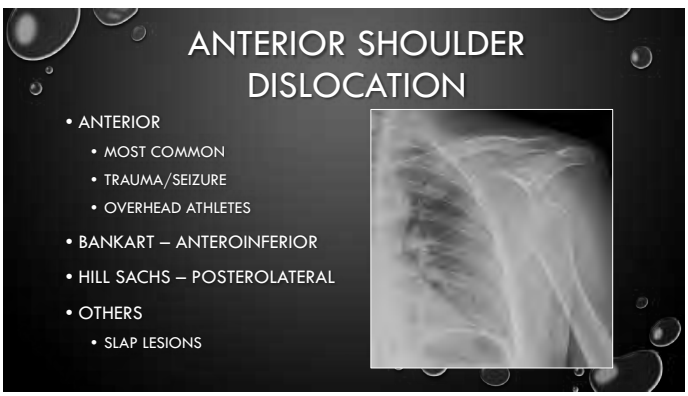
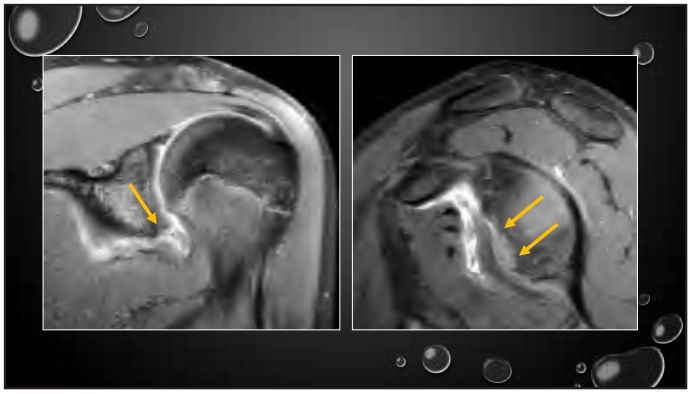
Upper Extremity Fractures



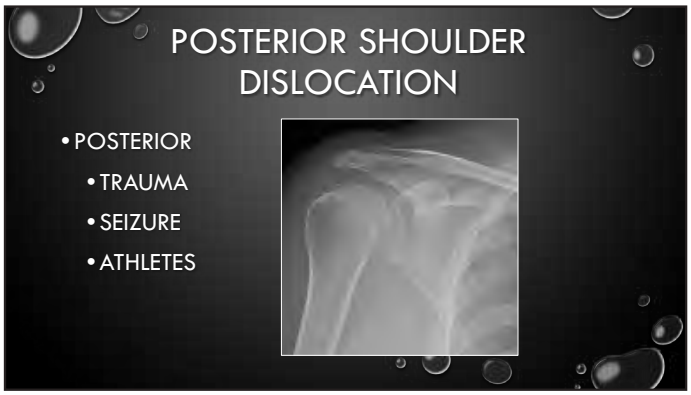


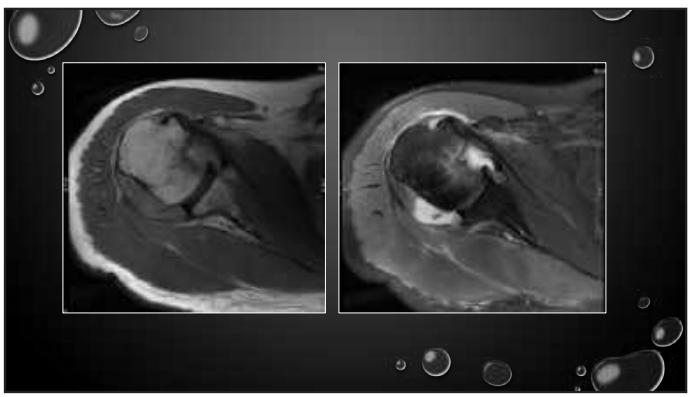


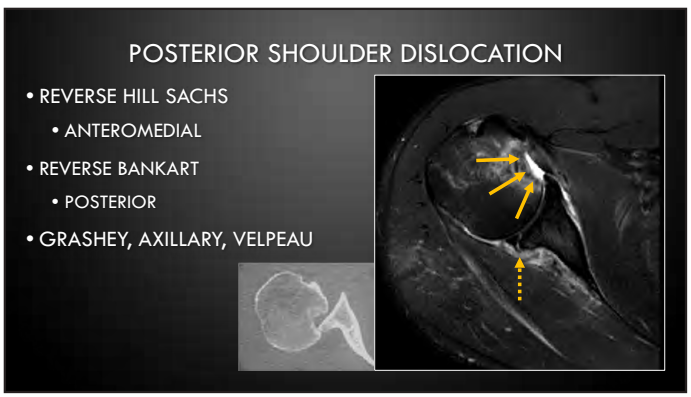

Companion Case

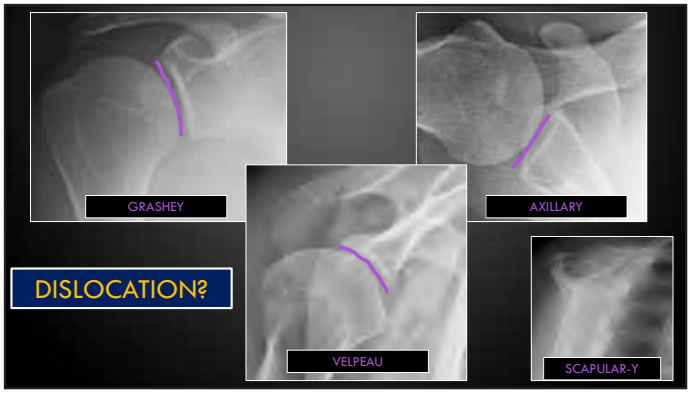

AAV

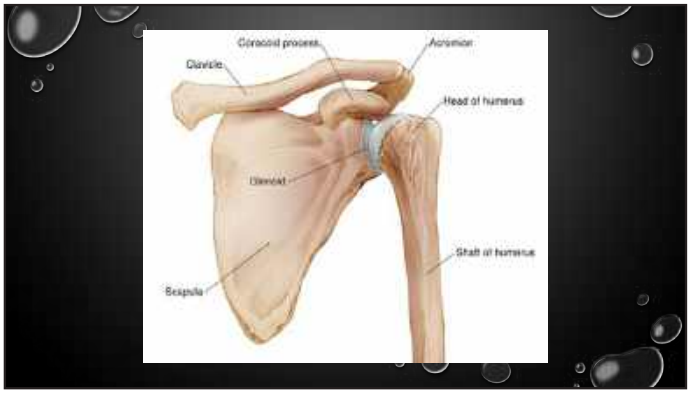

R
JAV

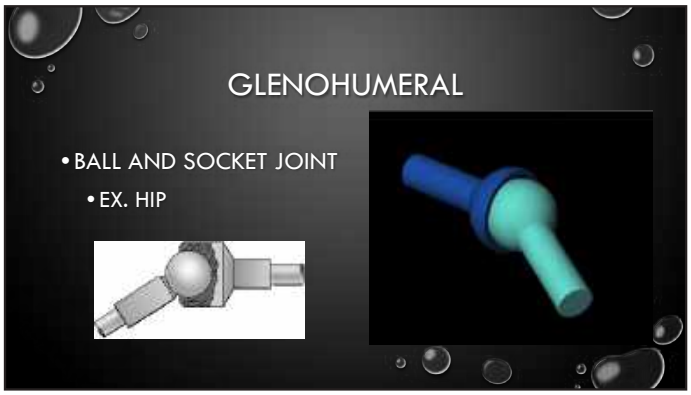

POSTERIOR SHOULDER DISLOCATION
• POSTERIOR
• TRAUMA
• SEIZURE
• ATHLETES

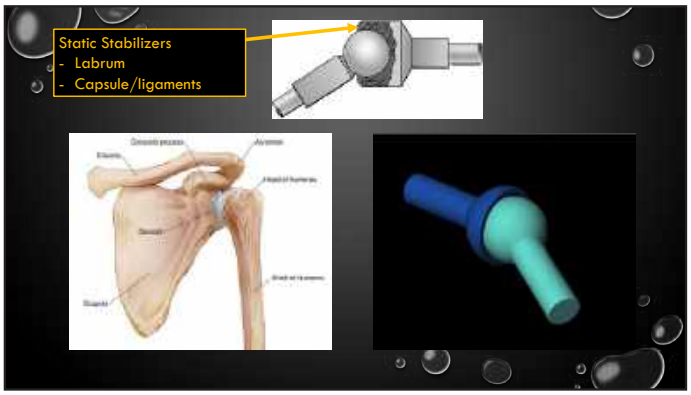


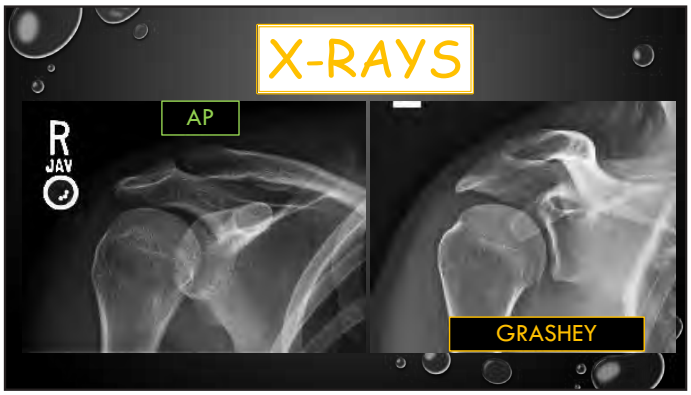

POSTERIOR SHOULDER DISLOCATION
• REVERSE HILL SACHS
• ANTEROMEDIAL
• REVERSE BANKART
• POSTERIOR
• GRASHEY, AXILLARY, VELPEAU

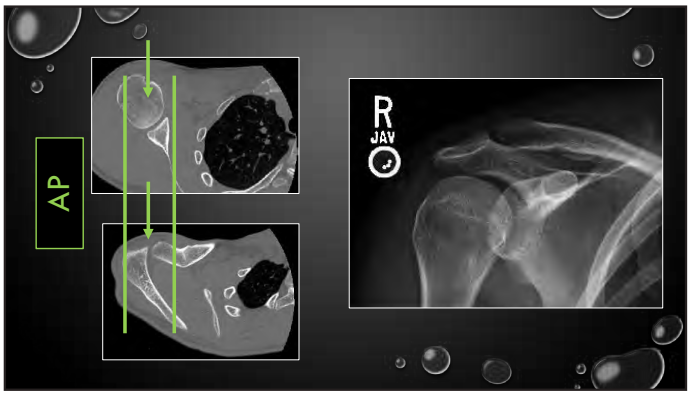

GRASHEY
AXILLARY
DISLOCATION?
VELPEAU
SCAPULAR-Y

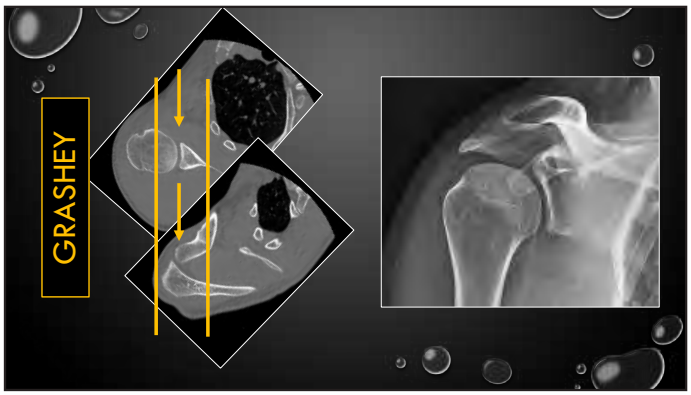

Coracoid process
Acromion
Clavicle
Head of humerus
Glenoid
Shaft of humerus
Scapula

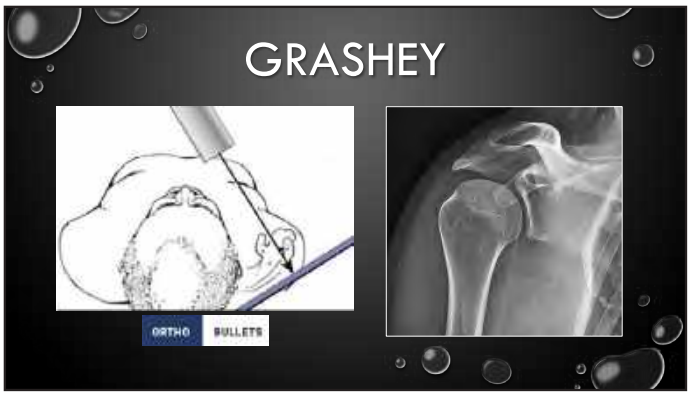

GLENOHUMERAL
• BALL AND SOCKET JOINT
• EX. HIP

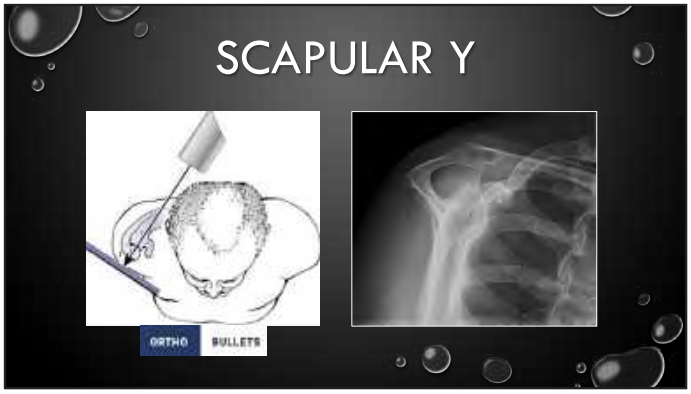

Static Stabilizers
- Labrum
- Capsule/ligaments

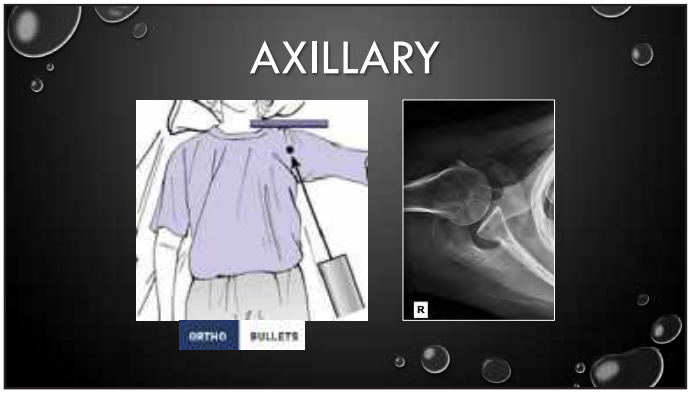

X-RAYS
AP
R
JAV
GRASHEY

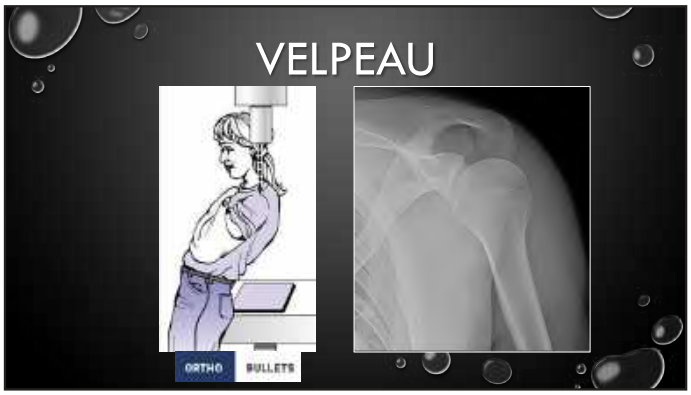

AP
R
JAV

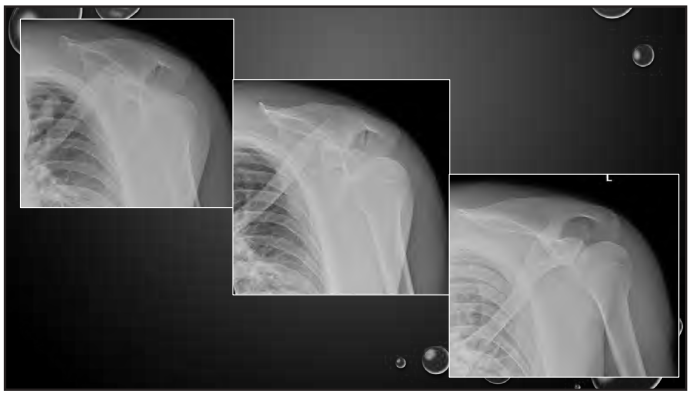

GRASHEY

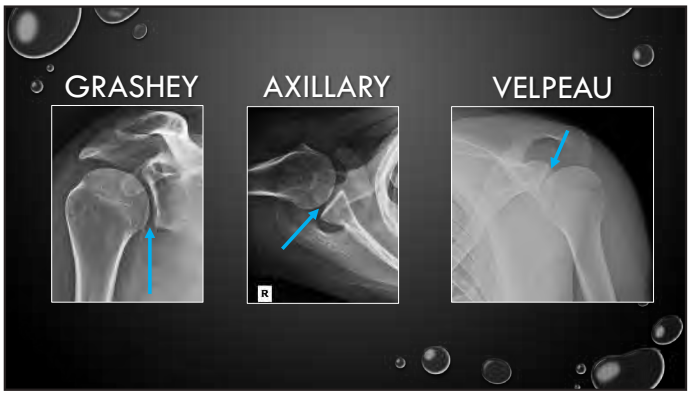

GRASHEY
ORTHO
BULLETS

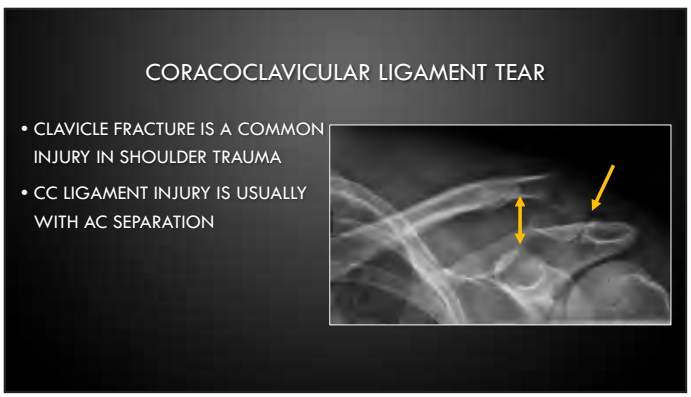

SCAPULAR Y
ORTHO BULLETS


AXILLARY
ORTHO BULLETS
R


VELPEAU
ORTHO BULLETS

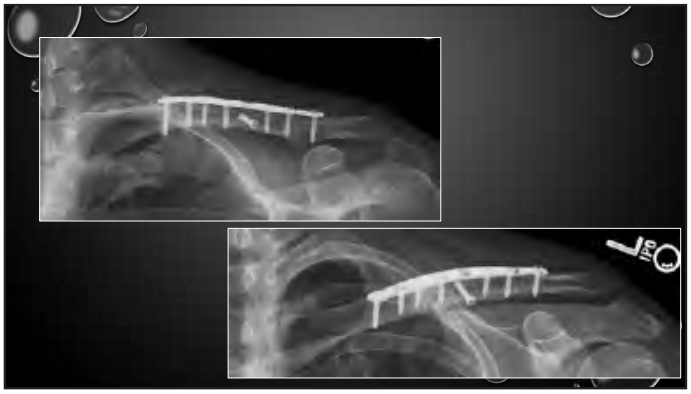



GRASHEY
AXILLARY
VELPEAU
R


CORACOCLAVICULAR LIGAMENT TEAR
• CLAVICLE FRACTURE IS A COMMON INJURY IN SHOULDER TRAUMA
• CC LIGAMENT INJURY IS USUALLY WITH AC SEPARATION

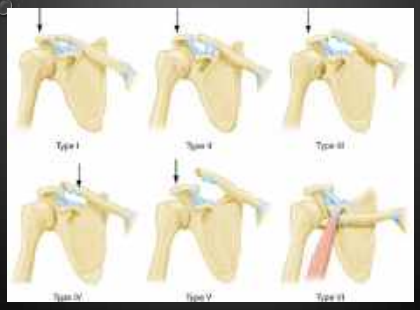
CLAVICLE FRACTURE

- 3-4% OF ADULT FRACTURES
- MIDDLE THIRD
- FOOSH OR DIRECT TRAUMA
- DISPLACEMENT
- TENTING
- BUTTERFLY FRAGMENTS
- VASCULAR TRAUMA

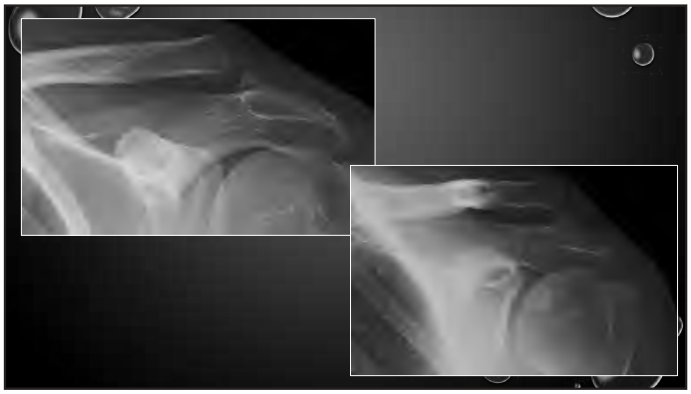


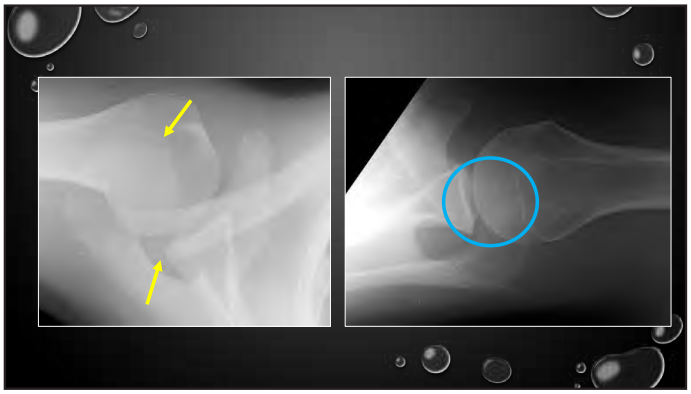
AC SEPARATION

- ACROMIOCLAVICULAR DISRUPTION
- CORACOCLAVICULAR DISTANCE (11-13MM)

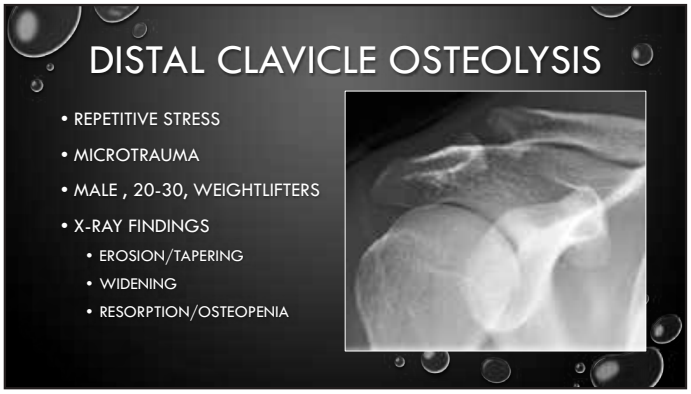


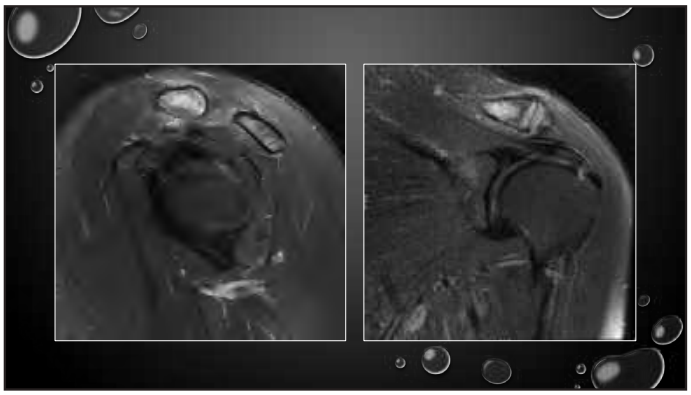
Nuber, GW, and MK Bowen. "Acromioclavicular Joint Injuries and Distal Clavicle Fractures." *Journal of the American Academy of Orthopaedic Surgeons.* 5.1 (1997): 11–18. Web.

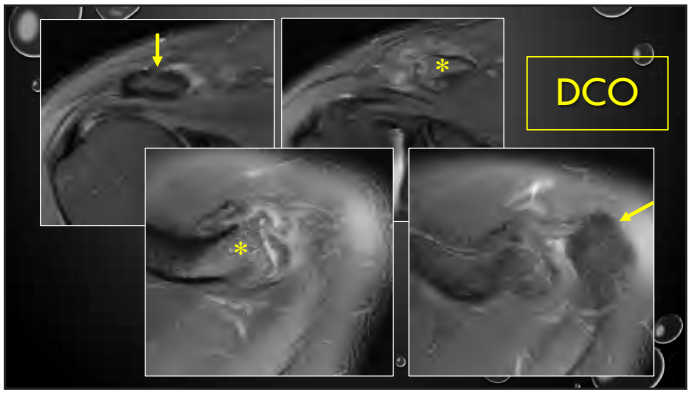




Companion Case


DISTAL CLAVICLE OSTEOLYSIS
• REPETITIVE STRESS
• MICROTRAUMA
• MALE , 20-30, WEIGHTLIFTERS
• X-RAY FINDINGS
• EROSION/TAPERING
• WIDENING
• RESORPTION/OSTEOPENIA

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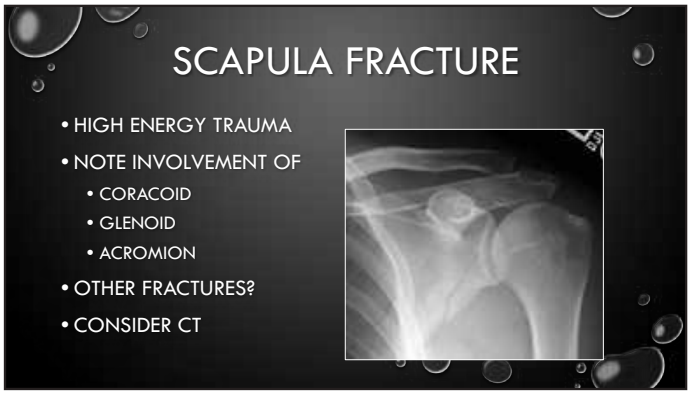
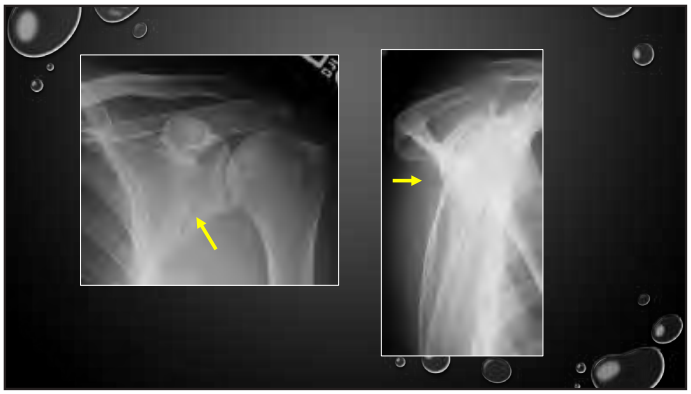
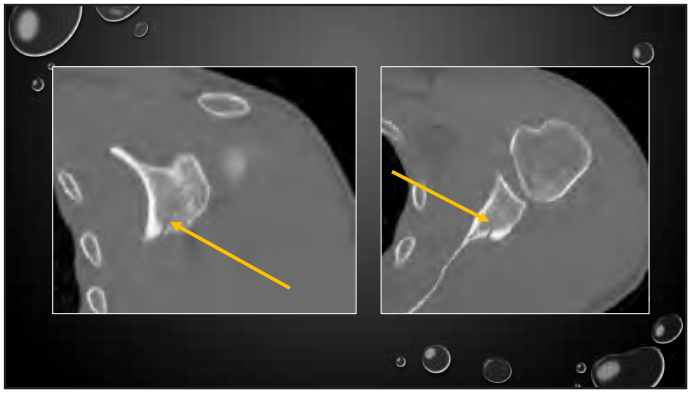
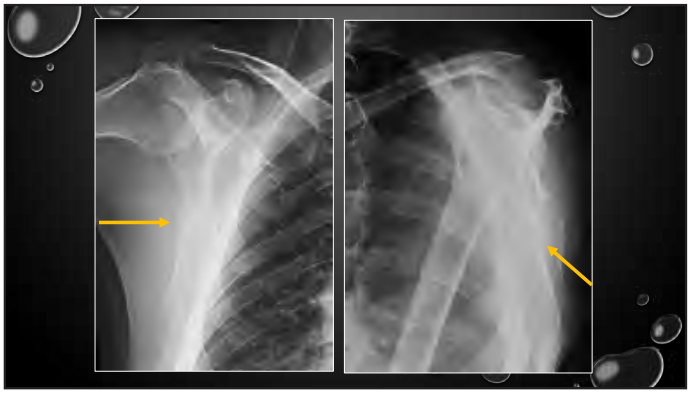

SCAPULA FRACTURE
• HIGH ENERGY TRAUMA
• NOTE INVOLVEMENT OF
• CORACOID
• GLENOID
• ACROMION
• OTHER FRACTURES?
• CONSIDER CT

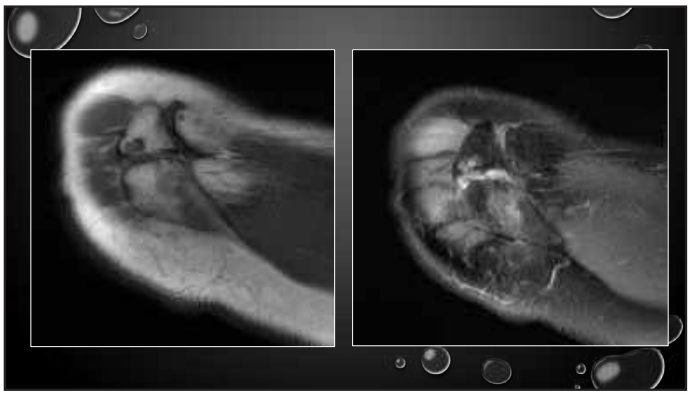






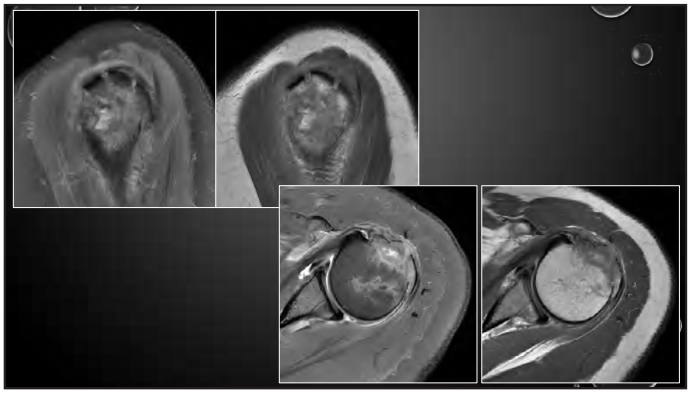
OS ACROMIALE

- 8% INCIDENCE
- 60% BILATERAL
- AXILLARY VIEW
- MULTIPLE TYPES
- MAY NOT FUSE UNTIL 25YO



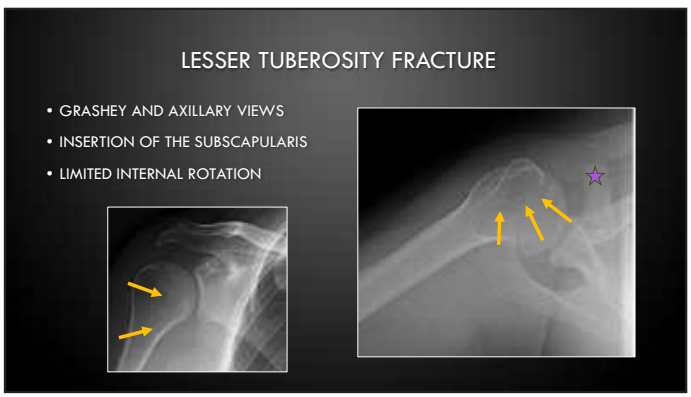
PROXIMAL HUMERUS FX

- LOW ENERGY => ELDERLY
- HIGH ENERGY => YOUNGER
- OFTEN TREATED NON OPERATIVELY
- REPORT
  - ANATOMIC/SURGICAL NECK
  - GREATER/LESSER TUBEROSITY
  - DISLOCATION

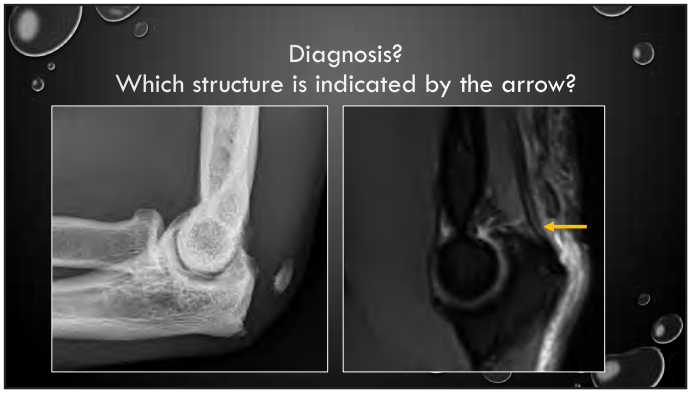


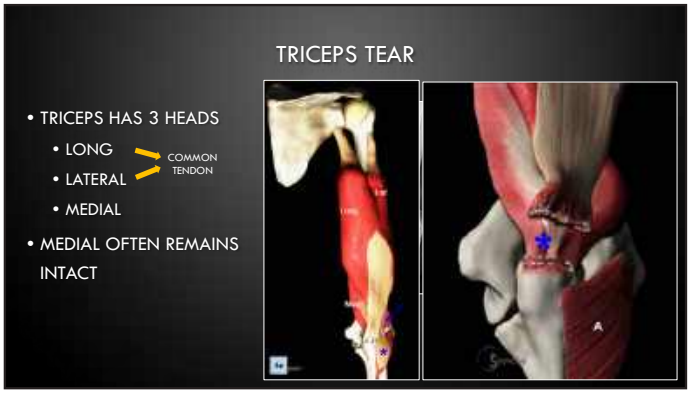

L
L


Companion Case


LESSER TUBEROSITY FRACTURE
• GRASHEY AND AXILLARY VIEWS
• INSERTION OF THE SUBSCAPULARIS
• LIMITED INTERNAL ROTATION


Elbow/Forearm


Diagnosis?
Which structure is indicated by the arrow?


TRICEPS TEAR
• TRICEPS HAS 3 HEADS
• LONG
• LATERAL
• MEDIAL
COMMON TENDON
• MEDIAL OFTEN REMAINS INTACT


?

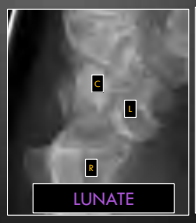

MONTEGGIA, GALEAZZI, ESSEX-LOPRESTI
• MONTEGGIA (CHILDREN > ADULTS)
• PROX 1/3 ULNA
• RADIAL HEAD DISLOCATION
• GALEAZZI
• DISTAL 1/3 RADIUS
• DRUJ INJURY
• ESSEX-LOPRESTI
• RADIAL HEAD FRACTURE
• DRUJ INJURY
• INTEROSSEOUS MEMBRANE INJURY

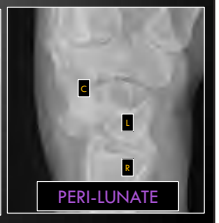

ELBOW DISLOCATION
• POSTEROLATERAL (80%)
• PEDS > ADULTS
• TERRIBLE TRIAD
• LAT ULNAR COLLATERAL (LUCL)
• RADIAL HEAD
• CORONOID TIP
AO


Wrist/Hand

LUNATE/PERILUNATE DISLOCATION

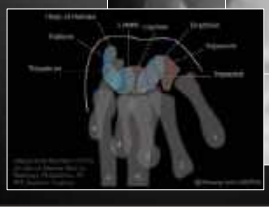
- HIGH ENERGY TRAUMA
- MEDIAN NERVE INJURY





HAMATE FRACTURE

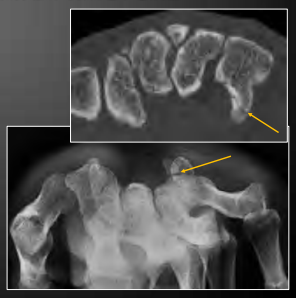
- CARPAL TUNNEL VIEW
- HAMATE
- PISIFORM
- TRAPEZIUM



HOOK OF HAMATE FRACTURE

- ULNAR NERVE (GUYON'S CANAL)
- FIRM GRIP SPORTS
  - TENNIS, BASEBALL, GOLF

Radiopaedia



Companion Case

OS HAMULI PROPRIUM

- UNFUSED HAMULI
- SMOOTH BORDERS
- MAY BE BILATERAL

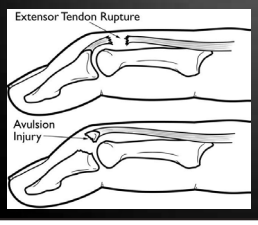
Radiopaedia

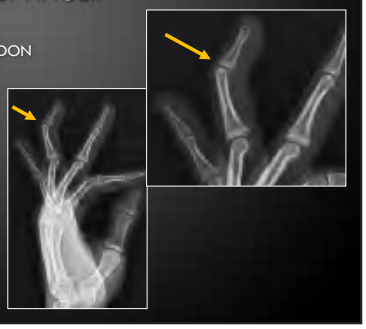
Hamate Fracture

Os Hamuli Proprium

MALLET FINGER

- DISRUPTION OF DISTAL EXTENSOR TENDON
- TRAUMATIC BLOW, LACERATION





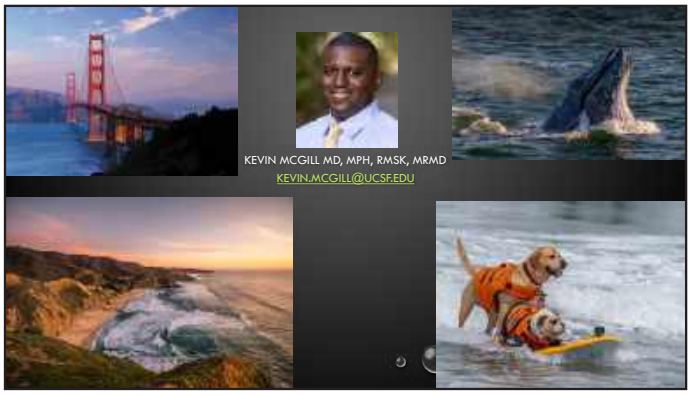
PULLEY TEAR

- MRI W/ FLEXION
- A3/A4 PULLEY
- ROCK CLIMBING

SUMMARY

- UPPER EXTREMITY TRAUMA
  - HIGH QUALITY X-RAY
  - ANATOMY
  - SOFT TISSUES

UCSF Department of Radiology and Biomedical Imaging



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SELF EVALUATION

Upper Extremity Fractures

True/False

1. A tear of the triceps most commonly involves the medial and lateral heads.

2. A carpal tunnel view can be used to evaluate fractures of the hamate, trapezium, and pisiform.

3. ”Bowstringing” on a finger MRI is a suggestive of a sagittal band injury.

4. Distal clavicle osteolysis is a more common in elderly females.

5. An Essex Lopresti injury of the forearm typically includes injury to the interosseous membrane.

Answer Key: 1. F, 2. T, 3. F, 4. F, 5. T

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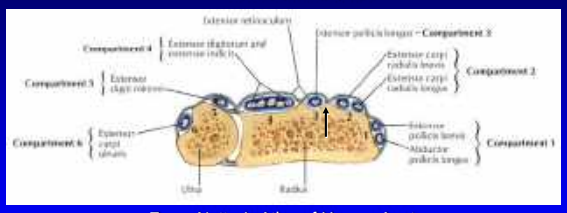
MR Imaging of the Wrist and Hand

Pathology:

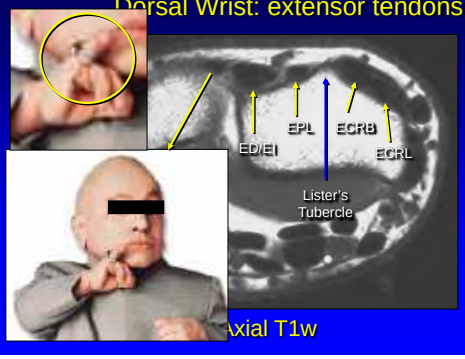
- Tendon
- Joint disease
- Ligament and TFC
- Nerves
- Osseous
- Cysts and masses

Dorsal Wrist

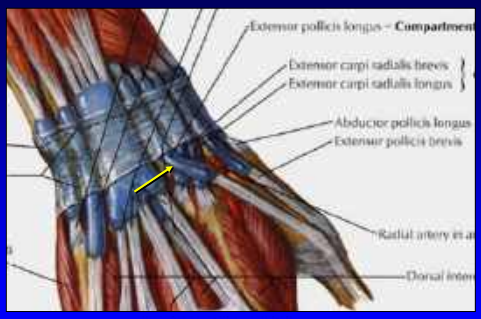


From: Netter's Atlas of Human Anatomy

Dorsal Wrist: extensor tendons



Axial T1w



From: Netter's Atlas of Human Anatomy

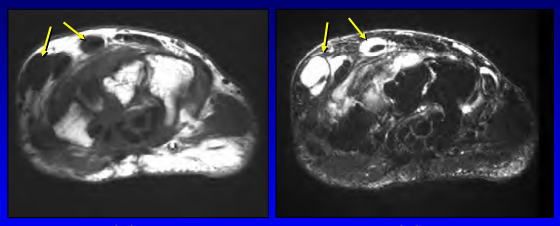
Tendon Abnormalities:

- Tenosynovitis
- Tendinosis
- Tendon tear:
  - Partial-thickness
  - Full-thickness

Tenosynovitis:

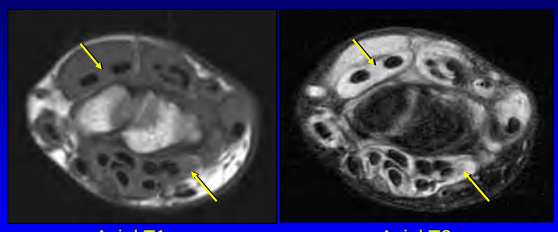
- Fluid distending tendon sheath
  - High signal T2w images
- Synovial hypertrophy:
  - Intermediate to high signal on T2w images
  - Immediate enhancement
- Inflammatory, reactive

Tenosynovitis: mechanical



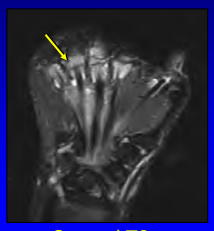
Axial T1w | Axial T2w

Tenosynovitis: spondyloarthritis

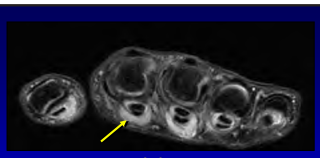


Axial T1w | Axial T2w

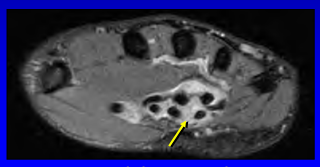
Tenosynovitis: spondyloarthritis



Coronal T2w

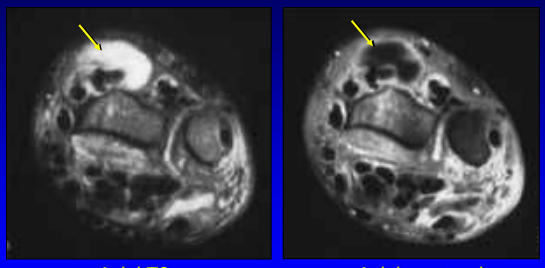


Axial T2w



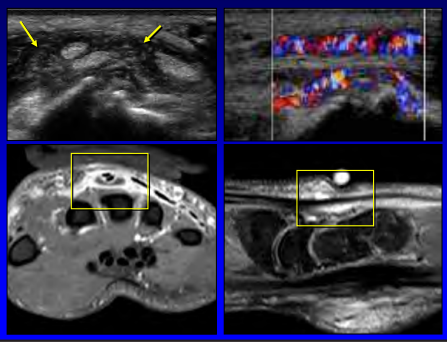
Axial post-gado

Tenosynovitis: infection



Axial T2w | Axial post-gado

Gout: extensor peritendinitis



Tendinosis:

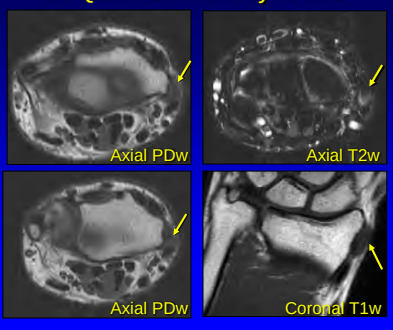
- No acute inflammatory cells
- Tendon:
  - Increased thickness
  - Intermediate signal: similar to muscle
  - Associated tenosynovitis
- Overuse conditions

de Quervain Tenosynovitis:

- Stenosing tenosynovitis
- 1st dorsal wrist compartment:
  - Extensor pollicis brevis
  - Abductor pollicis longus
- Thick tendons, adjacent edema

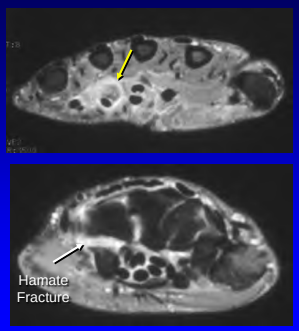
Glajchen. Skeletal Radiol 1996;25:63.

de Quervain Tenosynovitis



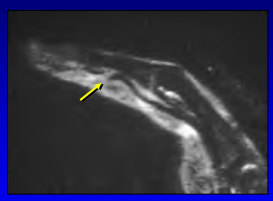
Tendon Tear

- Full-thickness tear
  - Acute trauma or laceration
  - Tendon discontinuity
  - Tendon retraction



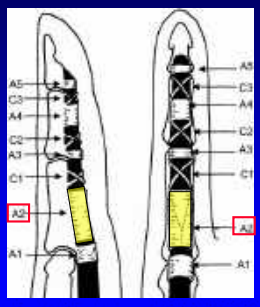
Flexor Digitorum Profundus Tear

Sagittal PDw



Sagittal T2w

Digit Pulley System



Zanetti. Radiology 1998; 206:339

Pulley Tear

- A2 pulley
- Sagittal image
  - Bowstringing
  - Fluid signal edema / hemorrhage

Hauger. Radiology 2000; 217:201

A2 Pulley Injury

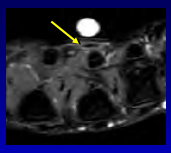
Abnormal

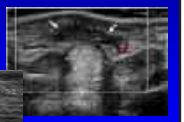
Normal

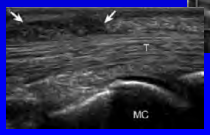
Dupuytren Contracture

- Palmar fibromatosis
- Palmar fascia
- Cord-like thickening
- Superficial to flexor tendons
- Digits: 4th > 3rd > 5th
- Most common proximal to MCP joint

Morris G. et al. J Ultrasound Med 2019; 38:387







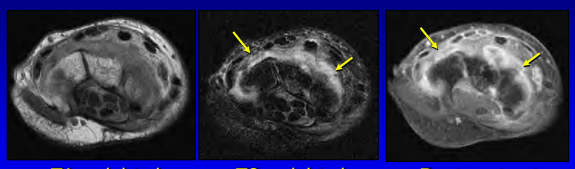
Pathology:

- Tendon
- Joint disease
- Ligament and TFC
- Nerves
- Osseous
- Cysts and masses

Joint Disease

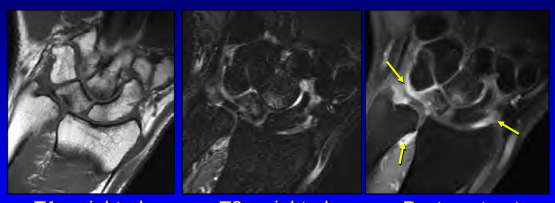
- Inflammatory arthritis:
  - Synovitis
  - Erosions
  - Possible tenosynovitis
- Degenerative arthritis
- Correlate with distribution, radiographs, and clinical information

Synovitis: lupus



T1-weighted T2-weighted Post-contrast

Synovitis: post-traumatic



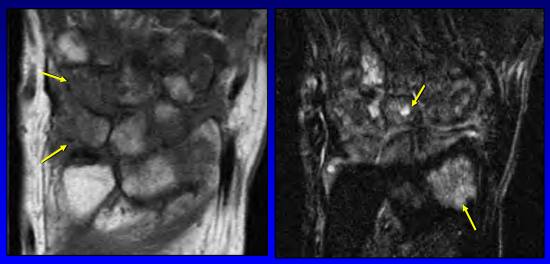
T1-weighted T2-weighted Post-contrast

Erosions

- MRI better than radiographs
- Cortical irregularity: ? erosion
  - Not specific by MRI
  - Rely on coexisting synovitis & radiographs
- Bone marrow edema (MRI): not specific
  - Precursor of erosion or mechanical edema

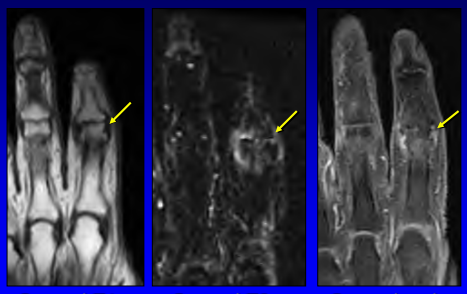
McQueen. Rheumatology 2000; 39:700

Rheumatoid Arthritis: wrist



T1-weighted T2-weighted

Rheumatoid Arthritis: digit

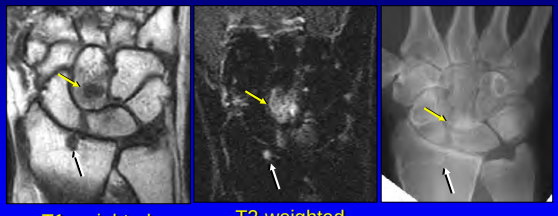


Coronal T1w Coronal T2w Coronal gado

Osteoarthritis: degenerative cysts

T1-weighted T2-weighted

Post-traumatic Osteoarthritis:
Degenerative Cysts



T1-weighted T2-weighted

Hamatolunate Impaction: Type 2 lunate

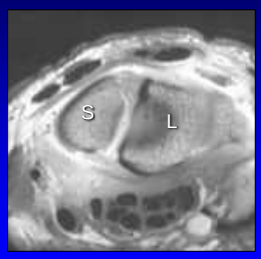
Coronal T2w

Cerezal. RadioGraphics 2002;22:105.

Pathology:

- Tendon
- Joint disease
- Ligament and TFC
- Nerves
- Osseous
- Cysts and masses

Scapholunate Ligament



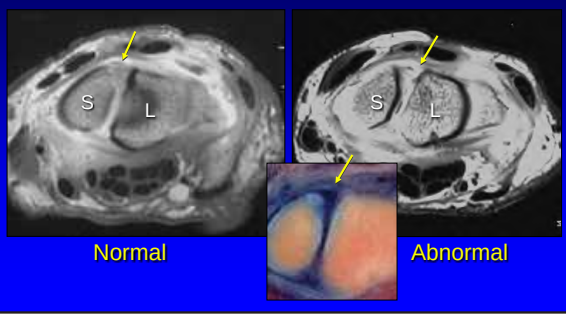
Axial T1w

From: Linkous MD, et al. Radiology 2000; 216:846

Scapholunate Ligament Tear

- Central component: perforation
  - Asymptomatic pathology
  - Degeneration and tear
- Dorsal component:
  - Most important functionally
  - Most significant tears

Scapholunate Ligament

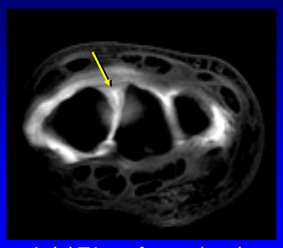


Normal

Abnormal

Scapholunate Ligament: tear

Coronal T1w + fat sat / gado

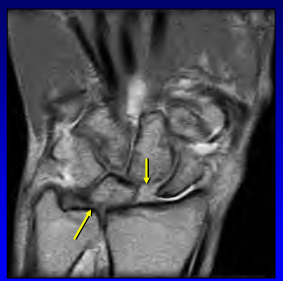


Axial T1w + fat sat / gado

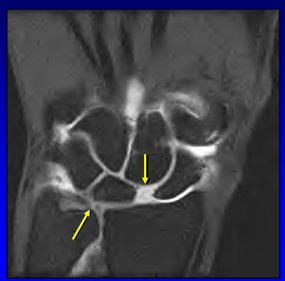
Scapholunate Ligament: tear

Coronal T1w
No gadolinium

TFC and SL ligament tears

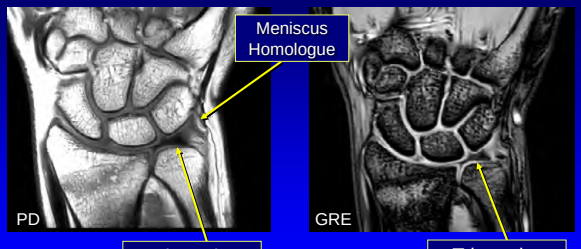


Coronal T1w + gado



Coronal T1w + fat sat / gado

Triangular Fibrocartilage Complex



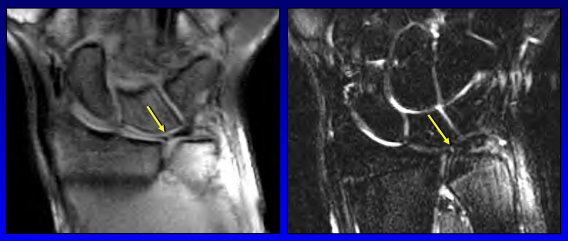
Palmer Classification

TABLE 1 Palmer's Classification of Triangular Fibrocartilage (TFC) Lesions

Traumatic Injury		Degenerative Injury	
Class	Features	Class	Features
IA	Central perforation	IIA	TFC wear
IB	Ulnar avulsion	IIB	TFC wear and chondromalacia
IC	Distal avulsion	IIC	TFC perforation and chondromalacia
ID	Radial avulsion	IID	TFC perforation, chondromalacia, lunotriquetral ligament perforation
		IIE	TFC perforation, chondromalacia, lunotriquetral ligament perforation, and ulnocarpal or radioulnar arthritis

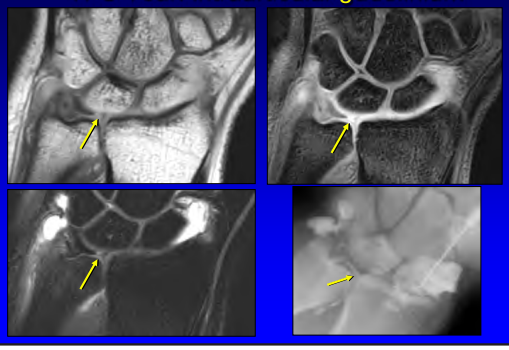
From: Resnick's Diagnosis of Bone and Joint Disorders

TFC Tear



Coronal T1w Coronal T2w

TFC Tear: intraarticular gadolinium



Triangular Fibrocartilage Tear

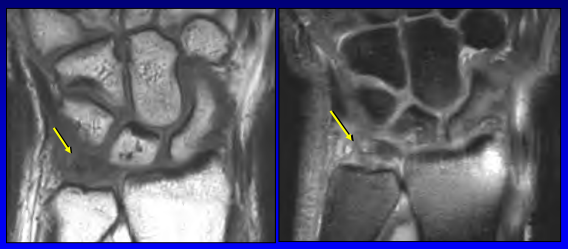
- 80% are communicating defects
- Non-communicating defects[1]
  - More often symptomatic
  - Arthrography: 2 compartment injection
- Pitfall: ulnar attachment variability[2]

[1]Zanetti. Radiology 2000; 216:840
[2]Haims. AJR 2002; 178:419

TFC Tear: Palmer 2C

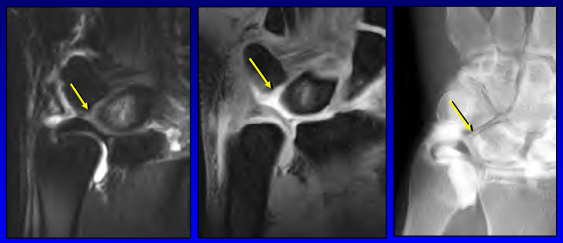
Coronal T1w Coronal T2w

Synovitis: Normal Triangular Fibrocartilage



Coronal T1w Coronal T2w

Lunotriquetral Ligament Tear

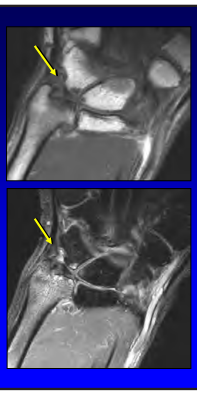


Coronal T2w and T1 with fat sat
Intra-articular gadolinium

Ulnar Abutment Syndrome

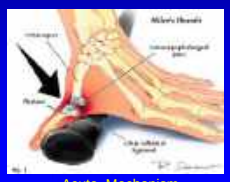
- Positive ulnar variance
- Degenerative tear of TFC
- Degenerative / traumatic changes:
  - Corner of lunate
  - Variant: ulnar styloid on triquetrum

Cerezal. RadioGraphics 2002;22:105.



Gamekeeper's Thumb

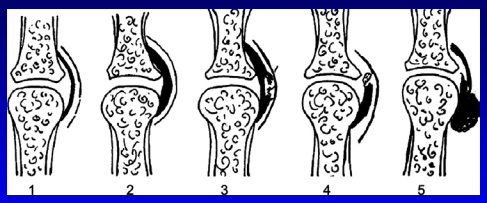
- Injury of the ulnar collateral ligament (UCL) of the thumb
  - Historically, chronic injury in Scottish gamekeepers
  - Frequently, due to acute MCP joint hyperabduction
  - Skier's thumb: up to 86% of thumb base injuries



Acute Mechanism

Chronic Mechanism

Ulnar Collateral Ligament: thumb



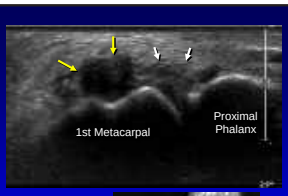
1	2	3	4	5
Normal	Sprain	Partial Tear	Nondisplaced Complete Tear (+ fracture)	Displaced Complete Tear (Stener Lesion)

Radiographics 2006;26:1007

RadioGraphics

Stener Lesion

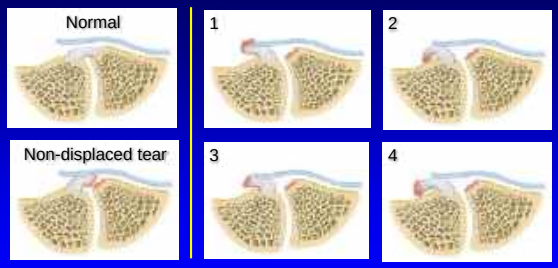
- Displaced proximal stump of UCL
  - Hypoechoic & round
  - Proximal to MCP joint
  - At proximal edge of adductor pollicis aponeurosis
- No tissue spanning MCP joint
- "Yo-yo on a string" sign
- Ultrasound: 100% accuracy



Yellow arrows: Stener
White arrows: aponeurosis

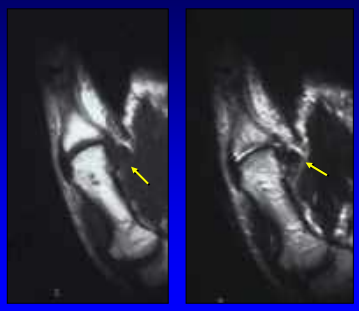
*Melville D. et al. Skeletal Radiology 2013; 42:667

Stener Lesion: variations



Displaced Full-thickness Tears

Gamekeeper Thumb + Stener Lesion

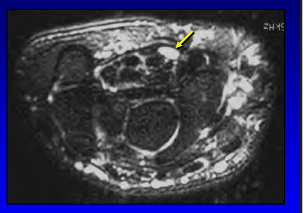


Pathology:

- Tendon
- Joint disease
- Ligament and cartilage
- Nerves
- Osseous
- Cysts and masses

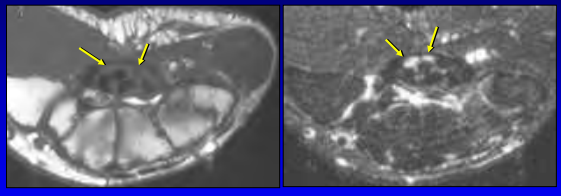
Carpal Tunnel Syndrome:

- Proximal median nerve swelling
  - >10 mm^2 cross-sectional area[1]
  - >9 mm circumferential[2]
- Distal median nerve flattening
- Flexor retinaculum bowing
- Abnormal fluid signal



[1]AJR 1997; 168:533
[2]AJR 1999; 173:681

Bifid Median Nerve: carpal tunnel syndrome

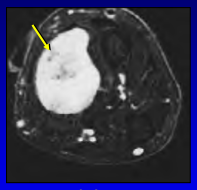


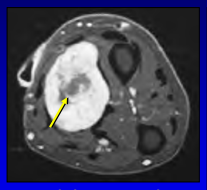
Axial T1w | Axial T2w

Peripheral Nerve Sheath Tumors:

- MRI:
  - Fusiform, surrounded by fat
  - High signal T2w, significant enhancement
  - Nerve continuity or tail
- Target sign:
  - Central low signal fibrous tissue
  - Peripheral myxoid tissue
  - If present, suggests benign

Schwannoma: median nerve


Axial T2w

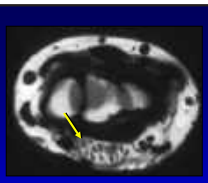

Axial post-gado


Sagittal PDw

Nerve Lipomatosis

- a.k.a. Fibrolipomatous Hamartoma
- Tumorlike lipomatous involvement
  - Peripheral nerves and branches
  - Median > tibial, peroneal
- Related to macrodystrophia lipomatosa
- MRI:
  - Increased fatty tissue
  - Interspersed among thick nerve bundles

De Maseseneer. Skeletal Radiol 1997;26:155



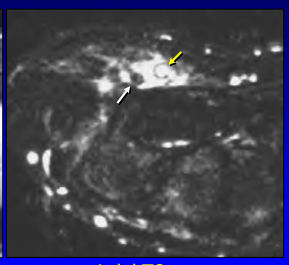
Guyon's Canal:

- Ulnar nerve compression
  - Ulnar tunnel syndrome
- Ulnar artery thrombosis
  - Hypothenar hammer syndrome*

Vayssairat. J Vasc Surg 1987; 5:838

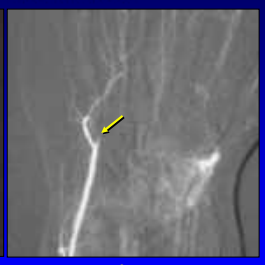
Ulnar Artery Thrombosis


Axial T1w


Axial T2w

Ulnar Artery Thrombosis


MR Angiogram


Angiogram

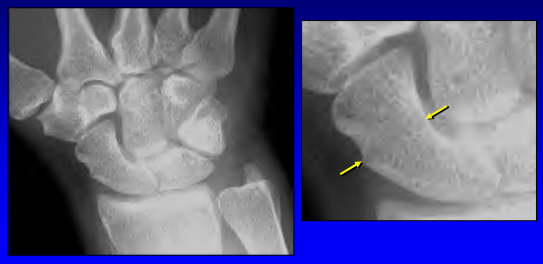
Pathology:

- Tendon
- Joint disease
- Ligament and TFC
- Nerves
- Osseous
- Cysts and masses

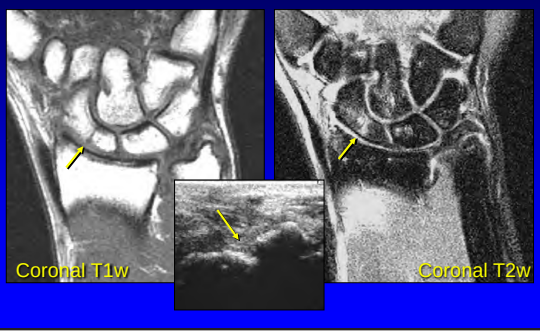
Osseous Abnormalities

- Scaphoid fracture
- Kienböck ischemic necrosis: lunate
- Post-traumatic cortical cyst

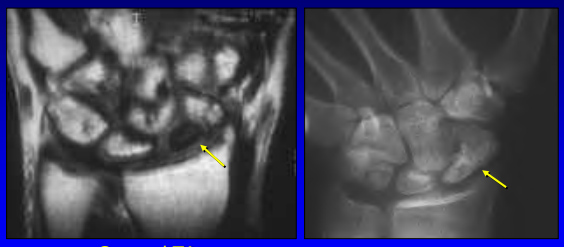
Scaphoid Fracture



Scaphoid Fracture



Scaphoid Fracture + AVN

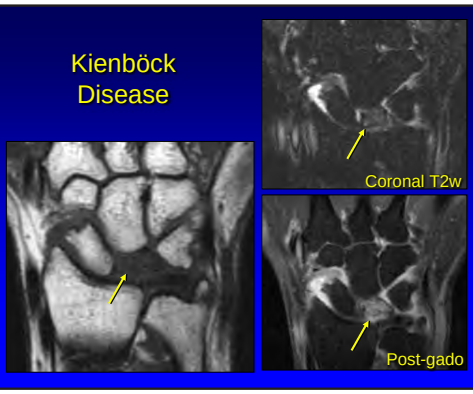


Kienböck Disease:

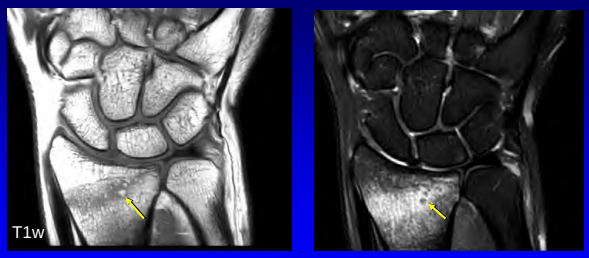
- Osteonecrosis
- Trauma
- Negative ulnar variance (questionable)
- Idiopathic
- MRI:
  - Bone marrow edema
  - Collapse, low signal

Dalinka. AJR 1995; 164:1

Kienböck Disease



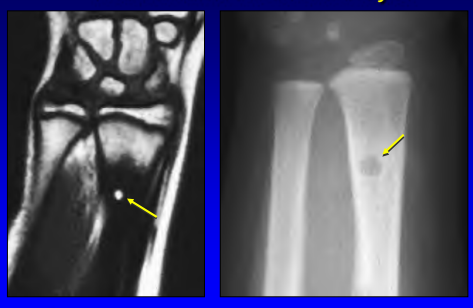
Radius Fracture: fat globules



Coalesced fat from fat necrosis

Wong A. et al. Skeletal Radiol 2014; 43:1713

Post-traumatic Cortical Cyst



Pathology:

- Tendon
- Joint disease
- Ligament and TFC
- Nerves
- Osseous
- Cysts and masses

Cysts and Masses: benign

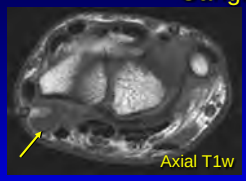
- Ganglion
- Giant cell tumor of tendon sheath
- Hemangioma
- Lipoma
- Glomus tumor

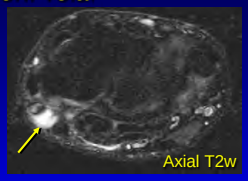
Soft Tissue Mass: wrist ganglia

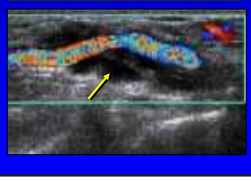
- Most wrist masses are ganglia
- Multilocular fluid
- Volar (70%): radial artery & flexor carpi radialis
  - Proximal from radioscaphoid joint capsule
- Dorsal (30%): scapholunate ligament
  - Not compressible (unlike joint recess)

Zhang A. et al. J Ultrasound Med 2018; 38:2155

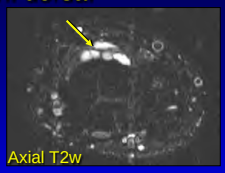
Ganglion: volar

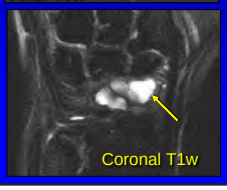


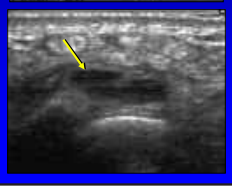




Ganglion: dorsal



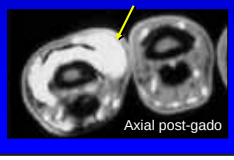




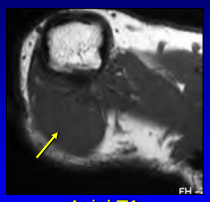
Giant Cell Tumor Tendon Sheath

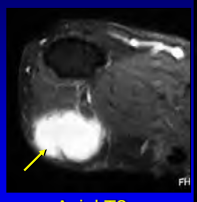
- Tenosynovial giant cell tumor
- 2nd most common mass of the hand
- Volar digits: #1 and 3
- Mass associated with tendon sheath
  - Intermediate to low signal

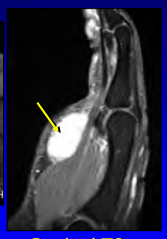
Walker EA . Semin Roentgenol 2010; 45:277



Fibroma of Tendon Sheath





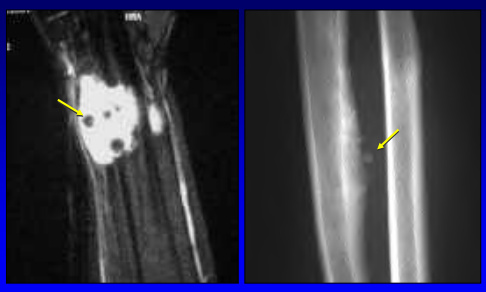


Soft Tissue Hemangioma:

- Benign vascular neoplasm
- MRI findings:*
  - high signal on T1w & T2w images
  - focal muscle atrophy
  - serpiginous pattern

*AJR 1987; 149:765

Hemangioma



Coronal T1w post-gado

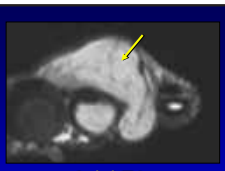
Lipoma:

- Fat signal
- Septations: 2 mm or less
- No soft tissue nodules
- Little or no enhancement

Hosono. Skeletal Radiol 1997; 26:150

Lipoma

Coronal T1w



Axial T1w

Axial post-gado

Glomus Tumor

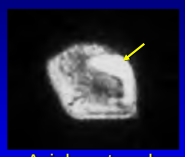
- Hamartoma:
  - Neuromyoarterial glomus body
- 75% in hand: subungual
- Pain, tenderness, temperature sensitivity
- MRI:
  - Intermediate T1-w, high T2-w
  - Vascular, enhancement

Drape. Radiology 1995;195:507

Glomus Tumor

Coronal T2w

Coronal post-gado



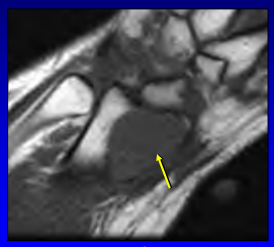
Axial post-gado

Giant Cell Tumor

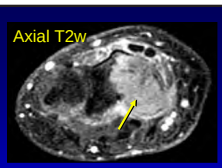
- Articular, eccentric, closed growth plate, non-sclerotic border
- Location:
  - Knee (femur, tibia)
  - Distal radius, sacrum
- MRI: solid mass

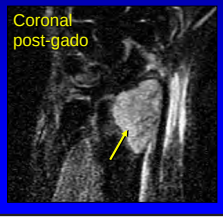
Murphey. RadioGraphics 2001; 21:183

Giant Cell Tumor



Coronal T1w





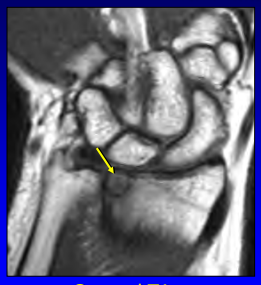
Osteoid Osteoma

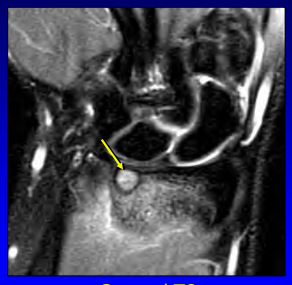
- Benign
- First 3 decades of life
- Nocturnal pain
  - Relieved with NSAIDS
- Radiograph: sclerosis, periostitis
- Bone scan: focal uptake, 3 phases

Osteoid Osteoma

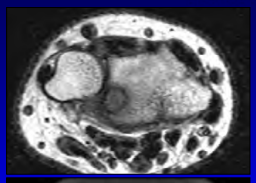
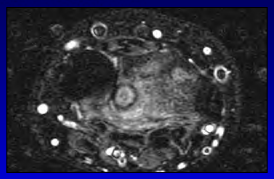
- MRI:
  - Bone marrow edema is often extensive
  - Higher signal nidus
  - Possible low signal calcification
  - Adjacent soft tissue edema, joint effusion, synovitis
- Confirm with CT; guided ablation

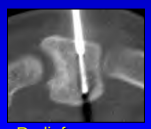
Osteoid Osteoma


Coronal T1w


Coronal T2w

Osteoid Osteoma



Radiofrequency Ablation

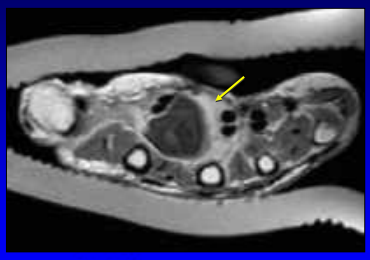
Cysts and Masses: malignant

- Undifferentiated pleomorphic sarcoma (#1)
- Epitheloid sarcoma
- Synovial sarcoma
- Fibrosarcoma (adult)
- Liposarcoma

Kransdorf. AJR 1995; 164:129

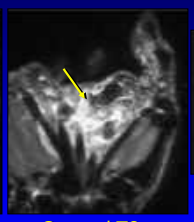
Undifferentiated Pleomorphic Sarcoma

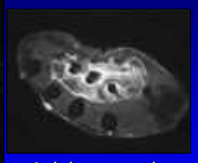

Coronal T1w


Axial T1w post-gadolinium

Liposarcoma


Coronal T1w


Coronal T2w


Axial post-gado

Take Home Points

- Tenosynovitis: identify synovitis
- Arthritis: sensitive, not specific
  - Emphasize: synovitis, marrow edema
- Scapholunate ligament: dorsal component
- Nerve entrapment: edema, enlargement
- Soft tissue ganglion: volar

Thank you!

Syllabus on line and other educational material:
www.jacobsonmskus.com

SELF EVALUATION

MR Imaging of the Wrist and Hand

True/False

1. The use of intravenous gadolinium is the most accurate way to identify synovitis on MRI.

2. Regarding scapholunate ligament tears, most symptomatic tears involve the dorsal component.

3. The characteristic MR imaging finding of a finger pulley tear is bowstringing of the flexor tendon.

4. Edema and enlargement of the median nerve at the carpal tunnel entrance are characteristics of carpal tunnel syndrome.

5. Regarding soft tissue ganglion cysts, dorsal location is most common.

Answer Key: 1. T, 2. T, 3. T, 4. T, 5. F

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Director of Musculoskeletal Interventions
Musculoskeletal Radiology
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Ultrasound of the Wrist

OBJECTIVES

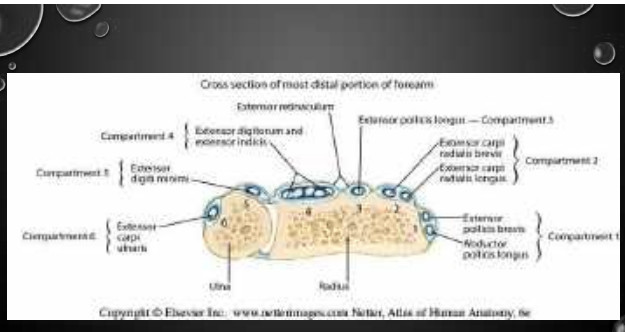
- ANATOMY
  - DORSAL
  - VOLAR
  - ACCESSORY MUSCLES
- PATHOLOGY
  - NERVE
  - TENDON
  - JOINTS

WRIST ANATOMY

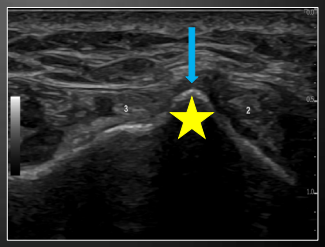
DORSAL WRIST

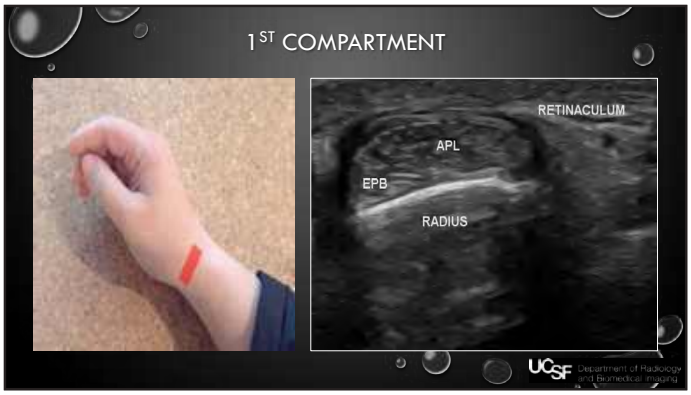
DORSAL WRIST

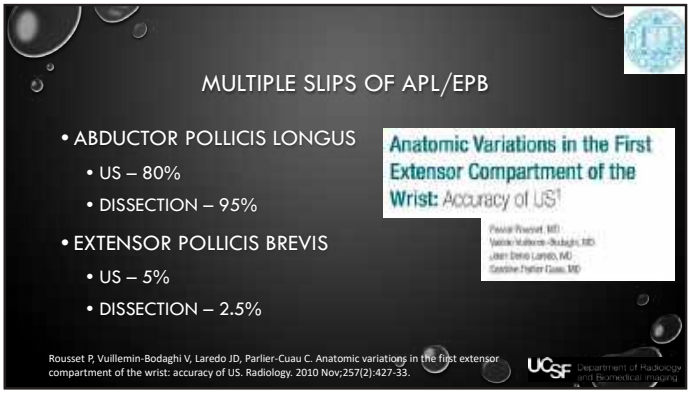
- EXTENSOR TENDONS
- SCAPHOLUNATE LIGAMENT

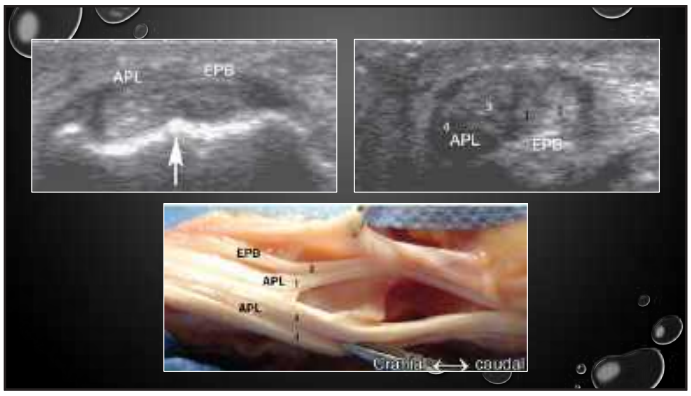


LISTER'S TUBERCLE

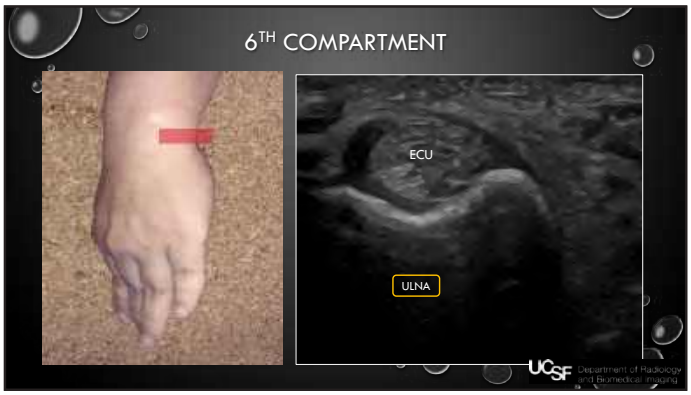


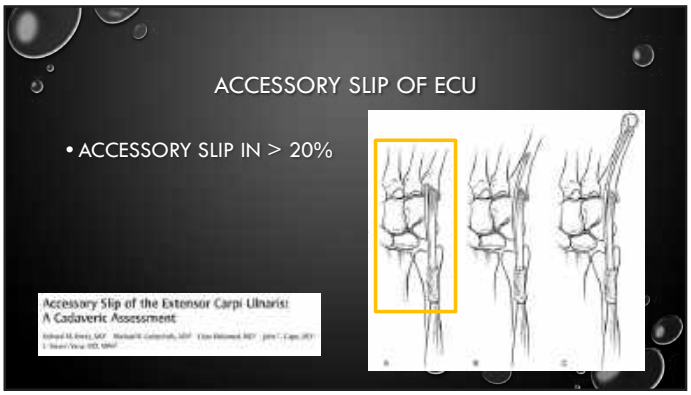

1ST COMPARTMENT
RETINACULUM
APL
EPB
RADIUS
UCSF Department of Radiology and Biomedical Imaging

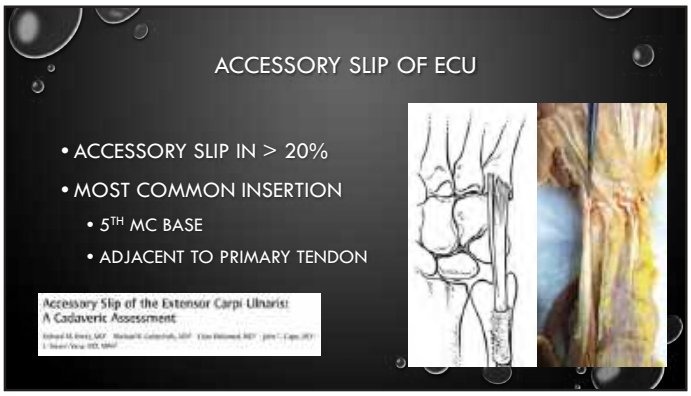

MULTIPLE SLIPS OF APL/EPB
• ABDUCTOR POLLICIS LONGUS
• US – 80%
• DISSECTION – 95%
• EXTENSOR POLLICIS BREVIS
• US – 5%
• DISSECTION – 2.5%
Anatomic Variations in the First Extensor Compartment of the Wrist: Accuracy of US1
Rousset P, Vuillemin-Bodaghi V, Laredo JD, Parlier-Cuau C. Anatomic variations in the first extensor compartment of the wrist: accuracy of US. Radiology. 2010 Nov;257(2):427-33.
UCSF Department of Radiology and Biomedical Imaging

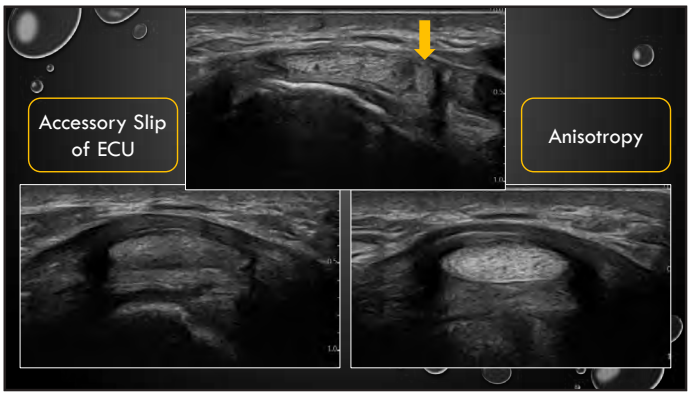

APL
EPB
APL
EPB
EPB
APL
APL
Cranial ↔ caudal


2ND COMPARTMENT
ECR(B)
ECR(L)
RT COMP 2
UCSF Department of Radiology and Biomedical Imaging

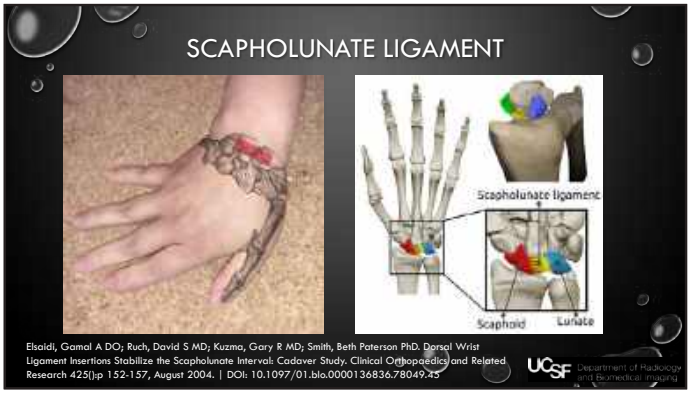

6TH COMPARTMENT
ECU
ULNA
UCSF Department of Radiology and Biomedical Imaging

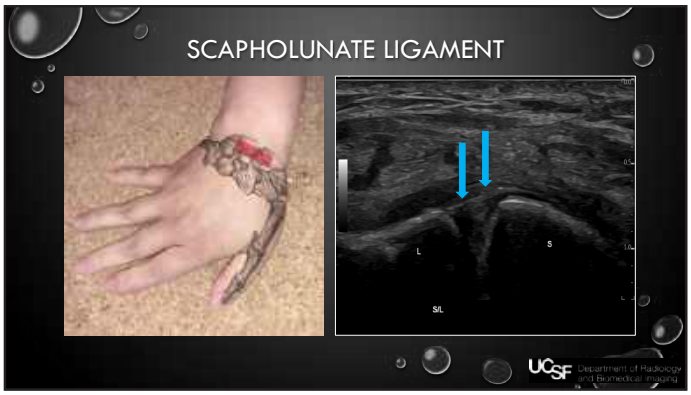

ACCESSORY SLIP OF ECU
• ACCESSORY SLIP IN > 20%
Accessory Slip of the Extensor Carpi Ulnaris: A Cadaveric Assessment

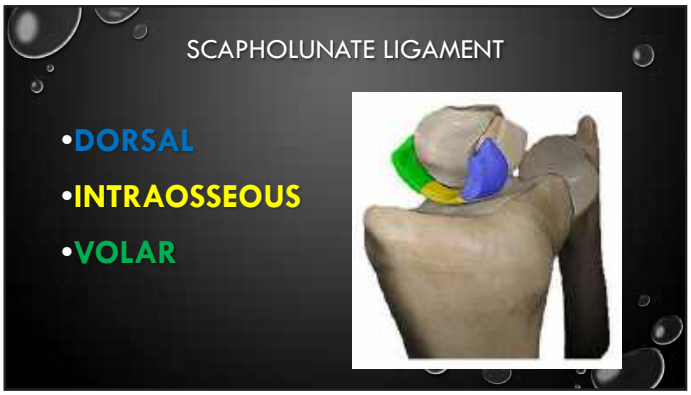

ACCESSORY SLIP OF ECU
• ACCESSORY SLIP IN > 20%
• MOST COMMON INSERTION
• 5TH MC BASE
• ADJACENT TO PRIMARY TENDON
Accessory Slip of the Extensor Carpi Ulnaris: A Cadaveric Assessment

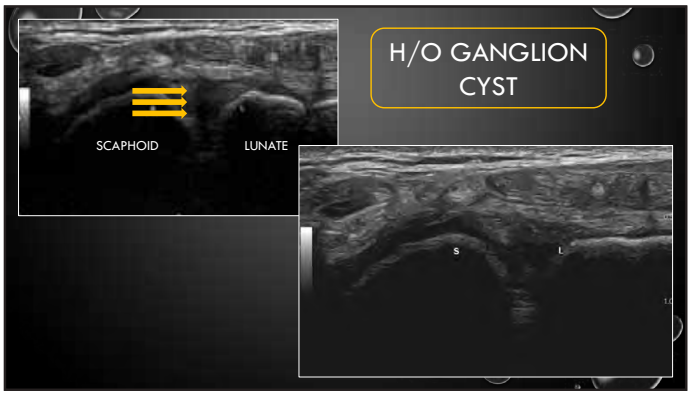

Accessory Slip of ECU
Anisotropy

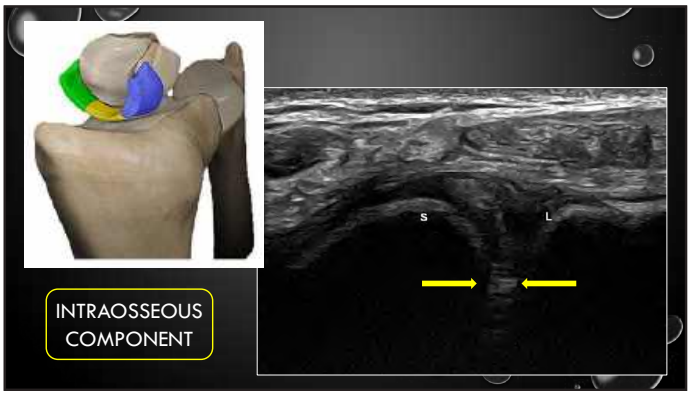

ACCESSORY SLIP OF ECU

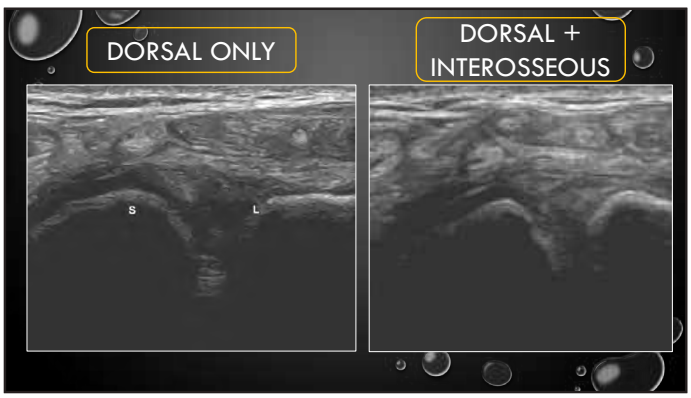

SCAPHOLUNATE LIGAMENT
Scapholunate ligament
Scaphoid
Lunate
Elsaidi, Gamal A DO; Ruch, David S MD; Kuzma, Gary R MD; Smith, Beth Paterson PhD. Dorsal Wrist Ligament Insertions Stabilize the Scapholunate Interval: Cadaver Study. Clinical Orthopaedics and Related Research 425():p 152-157, August 2004. | DOI: 10.1097/01.blo.0000136836.78049.45
UCSF Department of Radiology and Biomedical Imaging


SCAPHOLUNATE LIGAMENT
S
L
S/L
UCSF Department of Radiology and Biomedical Imaging


SCAPHOLUNATE LIGAMENT
•DORSAL
•INTRAOSSEOUS
•VOLAR


H/O GANGLION CYST
SCAPHOID
LUNATE
S
L

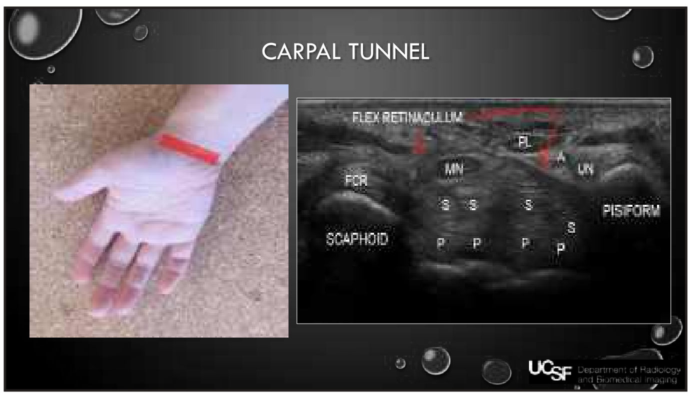

INTRAOSSEOUS COMPONENT
S
L

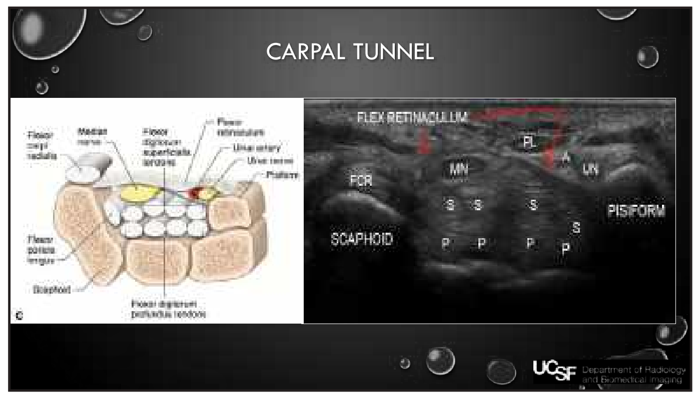

DORSAL ONLY
DORSAL + INTEROSSEOUS
S
L

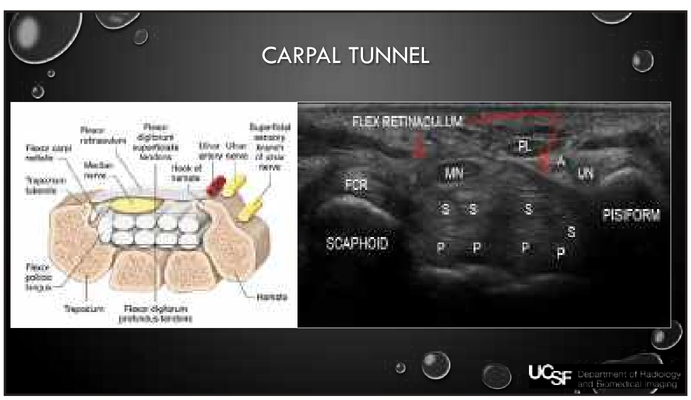

VOLAR WRIST

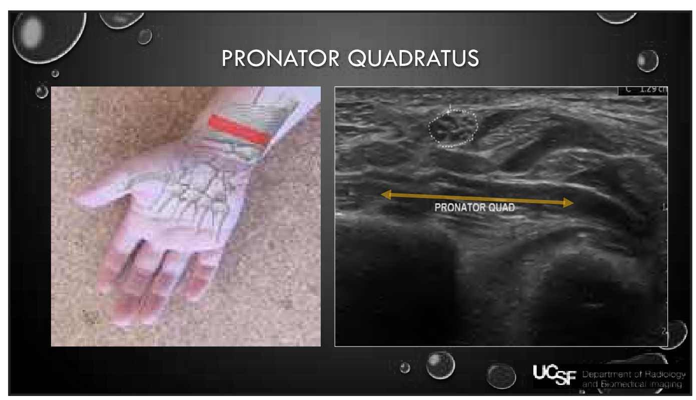

VOLAR WRIST
• FLEXOR TENDONS
• MEDIAN NERVE/ULNAR NERVE
• VOLAR JOINT RECESSES
UCSF


FLEXOR RETINACULUM
FLEX RETINACULUM
N
PISI
SCAPH
MED N / CARP TUNNEL
UCSF


CARPAL TUNNEL
FLEX RETINACULUM
PL
MN
UN
FCR
S S S
S
PISIFORM
SCAPHOID
P P P P
UCSF


CARPAL TUNNEL
FLEX RETINACULUM
PL
MN
UN
FCR
S S S
S
PISIFORM
SCAPHOID
P P P P
UCSF

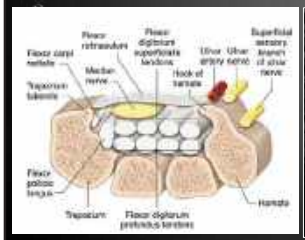

CARPAL TUNNEL
FLEX RETINACULUM
PL
MN
UN
FCR
S S S
S
PISIFORM
SCAPHOID
P P P P
UCSF


PRONATOR QUADRATUS
PRONATOR QUAD
UCSF


DISTAL CARPAL TUNNEL
TRAPEZIUM
HAMATE
MED N DIST CARP TUNNEL
UCSF


ULNAR NERVE
N
N
HAMATE H
UCSF

ULNAR NERVE



ACCESSORY MUSCLES

ACCESSORY MUSCLES

- PALMARIS LONGUS
- ACCESSORY ABDUCTOR DIGITI MINIMI

PALMARIS LONGUS

- VOLAR WRIST
- ORIGIN: MEDIAL EPICONDYLE
- INSERTION: PALMAR APONEUROSIS/FLEX RETINACULUM

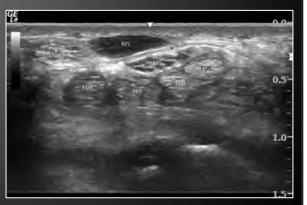
Cooper DW, Burns B. Anatomy, Shoulder and Upper Limb, Hand Palmaris Tendon. 2023 Aug 28. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. PMID: 30137801.

PALMARIS LONGUS

Cooper DW, Burns B. Anatomy, Shoulder and Upper Limb, Hand Palmaris Tendon. 2023 Aug 28. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. PMID: 30137801.

PALMARIS LONGUS

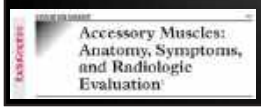
- SUPERFICIAL TO FLEXOR RETINACULUM
- OFTEN USED FOR TENDON GRAFT
- OTHER USES
  - OPPONENSPLASTY
  - LIP AUGMENTATION
  - FACIAL PARALYSIS



1. Getzmann JM, Schweizer A. Surgical Resection of a Reversed Palmaris Longus Muscle Causing Chronic Exertional Compartment Syndrome in a Competitive Swimmer: A Case Report. Orthop J Sports Med. 2018 May 1;6(5):2325967118769615. doi: 10.1177/2325967118769615. PMID: 29881730; PMCID: PMC5987899.
2. Ioannis D, Anastasios K, Konstantinos N, Lazaros K, Georgios N. Palmaris Longus Muscle's Prevalence in Different Nations and Interesting Anatomical Variations: Review of the Literature. J Clin Med Res. 2015 Nov;7(11):825-30. doi: 10.14740/jocmr2243w. Epub 2015 Sep 25. Erratum in: J Clin Med Res. 2016 Jan;8(1):62. doi: 10.14740/jocmr223wc1.

ACCESSORY ABDUCTOR DIGITI MINIMI

- VOLAR WRIST
- ORIGIN: ANTEBRACHIAL FASCIA
- INSERTION: ABDUCTOR DIGITI MINIMI PROPER



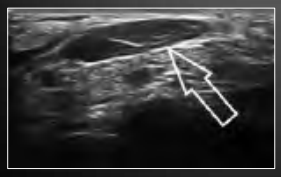
ACCESSORY ABDUCTOR DIGITI MINIMI

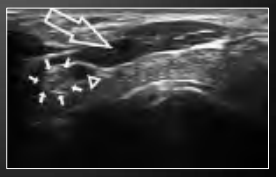
- SUPERFICIAL TO GUYON'S CANAL
- MOSTLY FASCIA PROXIMALLY
- PREVALENCE => 25%

Rikey A, Wenger D, Baffour F, Kakar S, McKenzie G. Accessory abductor digiti minimi muscle, less muscular than thought: an update on prevalence, morphology, and review of the literature. Skeletal Radiol. 2021 Aug;50(8):1687-1695. doi: 10.1007/s00256-021-03728-5. Epub 2021 Feb 3. PMID: 33533963.

ACCESSORY ABDUCTOR DIGITI MINIMI

- ULNAR NERVE COMPRESSION (RARE)





Coraci D, Luchetti R, Paolasso I, Santilli V, Padua L. Intermittent ulnar nerve compression due to accessory abductor digiti minimi muscle: Crucial diagnostic role of nerve ultrasound. Muscle Nerve. 2015 Sep;52(3):463-4. doi: 10.1002/mus.24660. Epub 2015 May 14. PMID: 25808715.

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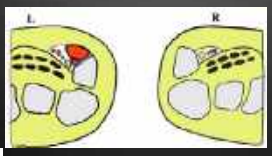
AADM + AFCU

- ACCESSORY ABDUCTOR DIGITI MINIMI
- ACCESSORY FLEXOR CARPI ULNARIS



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WRIST PATHOLOGY

NERVES

NERVES

- MEDIAN, ULNAR, AND RADIAL NERVES

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CARPAL TUNNEL SYNDROME

- COMPRESSION OF NERVE AT THE WRIST
- 7-16% OF ADULTS
- RISK FACTORS
  - FEMALE, INCREASED AGE, OCCUPATION
    - GRIPPING, FLEX/EXT, VIBRATION
  - SECONDARY FACTORS (INCREASE VOL SYNOVIAL SHEATH)
    - OBESITY, PREGNANCY, MENOPAUSE, HYPOTHYROIDISM, OCP USE, CHF

Osiak K, Elnazir P, Walocha JA, Pasternak A. Carpal tunnel syndrome: state-of-the-art review. Folia Morphol (Warsz). 2022;81(4):851-862.

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ROLE OF ULTRASOUND

- EQUIVOCAL CASES
- R/O OTHER CAUSES
  - INCREASED SIZE OF NERVE
    - FLH, NERVE SHEATH TUMOR
    - BIFID NERVE
  - DECREASED SIZE OF TUNNEL
    - TRAUMA, GANGLION, TUMOR
  - ADDITIONAL MN COMPRESSION
    - LIGAMENT OF STRUTHERS
- S/P CARPAL TUNNEL RELEASE

FIBROLIPOMATOUS HAMARTOMA

Teh J. Ultrasound of soft tissue masses of the hand. J Ultrason. 2012 Dec;12(51):381-401. doi: 10.15557/JoU.2012.0028. Epub 2012 Dec 30

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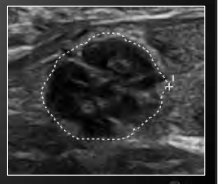
CARPAL TUNNEL

- ENLARGED MEDIAN NERVE
  - ≥12 MM^2 (0.12 CM^2)
    - EXCLUDE HYPERECHOIC EPINEURIUM
  - CARPAL TUNNEL – PRONATOR QUADRATUS ≥ 2 MM
- ABNORMAL MOVEMENT OF NERVE
  - COMPARE TO ADJACENT TENDONS
  - KINKING



Wong SM, Griffith JF, Hui AC, Lo SK, Fu M, Wong KS. Carpal tunnel syndrome: diagnostic usefulness of sonography. Radiology. 2004 Jul;232(1):93-9. doi: 10.1148/radiol.2321030071. Epub 2004 May 20. PMID: 15155897.

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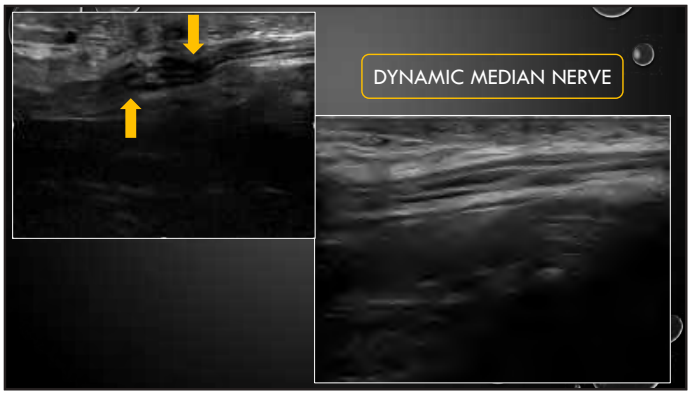
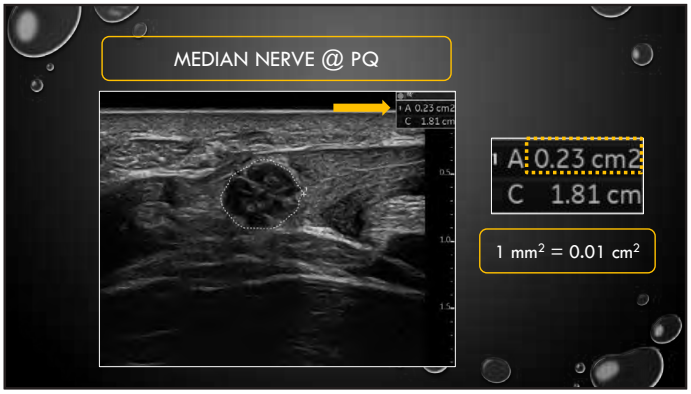
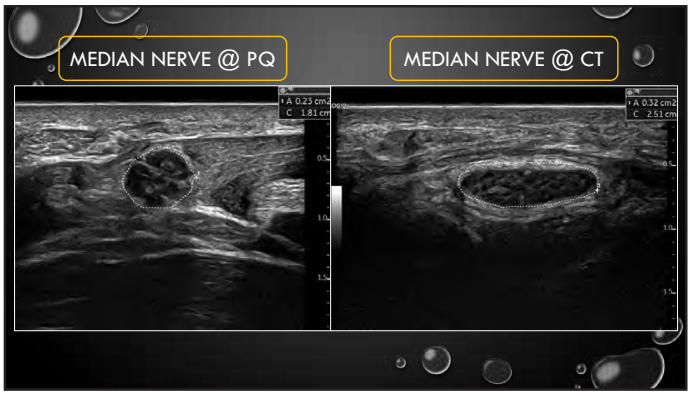
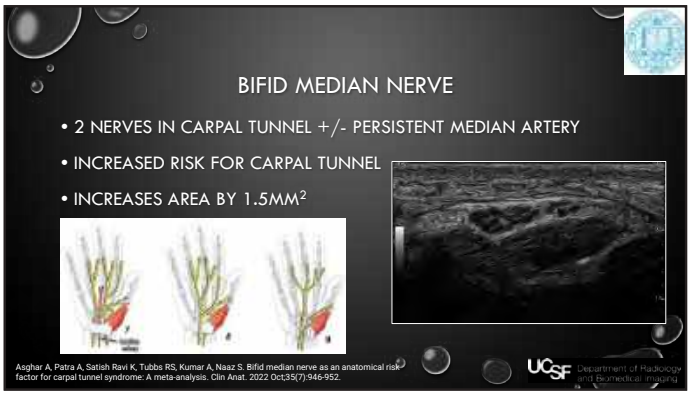

DYNAMIC MEDIAN NERVE


MEDIAN NERVE @ PQ
A 0.23 cm2
C 1.81 cm
1 mm2 = 0.01 cm2


MEDIAN NERVE @ PQ
MEDIAN NERVE @ CT


BIFID MEDIAN NERVE
• 2 NERVES IN CARPAL TUNNEL +/- PERSISTENT MEDIAN ARTERY
• INCREASED RISK FOR CARPAL TUNNEL
• INCREASES AREA BY 1.5MM2
Asghar A, Patra A, Satish Ravi K, Tubbs RS, Kumar A, Naaz S. Bifid median nerve as an anatomical risk factor for carpal tunnel syndrome: A meta-analysis. Clin Anat. 2022 Oct;35(7):946-952.
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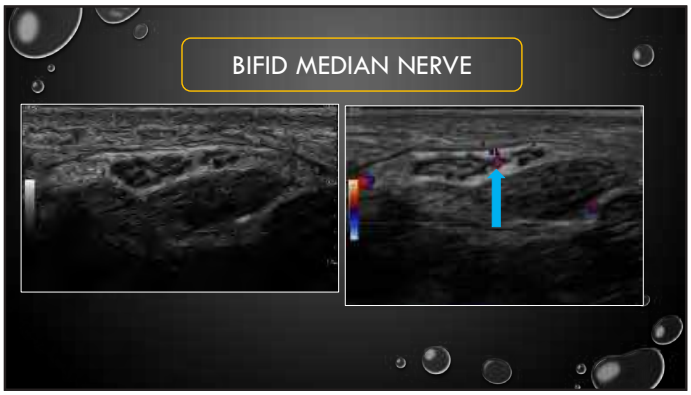
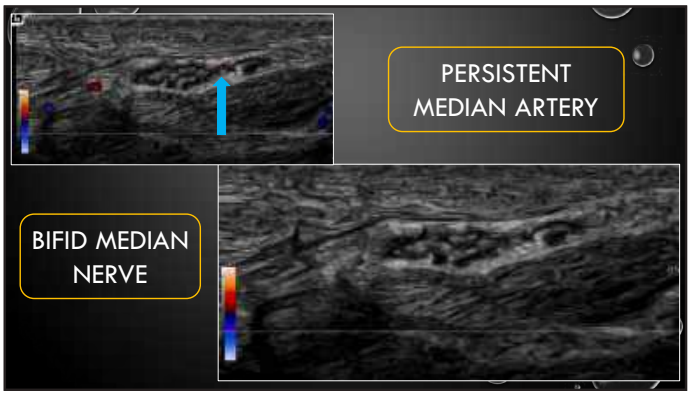
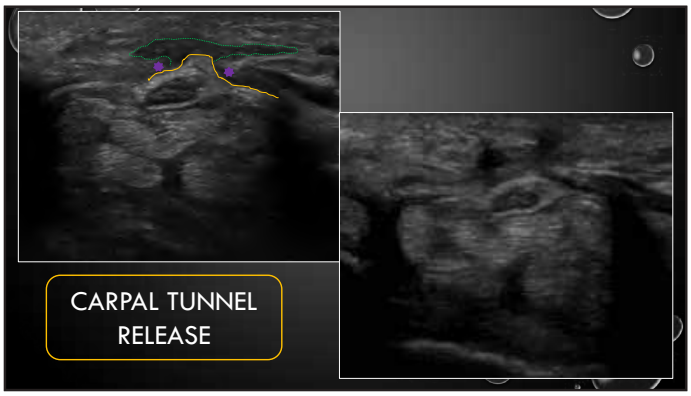
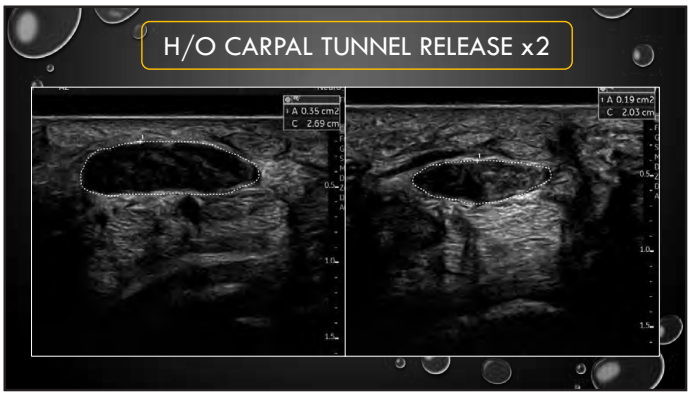
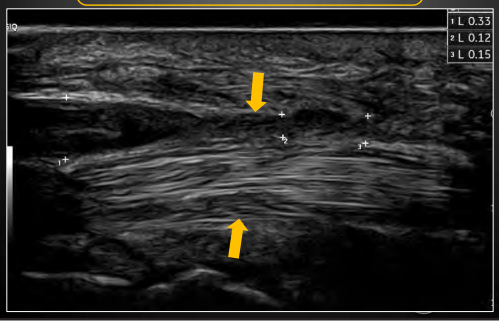

BIFID MEDIAN NERVE


PERSISTENT MEDIAN ARTERY
BIFID MEDIAN NERVE


CARPAL TUNNEL RELEASE

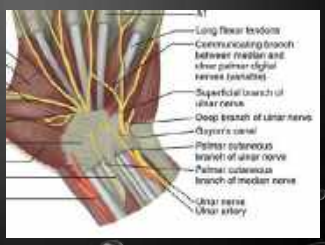

H/O CARPAL TUNNEL RELEASE x2

TAPERING OF MEDIAN NERVE



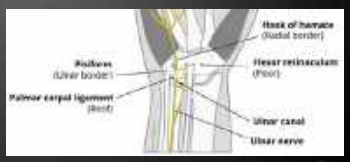
ULNAR NERVE

- GUYON'S CANAL
- GANGLION CYST
- JACKHAMMER, CYCLING



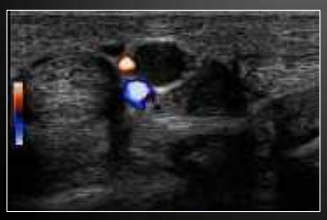
ULNAR NERVE

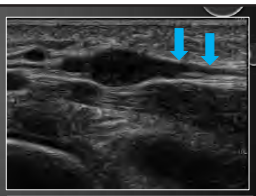
- GUYON'S CANAL
- GANGLION CYST
- JACKHAMMER, CYCLING

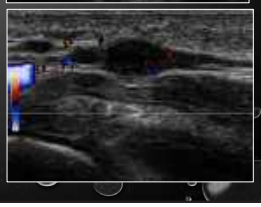


ULNAR SIDED MASS

ULNAR NERVE NEUROMA

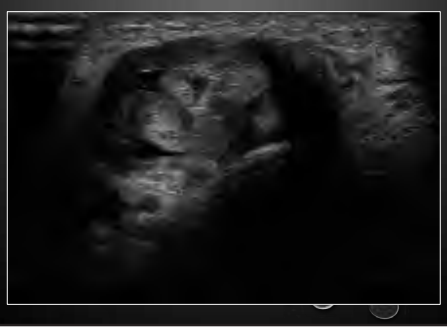






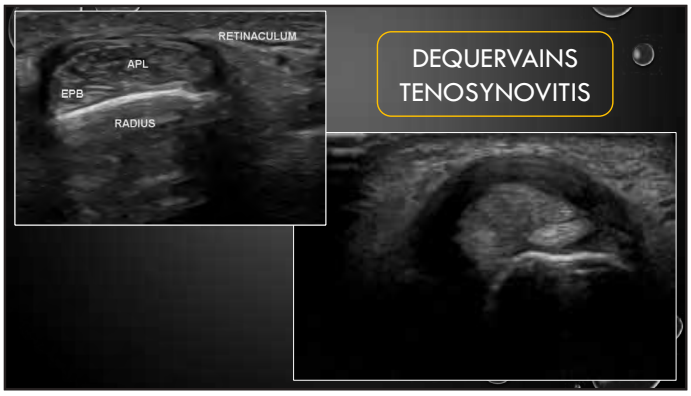
TENDONS

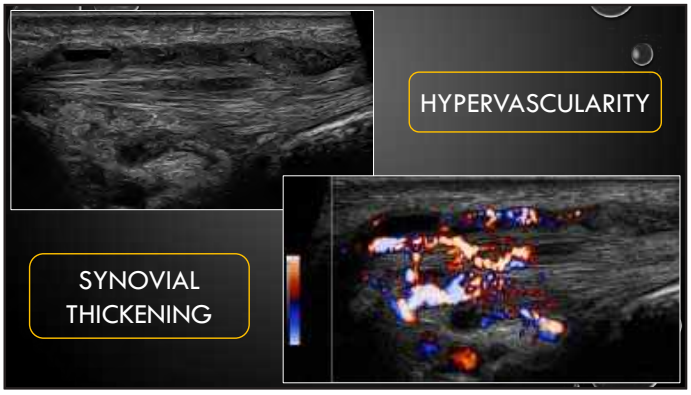
1ST DORSAL COMPARTMENT



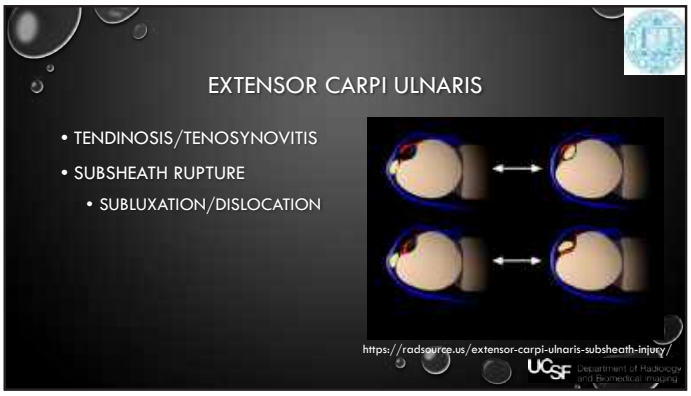
DE QUERVAIN TENOSYNOVITIS

- 1ST DORSAL COMPARTMENT
- APL/EPB TENDON SHEATH
- THICKENING/MYXOID DEGENERATION
- RISK FACTORS: FEMALE, AGE > 40, BLACK


RETINACULUM
APL
EPB
RADIUS
DEQUERVAINS TENOSYNOVITIS


HYPERVASCULARITY
SYNOVIAL THICKENING


DEQUERVAINS TENOSYNOVITIS


EXTENSOR CARPI ULNARIS
• TENDINOSIS/TENOSYNOVITIS
• SUBSHEATH RUPTURE
• SUBLUXATION/DISLOCATION
https://radsource.us/extensor-carpi-ulnaris-subsheath-injury/
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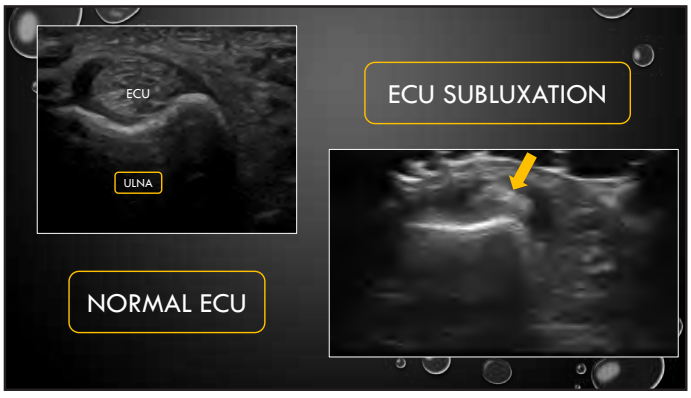
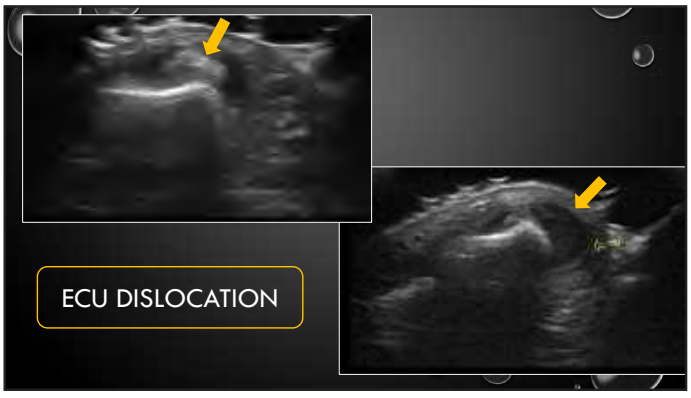
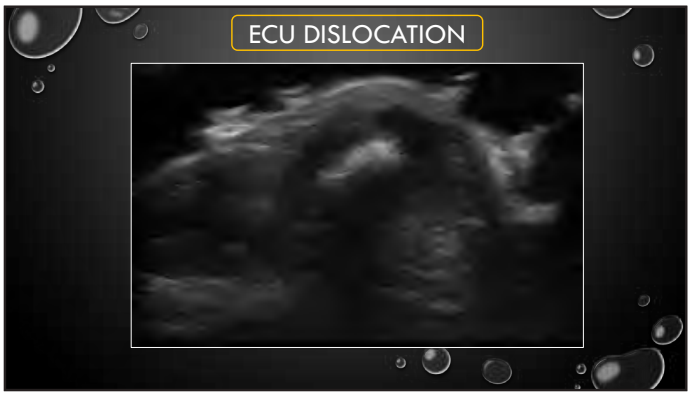
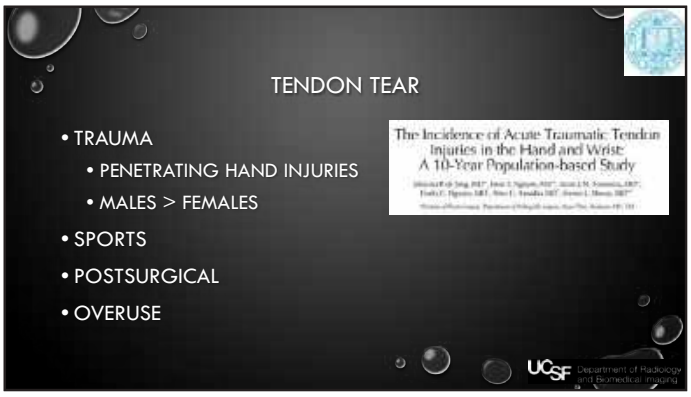
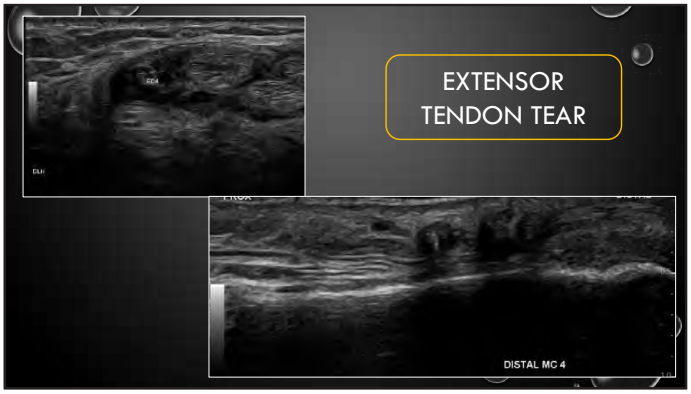
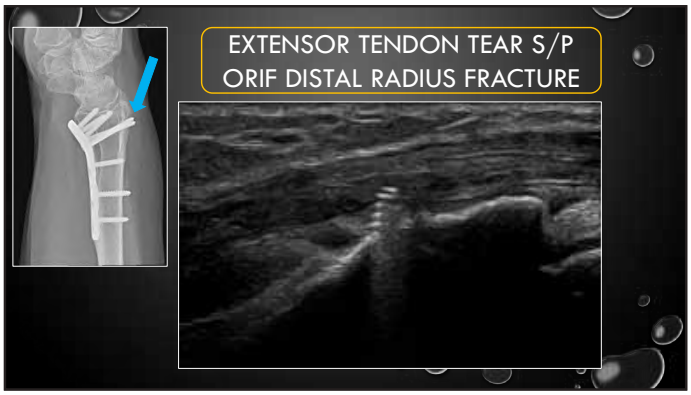

ECU
ULNA
ECU SUBLUXATION
NORMAL ECU

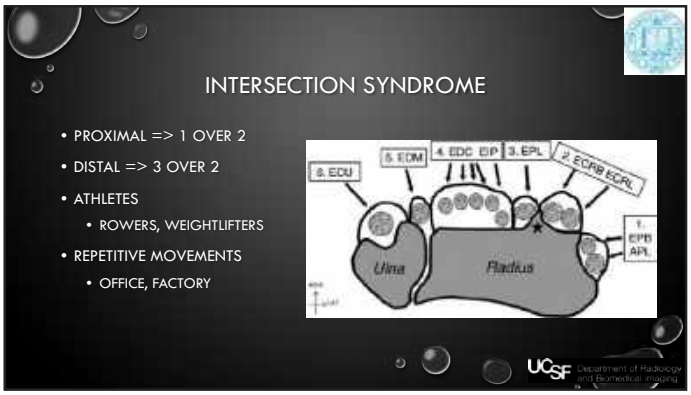

ECU DISLOCATION

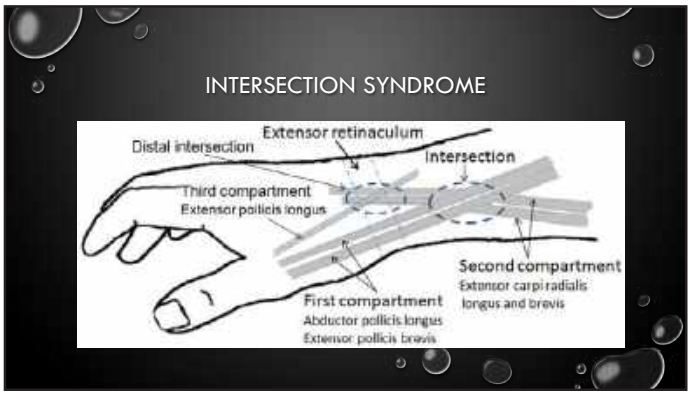

ECU DISLOCATION

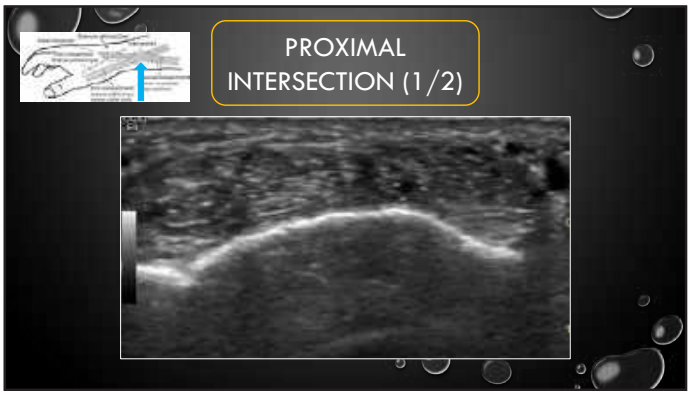

TENDON TEAR
• TRAUMA
• PENETRATING HAND INJURIES
• MALES > FEMALES
• SPORTS
• POSTSURGICAL
• OVERUSE
The Incidence of Acute Traumatic Tendon Injuries in the Hand and Wrist: A 10-Year Population-based Study
UCSF Department of Radiology and Biomedical Imaging

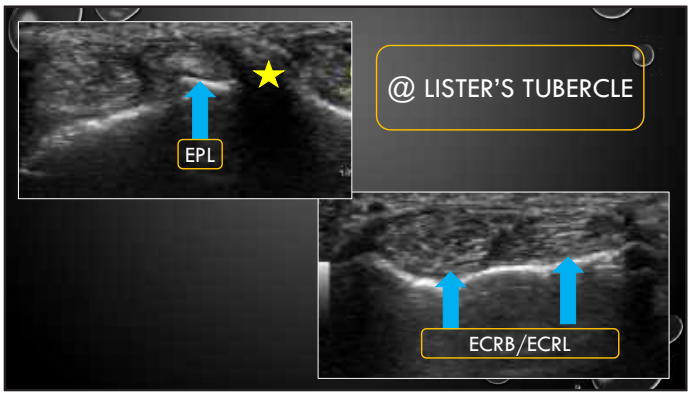

EXTENSOR
TENDON TEAR
DISTAL MC 4

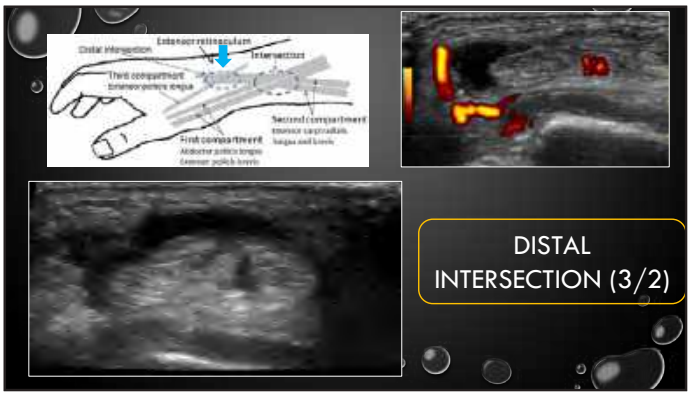

EXTENSOR TENDON TEAR S/P
ORIF DISTAL RADIUS FRACTURE


INTERSECTION SYNDROME
• PROXIMAL => 1 OVER 2
• DISTAL => 3 OVER 2
• ATHLETES
• ROWERS, WEIGHTLIFTERS
• REPETITIVE MOVEMENTS
• OFFICE, FACTORY
6. ECU
5. EDM
4. EDC EIP
3. EPL
2. ECRB ECRL
1. EPB APL
Ulna
Radius
UCSF


INTERSECTION SYNDROME
Distal intersection
Extensor retinaculum
Intersection
Third compartment
Extensor pollicis longus
Second compartment
Extensor carpi radialis
longus and brevis
First compartment
Abductor pollicis longus
Extensor pollicis brevis


PROXIMAL
INTERSECTION (1/2)


EPL
@ LISTER'S TUBERCLE
ECRB/ECRL


DISTAL
INTERSECTION (3/2)

JOINTS

INFLAMMATORY ARTHROPATHY

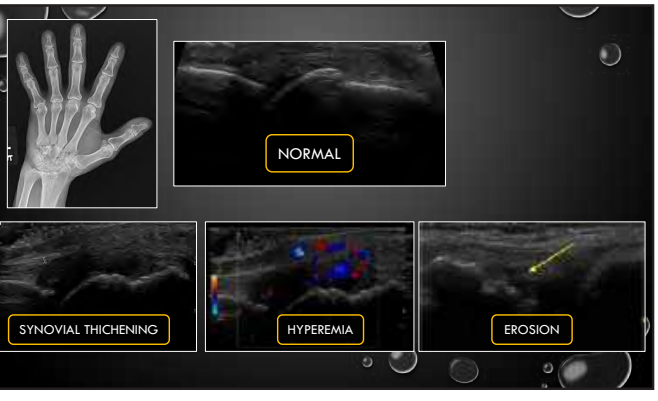
- SYNOVIAL HYPERTROPHY
- EROSION
- VASCULARITY
- EFFUSION

Radiology Assistant

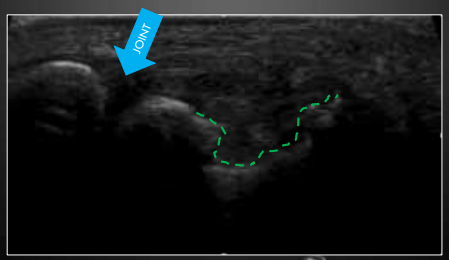
UCSF Department of Radiology and Biomedical Imaging

RHEUMATOID ARTHRITIS

RADIOLOGY Illustrated



MARGINAL EROSION



MARGINAL EROSION

GANGLION CYST

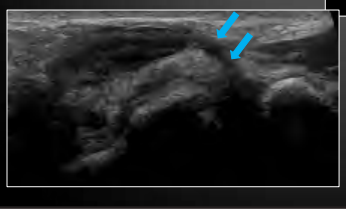
- MOST COMMON HAND/WRIST MASS
- SYMPTOMS (VARIABLE)
  - MASS, CHANGE IN SIZE, PAIN, PARESTHESIA
- LOCATIONS (VARIABLE)
  - VOLAR => BETWEEN RADIAL ARTERY AND FCR
  - DORSAL => SCAPHOLUNATE LIGAMENT/DORSAL CAPSULE

Cluts LM, Fowler JR. Factors Impacting Recurrence Rate After Open Ganglion Cyst Excision. Hand (N Y). 2022 Mar;17(2):261-265.

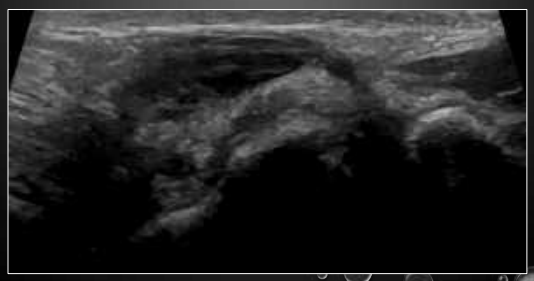
HYPOECHOIC MASS

AVASCULAR SEPTATION

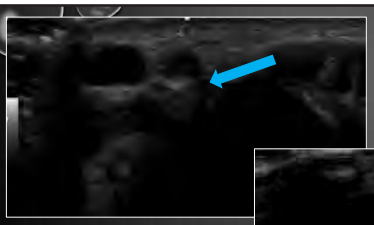
CONNECTION TO RADIOCARPAL JOINT



GANGLION CYST TO RADIOCARPAL JOINT

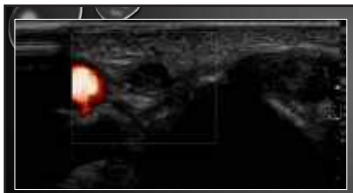


CASE #1

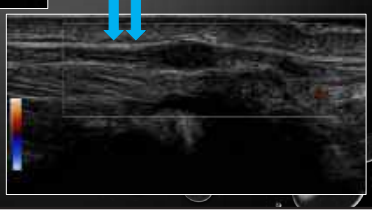


RADIAL SIDED WRIST MASS

EXTENSION TO JOINT? EDGE SHADOWING?



RADIAL NERVE NEUROMA



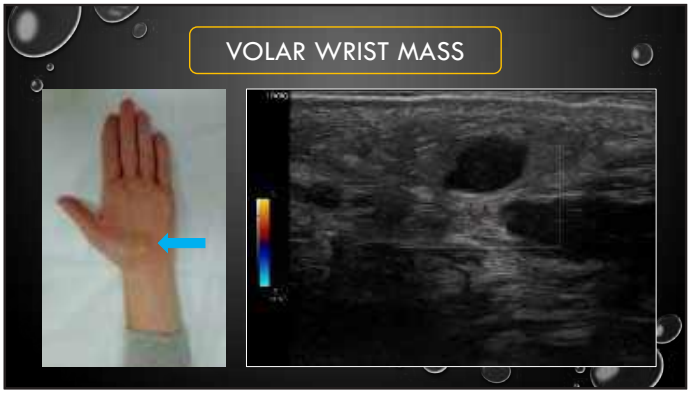
CONTINUITY WITH NERVE

SUPERFICIAL RADIAL NEUROPATHY

- WARTENBERG'S SYNDROME
  - COMPRESSION OF SUPERFICIAL RADIAL NERVE AT WRIST
  - BRACELET, HANDCUFFS, FOREARM FRACTURE
  - PAIN/NUMBNESS DORSORADIAL HAND

UCSF Department of Radiology and Biomedical Imaging

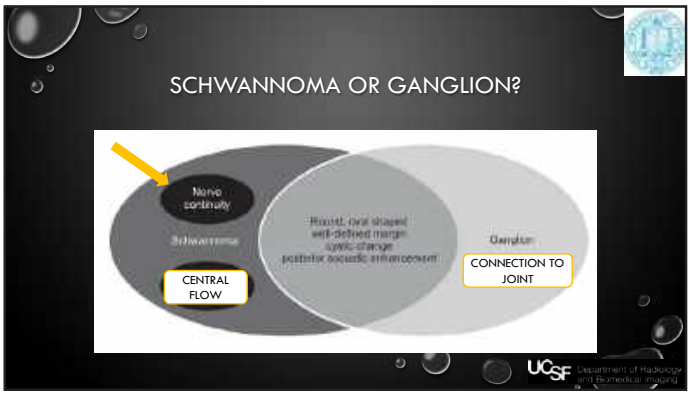

CASE #2


VOLAR WRIST MASS

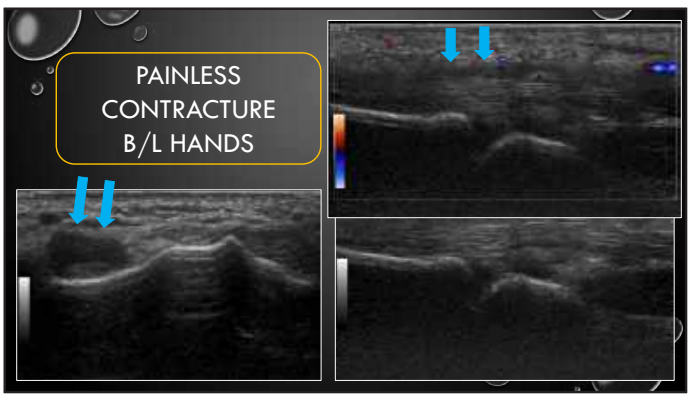

LT PALMAR MASS
DISTAL


LT PALMAR MASS
NOT PAINFUL
LONG AXIS
SHORT AXIS

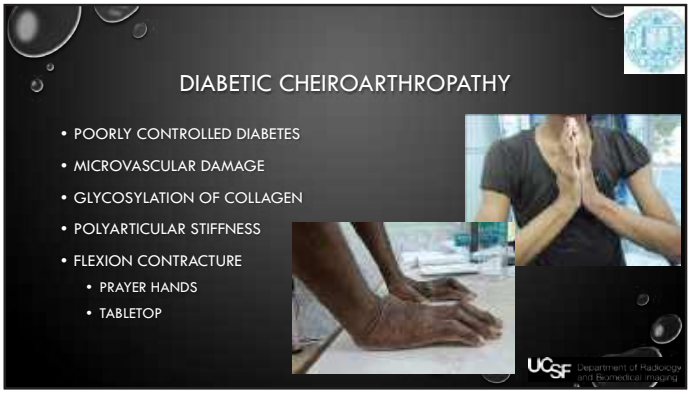

PLEXIFORM SCHWANNOMA


SCHWANNOMA OR GANGLION?
Nerve continuity
CENTRAL FLOW
CONNECTION TO JOINT
UCSF

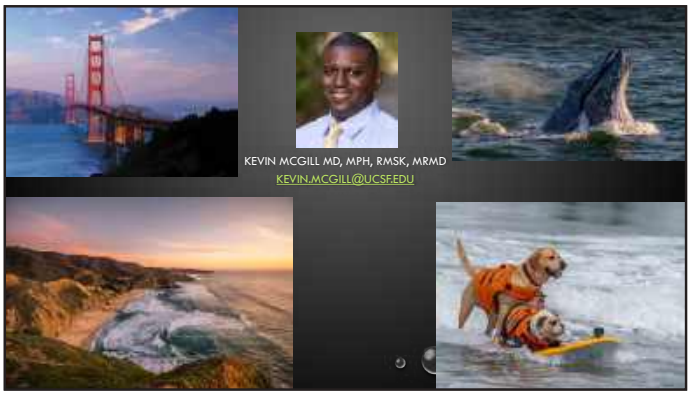

CASE #3


PAINLESS
CONTRACTURE
B/L HANDS


LIMITED MOVEMENT


DIABETIC CHEIROARTHROPATHY
• POORLY CONTROLLED DIABETES
• MICROVASCULAR DAMAGE
• GLYCOSYLATION OF COLLAGEN
• POLYARTICULAR STIFFNESS
• FLEXION CONTRACTURE
• PRAYER HANDS
• TABLETOP
UCSF Department of Radiology and Biomedical Imaging


SUMMARY
• ANATOMY
• VOLAR/DORSAL
• PATHOLOGY
• NERVE: CARPAL TUNNEL, GUYON CANAL, NEUROMA
• TENDON: DEQUERVAINS, ECU SUBSHEATH
• JOINTS: GANGLION CYST, INFLAMMATORY ARTHROPATHY
UCSF Department of Radiology and Biomedical Imaging


KEVIN MCGILL MD, MPH, RMSK, MRMD
KEVIN.MCGILL@UCSF.EDU

SELF EVALUATION

Ultrasound of the Wrist

True/False

1. The extensor pollicis brevis often has multiple slips on ultrasound.

2. There are 3 components of the scapholunate ligament

3. Proximal Intersection syndrome involves the tendons of the 2nd dorsal compartment traveling superficial to the tendons of the 1st dorsal compartment.

4. The palmaris longus travels within the carpal tunnel.

5. On ultrasound a median nerve measurement of 13 mm in circumference in the carpal tunnel is suggestive of carpal tunnel syndrome.

Answer Key: 1. F, 2. T, 3. F, 4. F, 5. F

FACULTY

Steven Soliman, DO, RMSK, FAIUM, FAOCR

Dr. Steven Soliman is a board-certified and fellowship-trained musculoskeletal radiologist at the University of Michigan/Michigan Medicine. He is also the Program Director of the MSK Radiology Fellowship and the Director of MSK Ultrasound at the University of Michigan. His areas of expertise and interest include musculoskeletal ultrasound, sports injuries, MRI, diabetes, foot and ankle imaging, peripheral nerve imaging, arthritis, and minimally invasive image-guided pain procedures and biopsies. Dr. Soliman is a frequent speaker on musculoskeletal radiology topics.

You may contact Dr. Soliman with your questions and comments at ssoliman@med.umich.edu.

MICHIGAN MEDICINE
UNIVERSITY OF MICHIGAN

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ssoliman@med.umich.edu

Ultrasound of the Elbow

OUTLINE

- Elbow Anatomy Review
- US Elbow Protocol
- Normal Elbow US

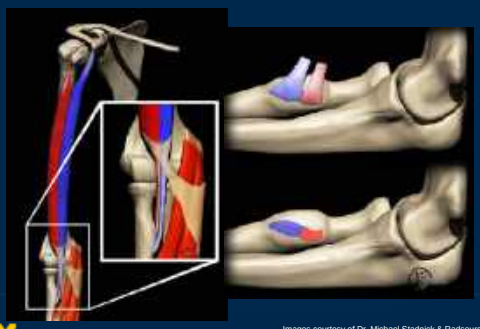
NORMAL ELBOW ANATOMY

Image courtesy of Dr. Robin Smithuis & Radiology Assistant.
https://radiologyassistant.nl/musculoskeletal/shoulder/mri-anatomy

RADIAL NERVE ANATOMY

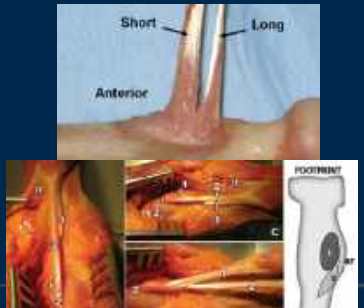
https://radiopaedia.org/cases/radial-nerve-anatomy-illustrations

DISTAL BICEPS TENDON



Images courtesy of Dr. Michael Stadnick & Radsource.
https://radsource.us/distal-biceps-tendon-rupture-elbow/

DISTAL BICEPS TENDON



Carrazana-Suarez LF, et al. Curr Rev Musculoskelet Med. 2022; 15(2):65-74
Tagliafico AS, et al. Radiology. 2015; 275(3):636-650

LATERAL ELBOW (RCL)

Jacobson JA, et al. J Ultrasound Med 2014; 33:1041-1048

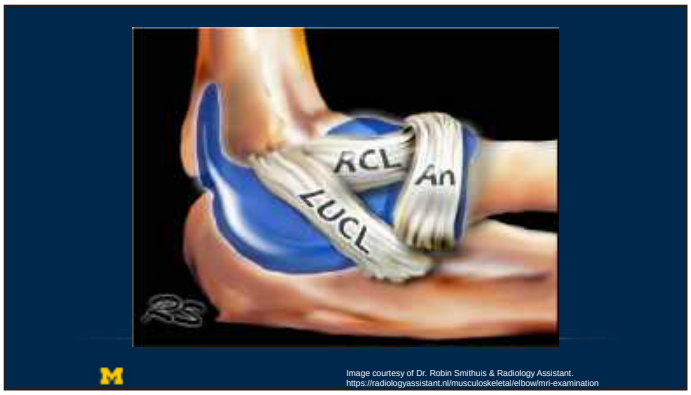
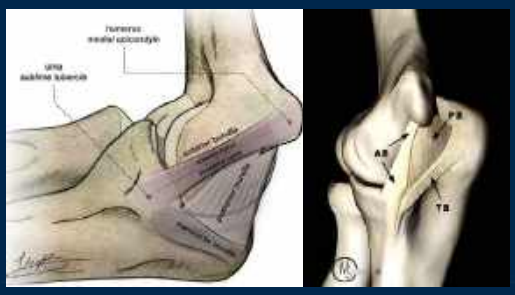


Image courtesy of Dr. Robin Smithuis & Radiology Assistant.
https://radiologyassistant.nl/musculoskeletal/elbow/mri-examination

MEDIAL ELBOW (UCL)



Molenaars RJ, et al. J Shoulder Elbow Surg. 2019; 28(8):1497-1504
Image courtesy of Dr. Michael Stadnick & Radsource.
https://radsource.us/ulnar-collateral-ligament-tears-of-the-elbow/

US ELBOW PROTOCOL

- ANTERIOR ELBOW:
  - Radiocapitellar & Ulnohumeral (ulnotrochlear) joints
  - Distal biceps tendon (anterior approach)
  - Brachial artery & paired veins
  - Median nerve

US ELBOW PROTOCOL

- LATERAL ELBOW:
  - Common extensor tendon
  - Radial collateral ligament
    - *(*dynamic-varus*)
  - Radial nerve branches & posterior interosseous nerve
  - Radiocapitellar joint
    - Elbow plica/synovial fold syndrome
      - *(*dynamics-flexion/extension & pronated flexion/extension*)
  - Distal biceps tendon (lateral approach)
    - *(*dynamic-supination/pronation*)

US ELBOW PROTOCOL

- MEDIAL ELBOW:
  - Common flexor tendon
  - Ulnar collateral ligament (anterior band/bundle)
    - *(*dynamic-valgus*)
  - Ulnohumeral joint
  - Distal biceps tendon (medial approach)
    - *(*dynamic-supination/pronation*)

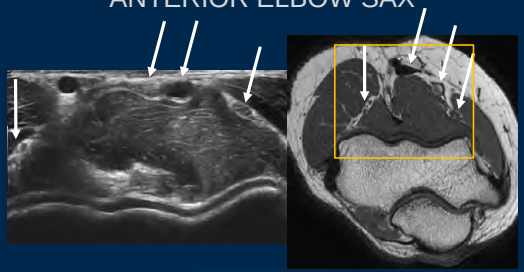
US ELBOW PROTOCOL

- POSTERIOR ELBOW:
  - Olecranon bursa
  - Posterior joint
    - *Most sensitive location to identify an elbow joint effusion*
  - Triceps tendon
  - Ulnar nerve
    - *(*dynamic-flexion/extension*)
  - Distal biceps tendon (posterior approach)
    - *(*dynamic-supination/pronation*)

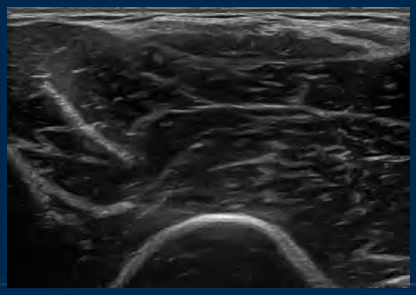
ANTERIOR ELBOW SAX

Tagliafico AS, et al. Radiology. 2015; 275(3):636-650

ANTERIOR ELBOW SAX



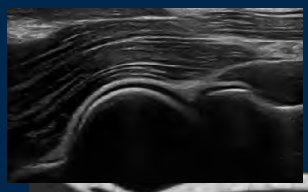
ANTERIOR ELBOW SAX

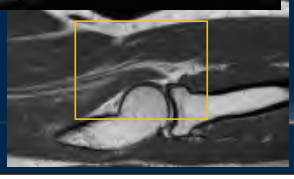


ANTERIOR ELBOW LAX

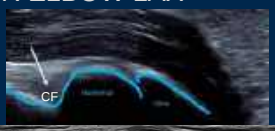
https://radiologykey.com/elbow-ultrasound/

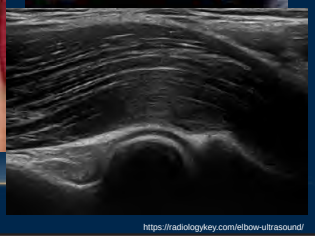
ANTERIOR ELBOW LAX





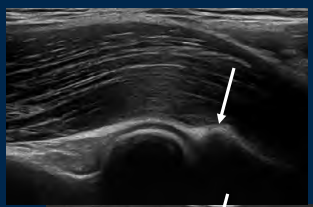
ANTERIOR ELBOW LAX

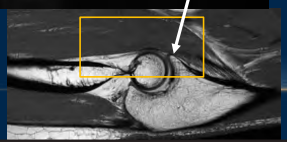




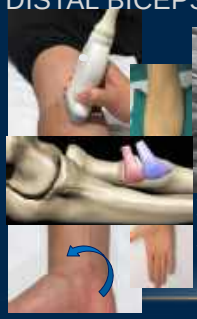
https://radiologykey.com/elbow-ultrasound/

ANTERIOR ELBOW LAX





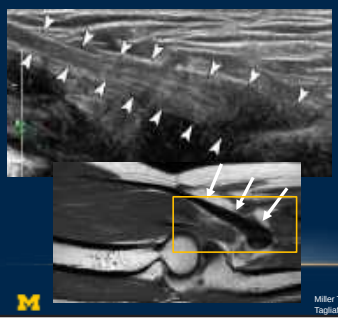
DISTAL BICEPS - ANTERIOR APPROACH



- No tendon sheath
- Bicipitoradial bursal distention rarely seen
- Short head more distal & superficial (use anisotropy)
- Benefit:
  - Can follow back to myotendinous junction/stump
  - Visualize anterior surrounding fluid
- Limitation:
  - *Most commonly associated with anisotropy*

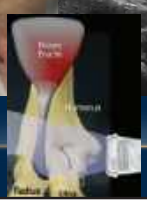
Miller TT, et al. Skeletal Radiol. 2021; 50(5):937-943
Tagliafico AS, et al. Radiology. 2015; 275(3):636-650
https://essr.org/content-essr/uploads/2016/10/elbow.pdf

DISTAL BICEPS - ANTERIOR APPROACH



Miller TT, et al. Skeletal Radiol. 2021; 50(5):937-943
Tagliafico AS, et al. Radiology. 2015; 275(3):636-650

DISTAL BICEPS - MEDIAL APPROACH/ “Pronator Window”



Tagliafico AS, et al. Radiology. 2015; 275(3):636-650

DISTAL BICEPS - MEDIAL APPROACH/ "Pronator Window"

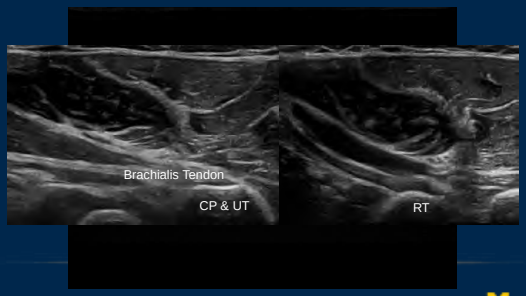
- Position:
  - Flexed 90 degrees
  - Supination
- Benefits:
  - Visualize insertion
  - Dynamics
- Limitations:
  - Visualization of more proximal tendon & myotendinous junction (retraction)
  - Assessment of anterior surrounding fluid

DISTAL BICEPS - MEDIAL APPROACH/ "Pronator Window"

DISTAL BICEPS - MEDIAL APPROACH/ "Pronator Window"

DISTAL BICEPS - MEDIAL APPROACH/ "Pronator Window"

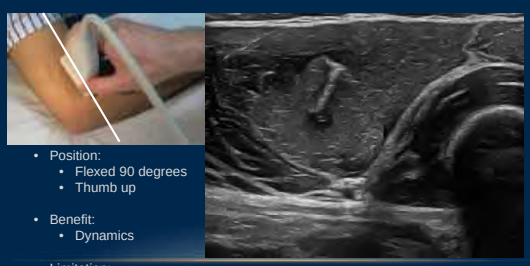
DISTAL BICEPS - MEDIAL APPROACH/ "Pronator Window"



DISTAL BICEPS - MEDIAL APPROACH/ "Pronator Window"

Smith J, et al. J Ultrasound Med. 2010; 29(5):861-865

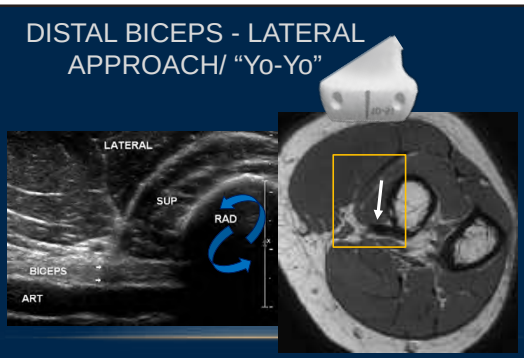
DISTAL BICEPS - LATERAL APPROACH/ "Yo-Yo"



- Position:
  - Flexed 90 degrees
  - Thumb up
- Benefit:
  - Dynamics
- Limitation:
  - Visualization of insertion

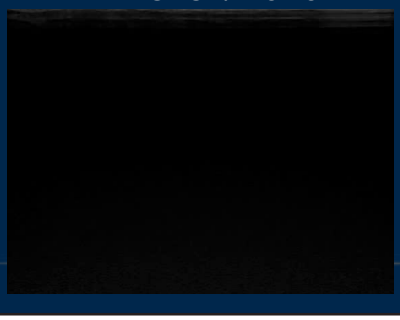
Tagliafico AS, et al. Radiology. 2015; 275(3):636-650

DISTAL BICEPS - LATERAL APPROACH/ "Yo-Yo"



Smith J, et al. J Ultrasound Med. 2010; 29(5):861-865

DISTAL BICEPS - LATERAL APPROACH/ “Yo-Yo”



DISTAL BICEPS - LATERAL APPROACH/ “Yo-Yo”

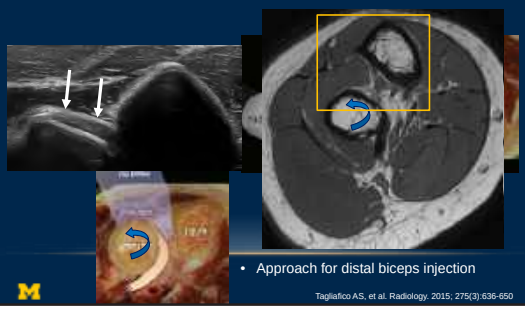
Smith J, et al. J Ultrasound Med. 2010; 29(5):861-865

DISTAL BICEPS - POSTERIOR APPROACH/ “Cobra” (4th)

- Position:
  - Hyperflexion/pronation
- Benefits:
  - Dynamics & injections
- Limitation:
  - Visualize only distal insertion

Tagliafico AS, et al. Radiology. 2015; 275(3):636-650

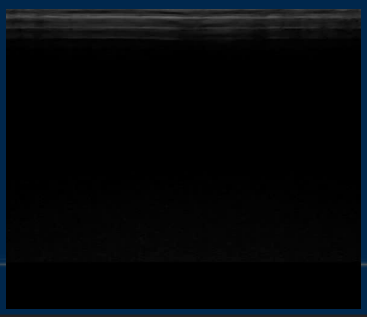
DISTAL BICEPS - POSTERIOR APPROACH/ “Cobra”



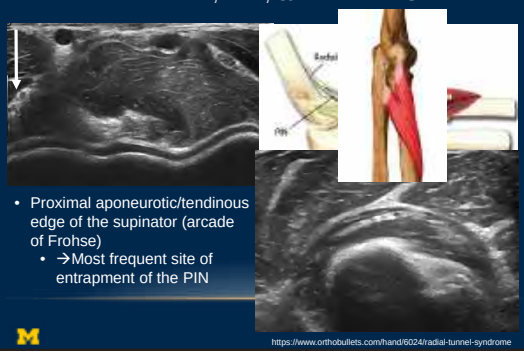
- Approach for distal biceps injection

Tagliafico AS, et al. Radiology. 2015; 275(3):636-650

DISTAL BICEPS - POSTERIOR APPROACH/ “Cobra”



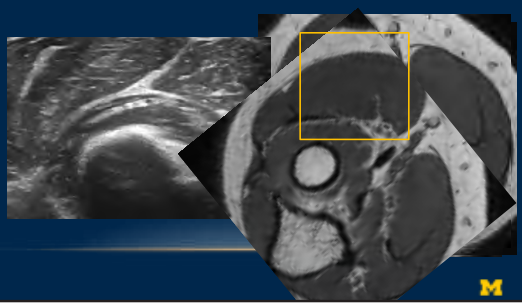
RADIAL NERVE, PIN, & RADIAL TUNNEL



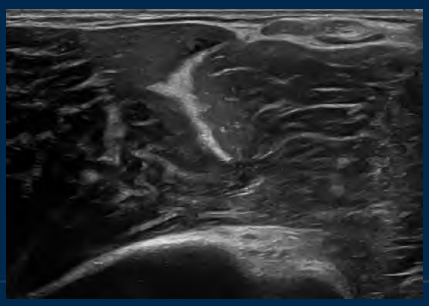
- Proximal aponeurotic/tendinous edge of the supinator (arcade of Frohse)
  - →Most frequent site of entrapment of the PIN

https://www.orthobullets.com/hand/6024/radial-tunnel-syndrome

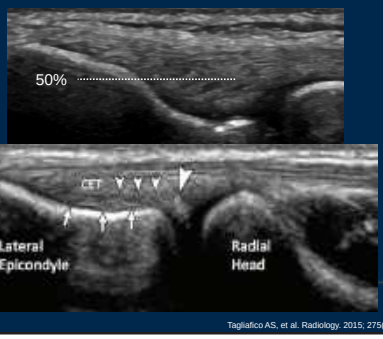
RADIAL NERVE, PIN, & RADIAL TUNNEL



RADIAL NERVE, PIN, & RADIAL TUNNEL



COMMON EXTENSOR TENDON & RCL



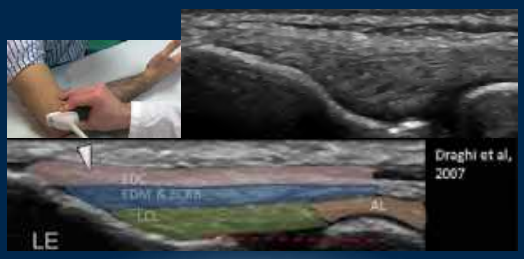
Tagliafico AS, et al. Radiology. 2015; 275(3):636-650

COMMON EXTENSOR TENDON & RCL

COMMON EXTENSOR TENDON & RCL

Jacobson JA, et al. J Ultrasound Med. 2014; 33:1041-1048

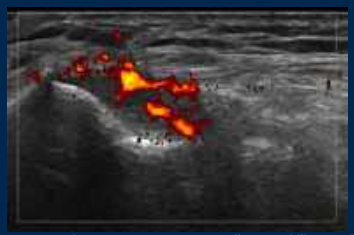
COMMON EXTENSOR TENDON LAX



- Lateral epicondylitis, predominantly affects the extensor carpi radialis brevis (ECRB)

Draghi F, et al, J Ultrasound. 2007;10(2):76-84
Levin D, et al. Radiology. 2005; 237(1):230-234

COMMON EXTENSOR TENDON



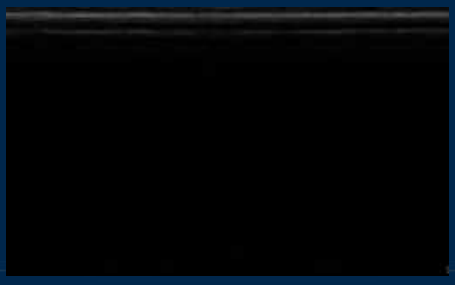
- Most common in common extensor, patellar, & Achilles tendons
- Corresponds to neovascularity, not inflammation
- Target for anesthetic injection to reduce pain

du Toit C, et al. Br J Sports Med. 2008; 42:872-876

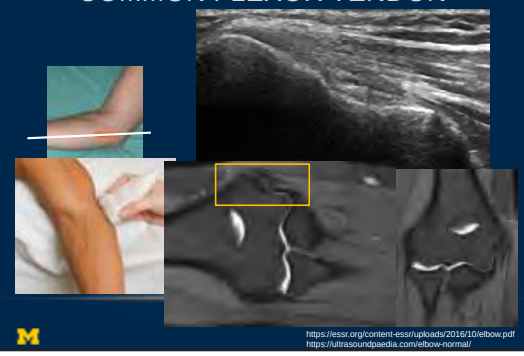
COMMON EXTENSOR TENDON SAX

Bhargava, et al. Indian Journal of PM&R. 2023; 33(3):109-114

COMMON EXTENSOR TENDON SAX



COMMON FLEXOR TENDON



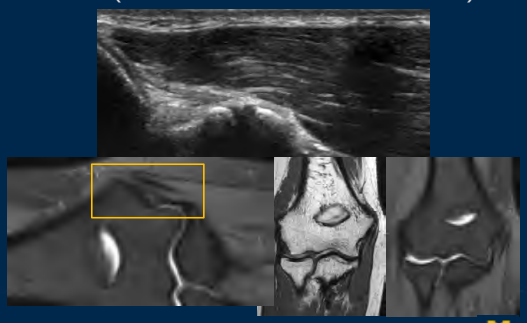
https://essr.org/content-essr/uploads/2016/10/elbow.pdf
https://ultrasoundpaedia.com/elbow-normal/

UCL (ANTERIOR BAND/BUNDLE)

- UCL (anterior band) main stabilizer against valgus stress when flexed >20-30°
- Position at 30° vs 70° flexion
- Significant preference for images obtained at 70° flexion compared to 30°

Konin GP, et al. Radiographics. 2013; 33(4):E125-147
Lueders DR, et al. PM R. 2015; 7(9):970-977

UCL (ANTERIOR BAND/BUNDLE)



UCL DYNAMIC IMAGING

- Compare stress gapping with asymptomatic contralateral elbow

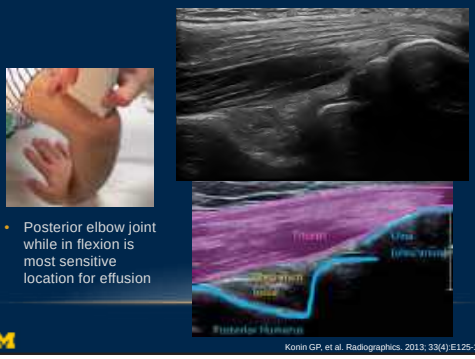
https://essr.org/content-essr/uploads/2016/10/elbow.pdf
Image courtesy of Dr. Michael Stadnick & Radsource.
https://radsource.us/ulnar-collateral-ligament-tears-of-the-elbow/
Roedl JB, et al. Radiology. 2016; 279(3):827-837

UCL DYNAMIC IMAGING

- >1 mm asymmetric joint space widening (gapping) with valgus stress → 96% sensitivity, 81% specificity, & 87% accuracy for UCL tear
- Asymmetric stress gapping:
  - Normal: ≤1 mm (≤1.3)
  - Partial tear: >1-< 3 mm (1.2-3.0)
  - Full-thickness tear: ≥3mm (2.8-4.8)
- Compare stress gapping with asymptomatic contralateral elbow

Roedl JB, et al. Radiology. 2016; 279(3):827-837

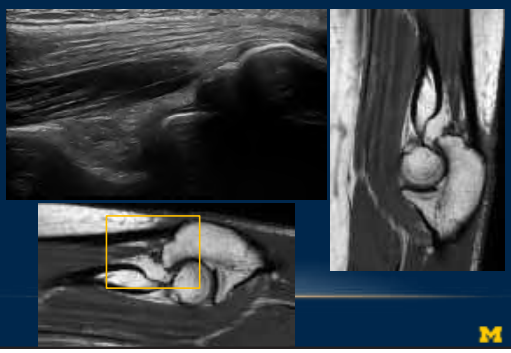
POSTERIOR ELBOW LAX



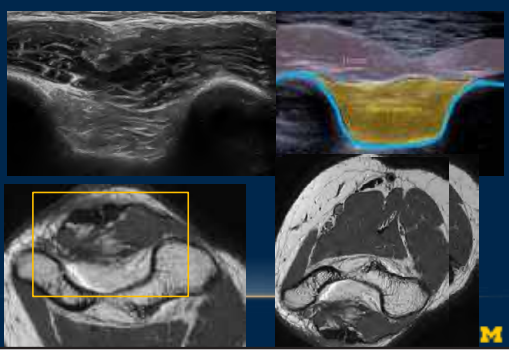
- Posterior elbow joint while in flexion is most sensitive location for effusion

Konin GP, et al. Radiographics. 2013; 33(4):E125-147

POSTERIOR ELBOW LAX



POSTERIOR ELBOW SAX



POSTERIOR ELBOW

ULNAR NERVE ANATOMY

- Brachial plexus inferiorly into medial aspect of upper arm
- Extends to posteromedial aspect of humerus to pass behind medial epicondyle
- Enters cubital tunnel at elbow
- Runs btw flexor digitorum superficialis & profundus at volar ulnar forearm
- At wrist lies superficial to flexor retinaculum, covered by volar (palmar) carpal ligament in Guyon's canal
- Largest unprotected nerve in body

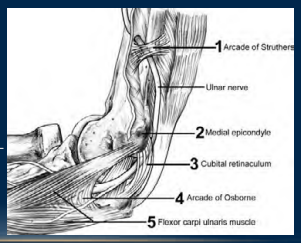
CUBITAL TUNNEL SYNDROME

- Ulnar nerve at elbow
- 2nd most frequent entrapment after CTS[1]
- Most common entrapment associated with alcoholism[2]
- May be affected by acute trauma, chronic repetitive injury with elbow flexion or ulnar nerve subluxation/dislocation

[1]Rota E, Morelli N. World J Diabetes 2016; 7(17):342-53
[2]Vinik A, et al. Diabetes Care 2004; 27(7):1783-1788

CUBITAL TUNNEL ANATOMY

- Ulnar n. pierces medial intermuscular septum
- Arcade of Struthers – Medial head triceps to MIS
- Boundaries:
  - Medial Epicondyle – FCU – humeral head
  - Olecranon – FCU – ulnar head
  - Floor: Posterior & transverse bands of UCL
  - Roof: Cubital tunnel retinaculum (Osborne ligament (fascia)) & Arcuate ligament



Caetano EB, et al. Rev Bras Ortop. 2017; 52 (3): 331-336
Dong Q, et al. Radiology Research & Practice. vol. 2012, Article ID 230679

CUBITAL TUNNEL ANATOMY

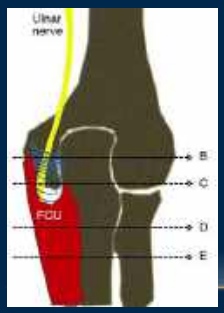
- Cubital tunnel retinaculum (Osborne ligament (fascia)) – fascial band btw olecranon & medial epicondyle
- Arcuate ligament – aponeurosis btw humeral & ulnar heads of FCU (true cubital tunnel)
  - Typically blend with each other

Dong Q, et al. Radiology Research & Practice, vol. 2012, Article ID 230679

CUBITAL TUNNEL ULTRASOUND

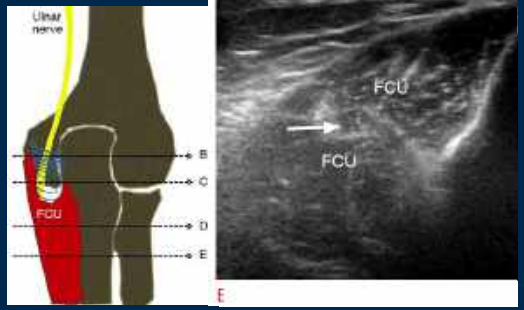
https://essr.org/content-essr/uploads/2016/10/elbow.pdf

CUBITAL TUNNEL ULTRASOUND



Choi S, et al. Ultrasonography. 2015; 34 (4): 275-291

CUBITAL TUNNEL ULTRASOUND



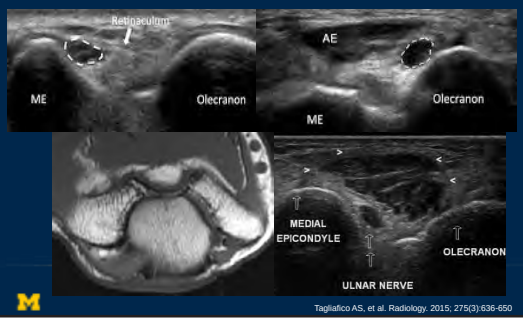
Choi S, et al. Ultrasonography. 2015; 34 (4): 275-291

ANCONEUS EPITROCHLEARIS

triceps can mimic[4]

[1]O'Driscoll SW, et al. J Bone Joint Surg Br. 1991;73(4):613-617
[3]Dellon AL. J Hand Surg Br. 1986;11(2):175-181
[3]Stein JM, et al. Magn Reson Imaging Clin N Am. 2011;19(3):609-619
[4]Jacobson JA, et al. J Ultra Med. 2016;35:683-693

ANCONEUS EPITROCHLEARIS



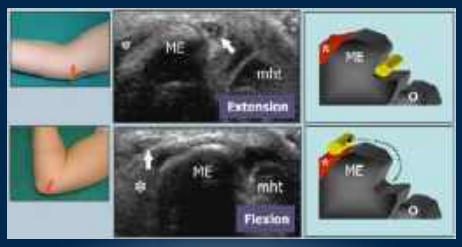
Tagliafico AS, et al. Radiology. 2015; 275(3):636-650

SONOGRAPHIC FINDINGS

- Hypoechoic enlargement of ulnar n. just proximal to cubital tunnel, usually w/transition to normal size within tunnel
  - Cross-sectional ulnar n. area > 9 mm^2 at site of maximal enlargement
    - 10 mm^2 or higher = sensitivity & specificity >88% for cubital tunnel syndrome
    - A mild enlargement at medial epicondyle can normally be seen in asymptomatic individuals

Jacobson JA. Fundamentals of musculoskeletal ultrasound. 3rd ed. Philadelphia: Elsevier; 2018
Brown J, et al. RadioGraphics. 2016; 36 (2): 452-463

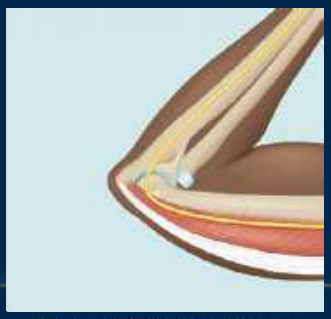
ULNAR NERVE INSTABILITY



- Active dynamic flexion & extension
- Present in ~16% of NML patients

https://essr.org/content-essr/uploads/2016/10/elbow.pdf
Brown J, et al. RadioGraphics. 2016; 36 (2): 452-463

ULNAR NERVE INSTABILITY



ULNAR NERVE INSTABILITY

TAKE HOME POINTS

- Ultrasound is excellent for elbow and ulnar nerve evaluation
- Understanding anatomy & MSK US basics is critical
- Follow protocol
  - Approaches to imaging the distal biceps
- Benefits of MSK US
  - Dynamic imaging for distal biceps & ulnar nerve subluxation/dislocation

THANK YOU

SELF EVALUATION

Ultrasound of the Elbow

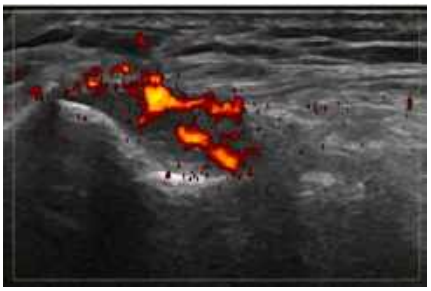
1. Which of following locations in the elbow is the most sensitive to identify an elbow joint effusion?

a. Anterior
b. Medial
c. Lateral
d. Posterior

2. Given the obliquity of the distal biceps tendon near its insertion, which of the following approaches to imaging the distal biceps tendon is most commonly associated with anisotropy?

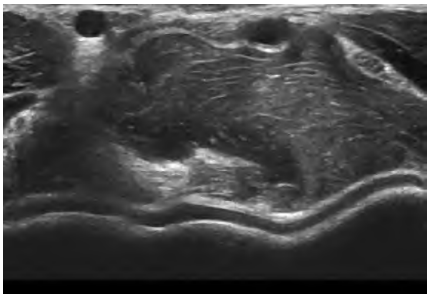
a. Anterior approach
b. Posterior (“Cobra”) approach
c. Medial (“Pronator window”) approach
d. Lateral (“Yo-yo”) approach

3. Which one of the following tendons (imaged below) is known to develop neovascularity and therefore demonstrate hyperemia on Doppler imaging?



a. Distal biceps tendon
b. Common extensor tendon
c. Common flexor tendon
d. Triceps tendon

4. When imaging the anterior elbow in the short-axis (shown below), which of the following is the correct order of structures when going from lateral to medial?



a. Median nerve, biceps tendon, brachial artery
b. Biceps tendon, median nerve, radial nerve
c. Biceps tendon, brachial artery, median nerve
d. Brachial artery, radial nerve, biceps tendon

5. T/F - Distally, the short head of the biceps inserts more distally than the long head.

6. T/F - The posterior band/bundle of the UCL is the most critical for elbow stability and most commonly injured.

7. T/F - Cubital tunnel syndrome is the most common nerve entrapment syndrome.

Answer Key: 1. D, 2. A, 3. B, 4. C, 5. T, 6. F, 7. F

MICHIGAN MEDICINE
UNIVERSITY OF MICHIGAN

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Ultrasound-Guided Musculoskeletal Procedures

OUTLINE

- Benefits of the use of US-guidance for MSK procedures
- Basic checklist & supplies
- Basic techniques of US-guided MSK procedures
- Overview of relevant anatomy & probe/needle placement with US & MRI correlation for common US-guided MSK procedures

US-GUIDED PROCEDURE BENEFITS

- Allows direct visualization of needle in real-time
- Simultaneous evaluation of surrounding soft tissues & neurovascular structures during aspiration, injection or biopsy
- Target simple fluid & visualize needle tip → more successful
- Direct biopsy towards areas of less necrosis & more hyperemia → more diagnostic sample
- Therapy performed simultaneously w/ diagnostic scan
- No contrast (no issues w/ allergies or altering joint sample)
- No radiation (no lead apron)
- Ease of accessibility & portability (only option for some injections)

PROCEDURE CHECKLIST

- Indications:
  - Therapeutic & diagnostic joint aspirations & injections
  - Diagnostic biopsies
- Check INR, platelet count, Hb (biopsies & certain meds)
- Obtain informed consent
  - Risks: bleeding, infection, allergic reaction (rare), osteonecrosis/AVN (low risk)
- Scan prior to procedure w/ accurate skin marking
- "Time-out" ("critical pause") before procedure to confirm patient, procedure type, location & side of procedure

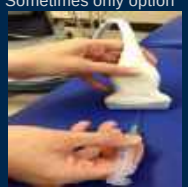
PROCEDURE SUPPLIES

- Sterile field & probe cover
- Thinnest needle for injection (22- or 20-gauge spinal)
  - 18-g for aspiration
  - Biopsy needle/gun
- Corticosteroid for injection (1 mL triamcinolone 40 mg/mL), 5 mL of lidocaine 1% (skin) & 3 mL ropivacaine/bupivacaine 0.25%
- Tubes for lab (cx/gram stain, qualitative alpha defensin test, cell count/diff, crystals)
- Formalin container for biopsy

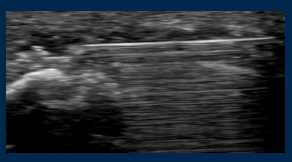
US-GUIDED PROCEDURE TECHNIQUES

- In-plane
  - Visualize entire needle (long axis of needle along long axis of transducer)
  - Most accurate
  - Reverberation (more common)

- Out-of-plane
  - Short axis of needle crosses US beam
  - Less accurate
  - Superficial targets/structures
  - Sometimes only option

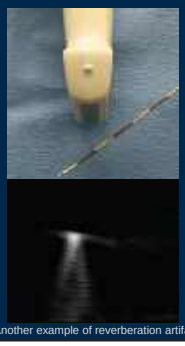


IN-PLANE TECHNIQUE



Reverberation artifact occurs when US beam reflects back & forth from 2 strong parallel reflectors

OUT-OF-PLANE TECHNIQUE



Another example of reverberation artifact

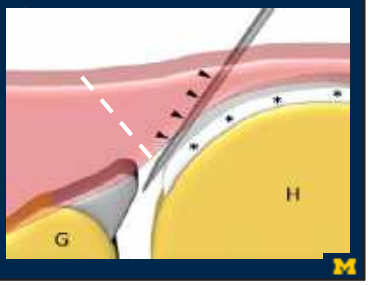
GLENOHUMERAL JT INJECTION

- US-guided vs Fluoroscopic-guided GH jt injection
  - Significantly less time
  - Less patient discomfort
  - More successful on 1st attempt
  - No radiation or contrast

Rutten JCM, et al. Eur Radiol 2009; 19:722-730

GLENOHUMERAL JT INJECTION

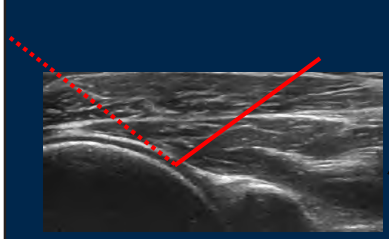
- Technique:
  - Probe: SAX
  - Needle: In-Plane
  - Medial to lateral or
  - Lateral to medial

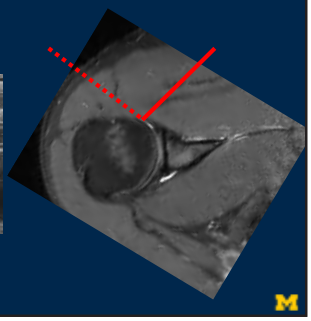


POST GLENOHUMERAL JOINT

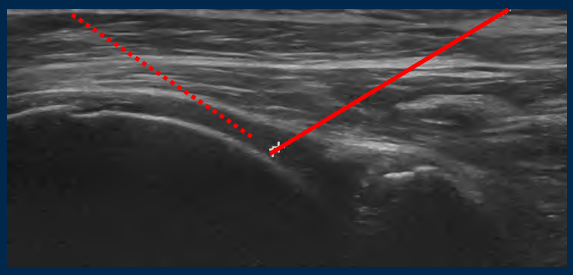
Image courtesy of Dr. Robin Smithuis & Radiology Assistar
https://radiologyassistant.nl/musculoskeletal/shoulder/insta

GLENOHUMERAL JT INJECTION





GLENOHUMERAL JT INJECTION

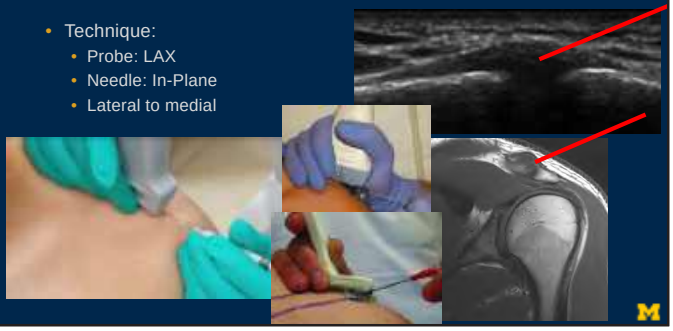


GLENOHUMERAL JT INJECTION

GLENOHUMERAL JT INJECTION

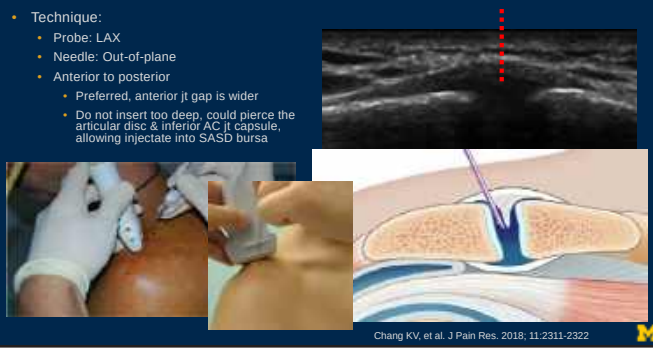
AC JT INJECTION

- Technique:
  - Probe: LAX
  - Needle: In-Plane
  - Lateral to medial



AC JT INJECTION

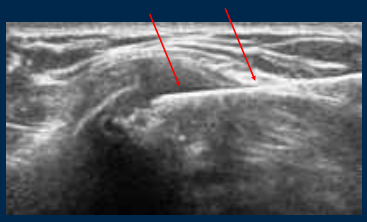
- Technique:
  - Probe: LAX
  - Needle: Out-of-plane
  - Anterior to posterior
    - Preferred, anterior jt gap is wider
    - Do not insert too deep, could pierce the articular disc & inferior AC jt capsule, allowing injectate into SASD bursa



Chang KV, et al. J Pain Res. 2018; 11:2311-2322

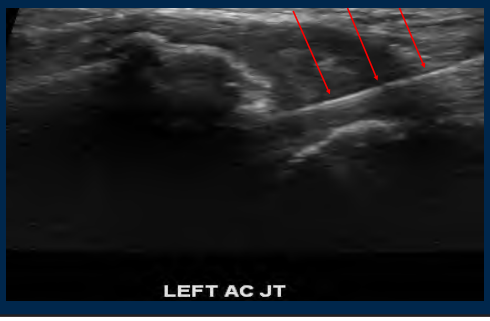
AC JT INJECTION

- Technique:
  - Probe: SAX (perpendicular to clavicle)
  - Needle: In-plane
  - Anterior to posterior
    - Preferred, anterior jt gap is wider

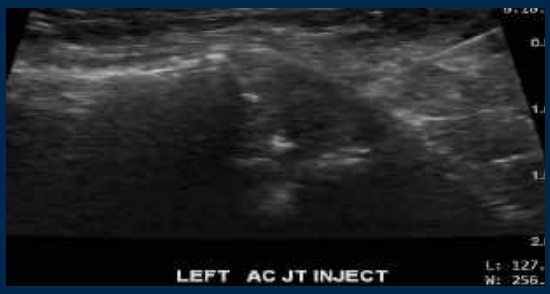


Chang KV, et al. J Pain Res. 2018; 11:2311-2322

AC JT INJECTION



AC JT INJECTION

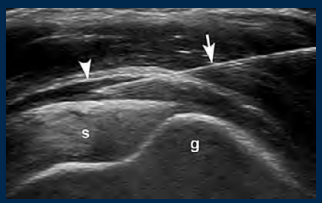


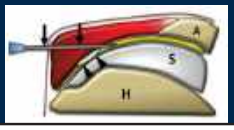
AC JT INJECTION

SASD BURSAL INJECTION

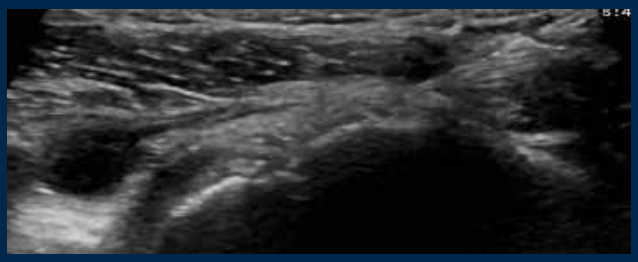
- Technique:
  - Probe: LAX
  - Needle: In-Plane
  - Lateral to medial

SASD BURSAL INJECTION



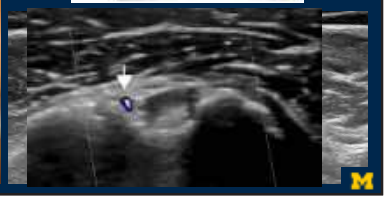


SASD BURSAL INJECTION

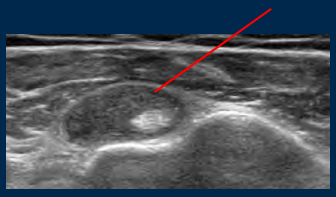


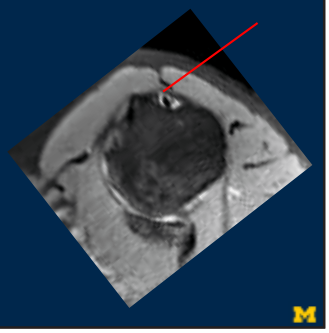
LHBT SHEATH INJECTION

- Technique:
  - Probe: SAX
  - Needle: In-Plane
  - Lateral to medial
    - Avoid branch of ant. circ. humeral a.

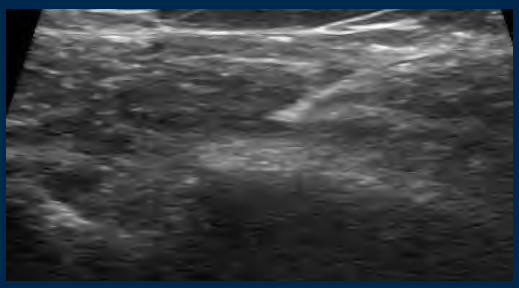


LHBT SHEATH INJECTION

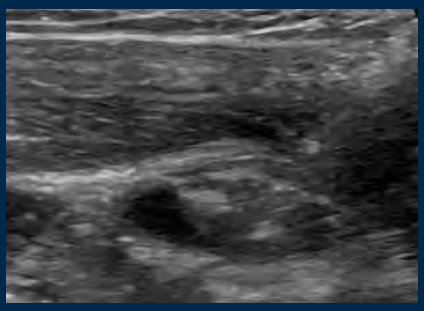




LHBT SHEATH INJECTION



LHBT SHEATH INJECTION



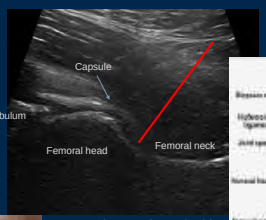
LHBT SHEATH INJECTION

- MESOTENON (Biceps vincula)
  - Synovial fold connecting tendon to tendon sheath
  - Contains blood supply to LHBT (anterior humeral circumflex a.)

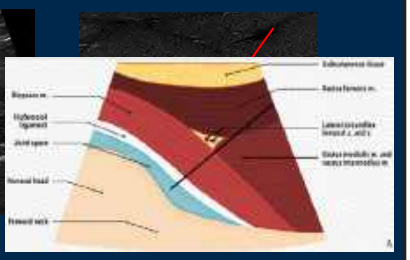
HIP JOINT INJECTION

- Technique:
  - Probe: LAX
  - Needle: In-Plane
  - Distal to proximal
    - Avoid branch of lat. circumflex fem. a.
  - Hip in slight internal rotation

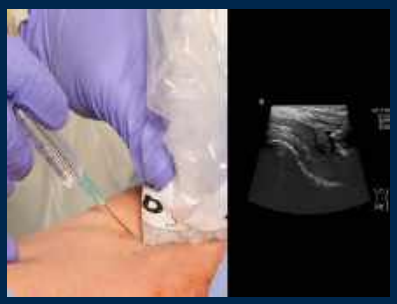
HIP JOINT INJECTION



LAX US image of anterior hip

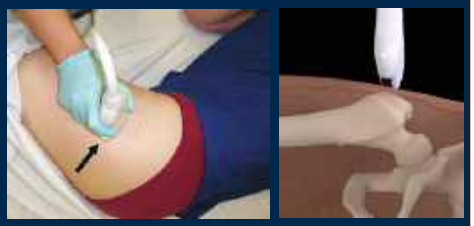


HIP JOINT INJECTION

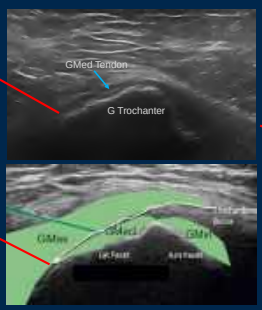


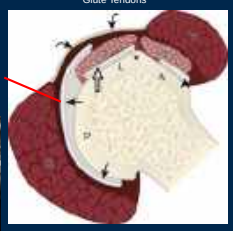
TROCHANTERIC BURSAL INJECTION

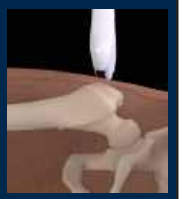
- Technique:
  - Probe: SAX
  - Needle: In-Plane
  - Posterior to anterior



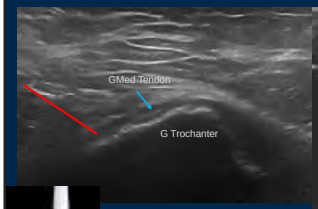
TROCHANTERIC BURSAL INJECTION

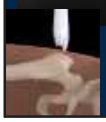






TROCHANTERIC BURSAL INJECTION



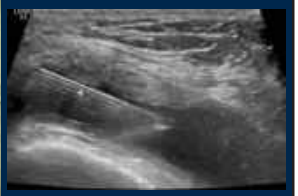


SAX US images of G. Trochanter

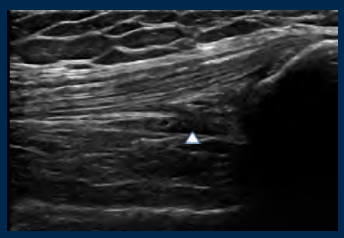
G. Trochanter

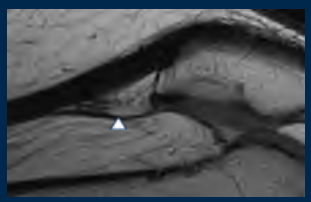
KNEE JOINT INJECTION

- Technique:
  - Probe: SAX
  - Needle: In-Plane
  - Lateral to medial
    - Avoid fat pads

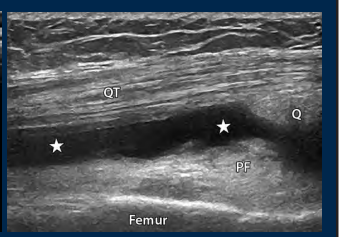


KNEE JOINT INJECTION

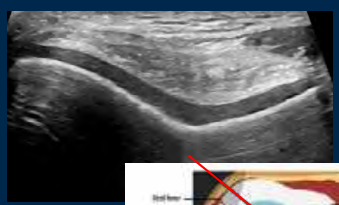


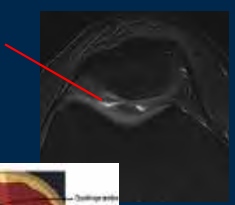


KNEE JOINT INJECTION / ASPIRATION

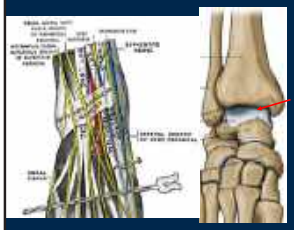


KNEE JOINT INJECTION / ASPIRATION

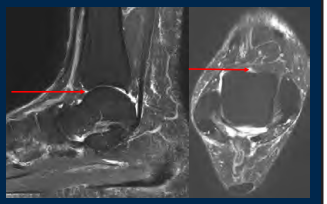




TIBIOTALAR JOINT INJECTION



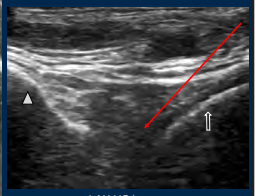
Tibiotalar Joint



TIBIOTALAR JOINT INJECTION

- Technique:
  - Probe: LAX (p. flex)
  - Needle: In-Plane
    - Distal to proximal
      - Avoid dorsalis pedis a., deep peroneal n. & superficial peroneal (fibular) n. branches

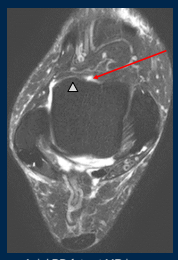
Sagittal PD fat sat MR image



LAX US image

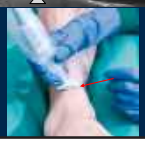
TIBIOTALAR JOINT INJECTION

- Technique:
  - Probe: SAX
  - Needle: In-Plane
    - Medial to lateral
      - Preferred as avoids the superficial peroneal n. branches & needle passes deep to dorsalis pedis a. & deep peroneal n.

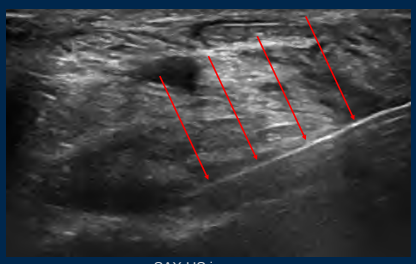


Axial PD fat sat MR image

SAX US image



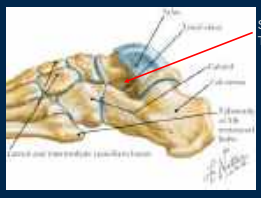
TIBIOTALAR JOINT INJECTION



SAX US image

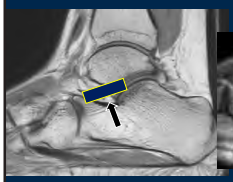
SINUS TARSI INJECTION

- Technique:
  - Probe: Oblique LAX
  - Needle: Out-of-plane
  - Posterior to anterior or
  - Anterior to posterior

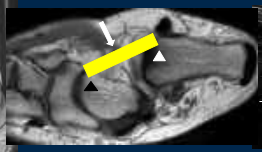


Sinus Tarsi

SINUS TARSI INJECTION



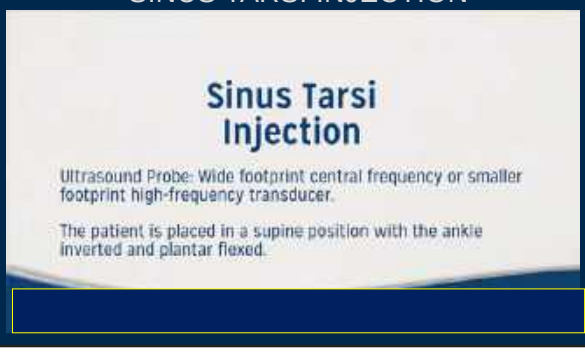
Sagittal PD MR image



Axial PD MR image

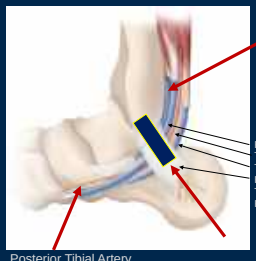
Oblique LAX US image

SINUS TARSI INJECTION

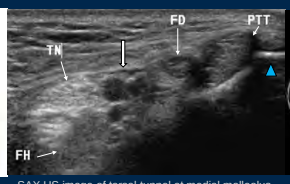


Tarsal Tunnel/Tibial n./PTT Injection

- Technique:
  - Probe: SAX
  - Needle: In-Plane
  - Posterior to anterior (avoid posterior tibial a.) or
  - Anterior to posterior



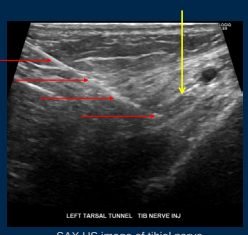
Tarsal Tunnel/Tibial n./PTT Injection



SAX US image of tarsal tunnel at medial malleolus

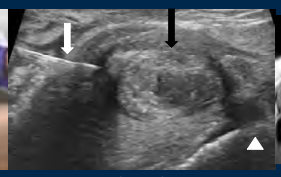
Axial T1-weighted MR image of ankle

TIBIAL PERINEURAL INJECTION

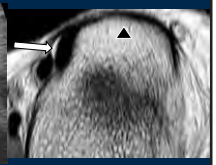


SAX US image of tibial nerve

POSTERIOR TIBIALIS TENDON SHEATH INJECTION



SAX US image of PTT



Axial T1-weighted MR image

POSTERIOR TIBIALIS TENDON SHEATH INJECTION

TAKE HOME POINTS

- US is excellent for image-guided MSK procedures
- Allows direct visualization of needle in real-time
- Directly visualize needle & evaluate surrounding soft tissues, neurovascular structures & fluid collections
- Therapy can be performed simultaneously w/ diagnostic scan
  No radiation or contrast
- Accessible & portable

THANK YOU

SELF EVALUATION

Ultrasound-Guided Musculoskeletal Procedures

1. T/F - The out-of-plane technique is the preferred method for most injections and the most accurate.

2. All of the following are correct regarding the in-plane technique except:

a. Most accurate
b. Visualizes the entire needle length
c. The short axis of the needle crosses the ultrasound beam
d. Reverberation is more commonly seen

3. T/F - The anterior AC joint space is wider.

4. T/F - When performing an US-guided AC joint injection it is important to insert the needle deep into the joint to ensure you are injecting all the medication.

5. T/F - When injecting the subacromial-subdeltoid bursa, the needle should be placed just superficial to the peribursal fat layer.

6. T/F - While performing a long head biceps tendon sheath injection one must be careful to avoid the branch of the anterior circumflex humeral artery which is located along the lateral aspect.

7. T/F - The gluteus medius tendon is located on the anterior facet of the greater trochanter.

Answer Key: 1. F, 2. C, 3. T, 4. F, 5. F, 6. T, 7. F

MICHIGAN MEDICINE
UNIVERSITY OF MICHIGAN

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MRI of the Knee

OBJECTIVES

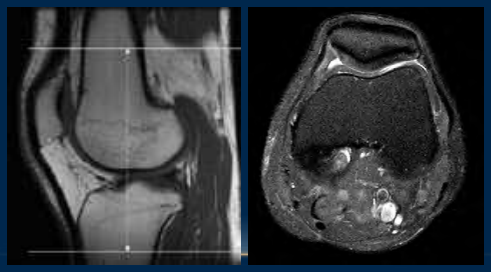
- Learn the Protocol for MRI Knee
- Review Selected Knee Anatomy
- Review Knee MRI Cases

KNEE MRI PROTOCOL

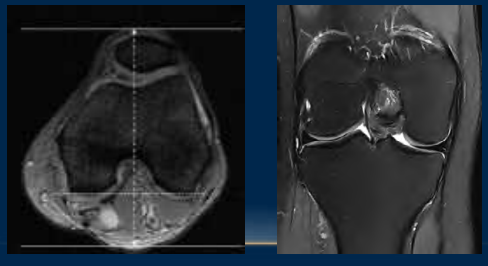
KNEE MRI PROTOCOL

- AX T2 FAT SAT
- COR PD FAT SAT
- SAG T1 NON FAT SAT
- SAG PD FAT SAT

AXIAL SEQUENCE (T2 FS)

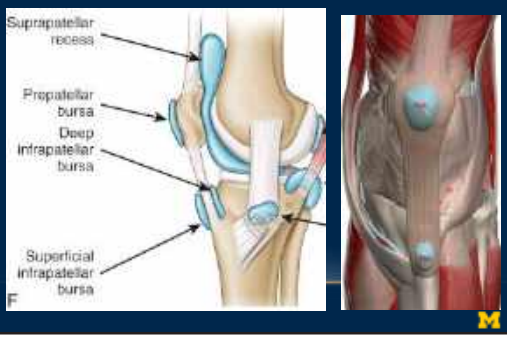


CORONAL SEQUENCE (PD FS)

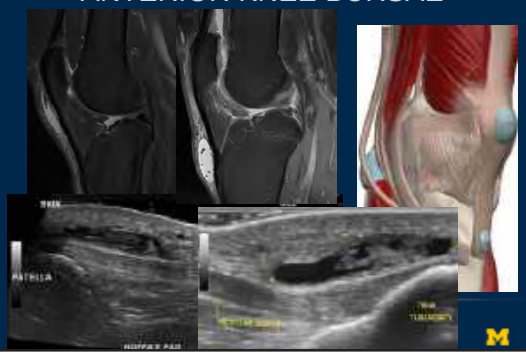


SAGITTAL SEQUENCE (PD FS & T1)

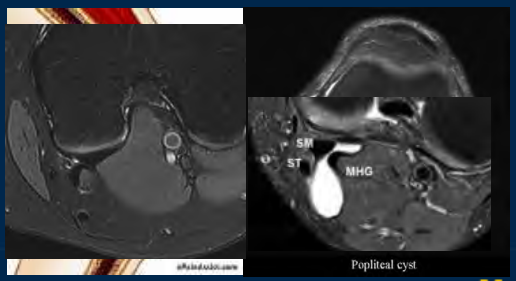
ANTERIOR KNEE BURSAE



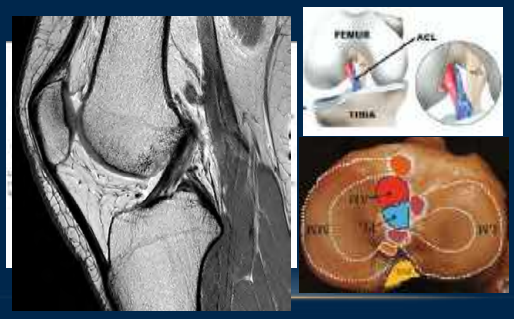
ANTERIOR KNEE BURSAE



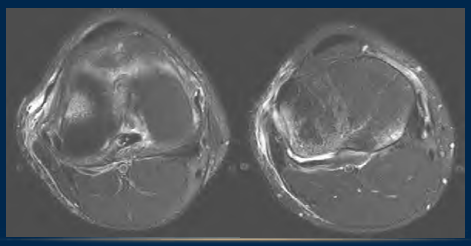
MEDIAL GASTROCNEMIUS-SEMIMEMBRANOSUS BURSA → BAKER'S CYST

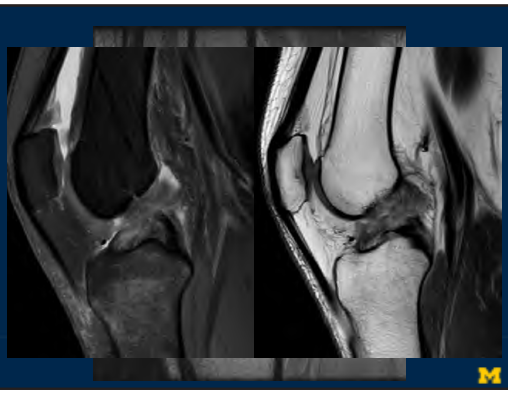


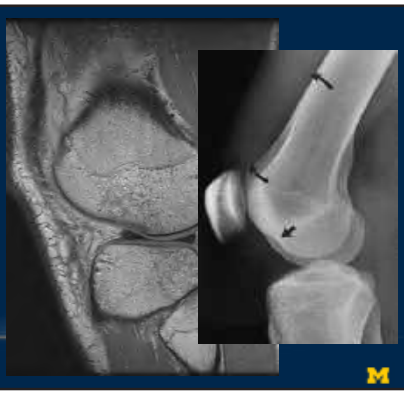
ACL



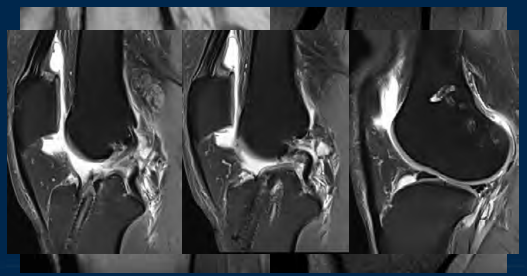
CLASSIC ACL TEAR CONTUSION



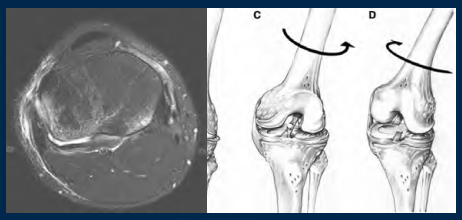




ACL TEAR

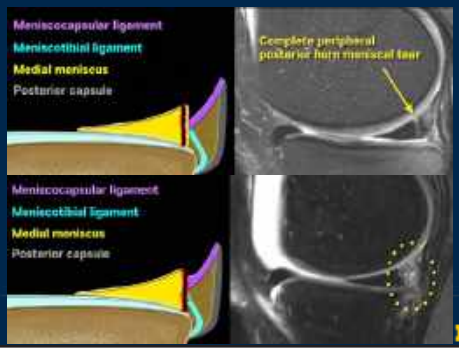


PIVOT-SHIFT & CONTRECOUP INJURY

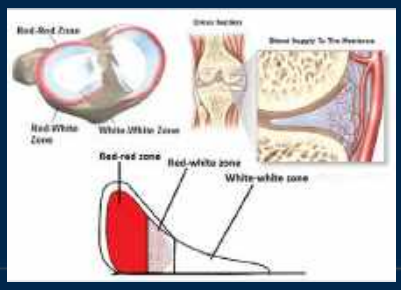


"Bone contusions of the posterior lip of the medial tibial plateau (contrecoup injury) & associated internal derangements of the knee at MRI"
Kaplan PA, et al., Radiology 1999; 211(3):747-53

RAMP LESIONS



MENISCAL ZONES

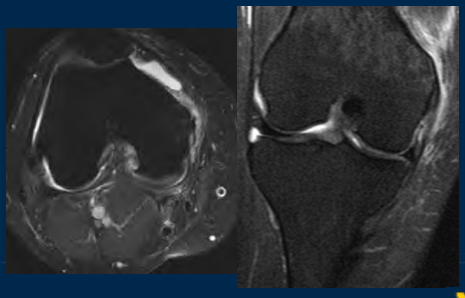


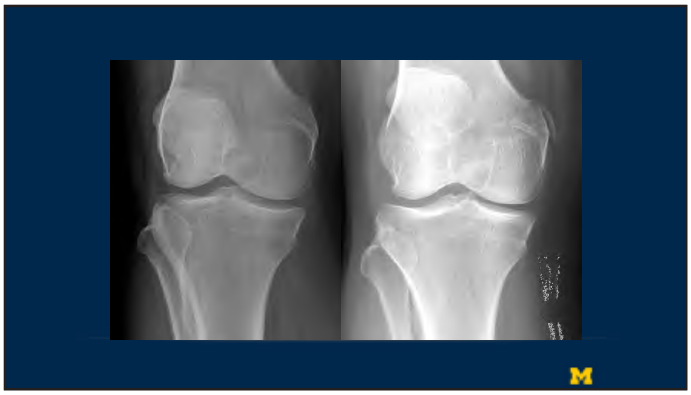
O'DONOGHUE UNHAPPY (TERRIBLE) TRIAD

PELLEGRINI-STIEDA LESION

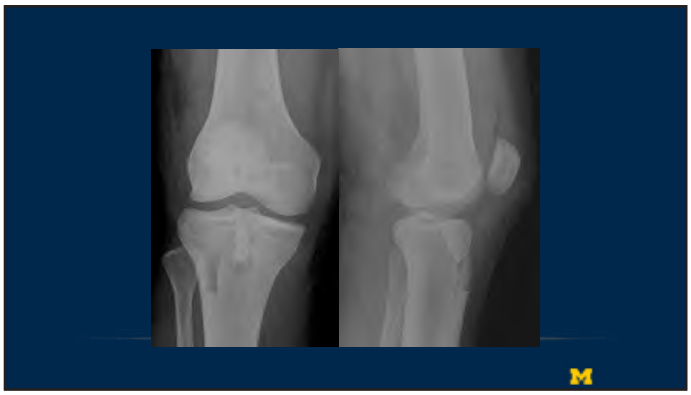
- Sequela of a prior injury to the MCL
  - Begins ~2-3 weeks after injury
- Ossified post-traumatic lesions at the MCL, adjacent to insertion site at the medial femoral condyle
- One presumed mechanism is a small avulsion injury of the medial collateral ligament at the medial femoral condyle

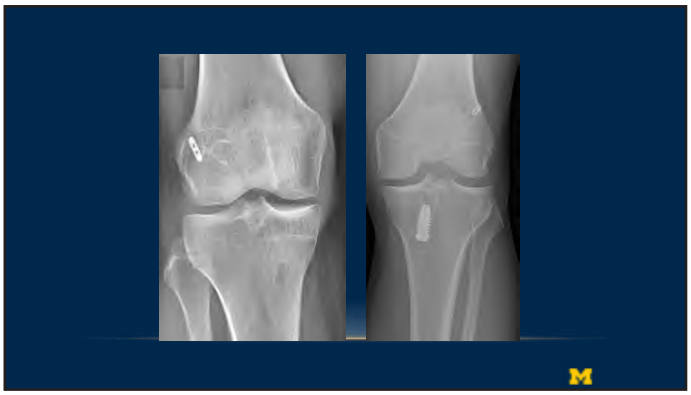
MCL W/ PELLEGRINI-STIEDA

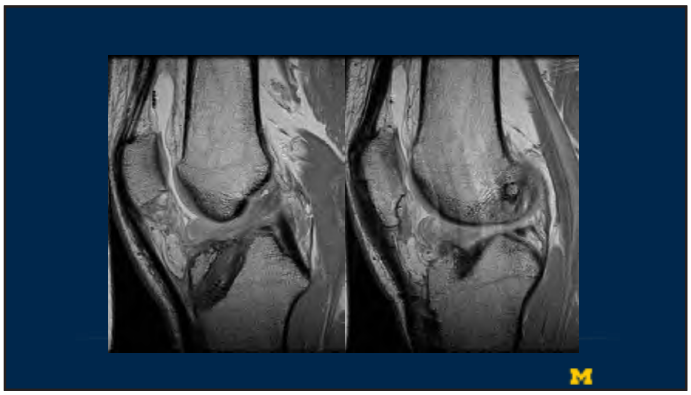


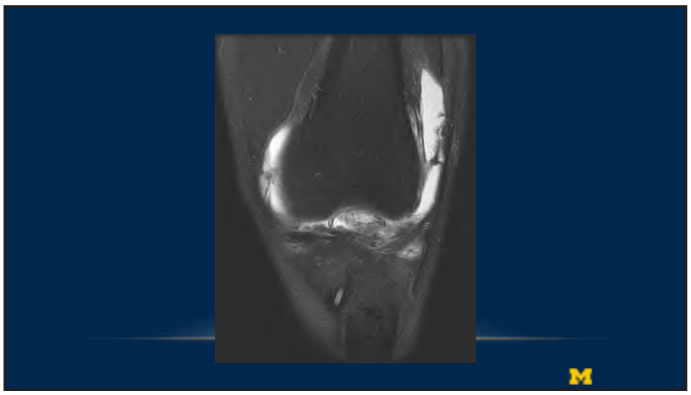


ACL BONE-PATELLAR TENDON-BONE AUTOGRAFT



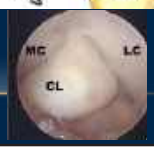




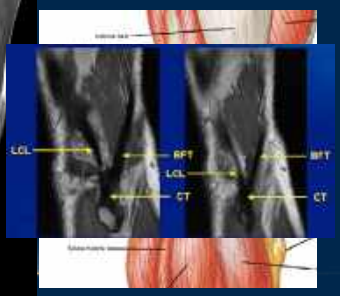


ACL ARTHROFIBROSIS/CYCLOPS

- Localized anterior arthrofibrosis of ACL reconstruction
- ~5% following ACL reconstruction
- Pain during extension of knee, eventual audible & palpable “clunk”
  - Occurs typically 8 to 32 weeks (2-8 months) after ACL repair
- Treatment: arthroscopic excision

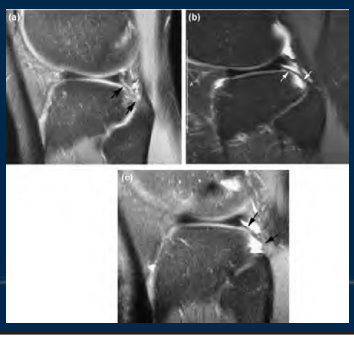


LATERAL STRUCTURES

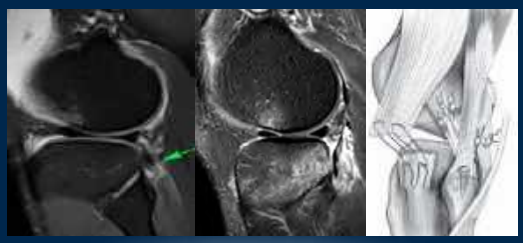


POSTERIOR LATERAL CORNER

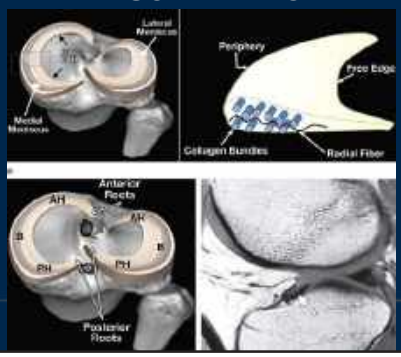
POPLITEOMENISCAL FASCICLES



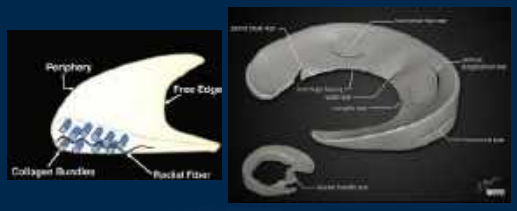
POSTERIOR LATERAL CORNER INJURY



MENISCAL ANATOMY

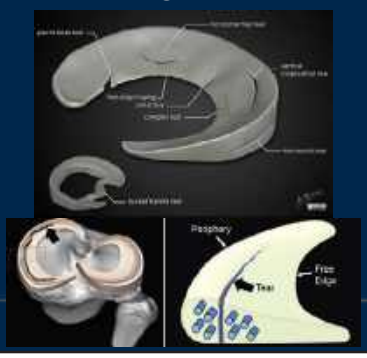


MENISCAL TEARS



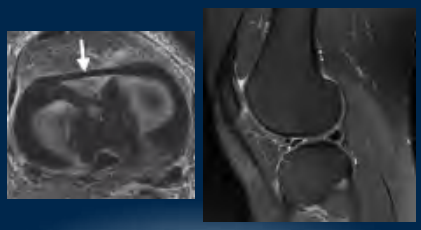
HORIZONTAL TEAR

VERTICAL TEAR



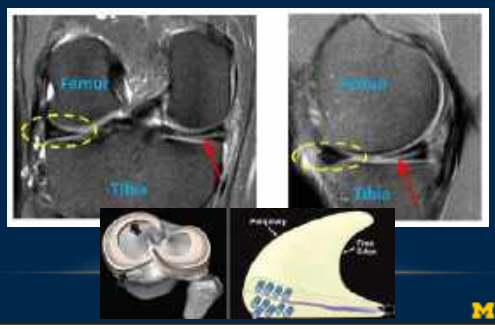
RADIAL TEAR

ANTERIOR TRANSVERSE (INTERMENISCAL) LIGAMENT



MENISCOFEMORAL LIGAMENTS

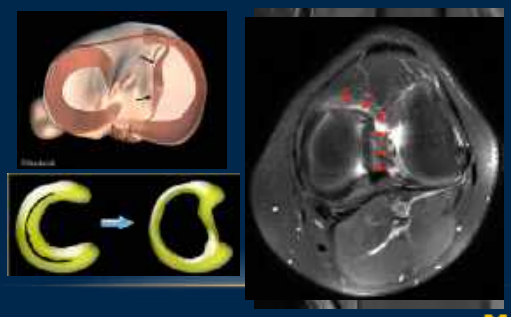
HORIZONTAL TEAR

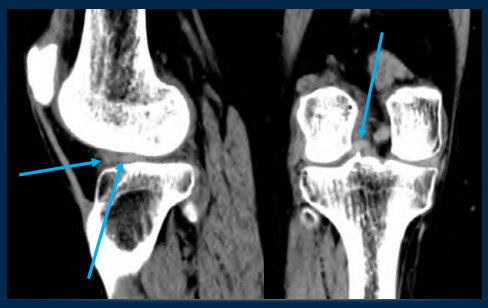


- "Use of the "two-slice-touch" rule for the MRI diagnosis of meniscal tears"
  De Smet AA, Tuite MJ. AJR Am J Roentgenol. 2006;187(4):911-4

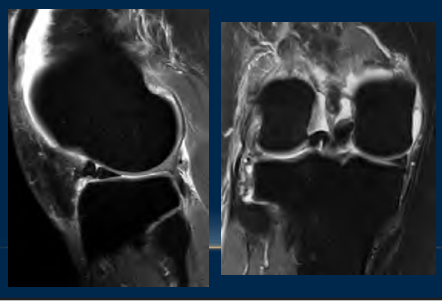
VERTICAL TEAR

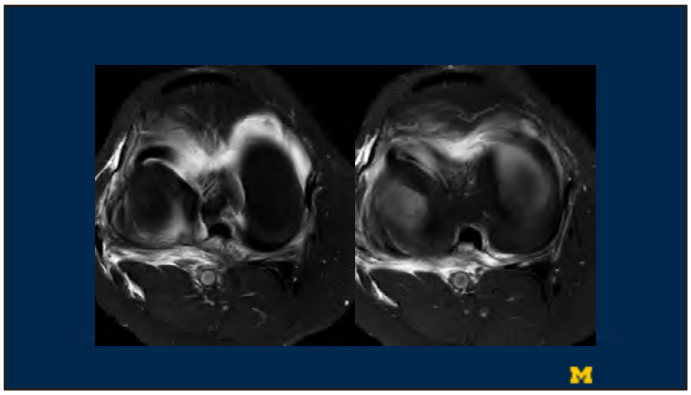
BUCKET HANDLE TEAR

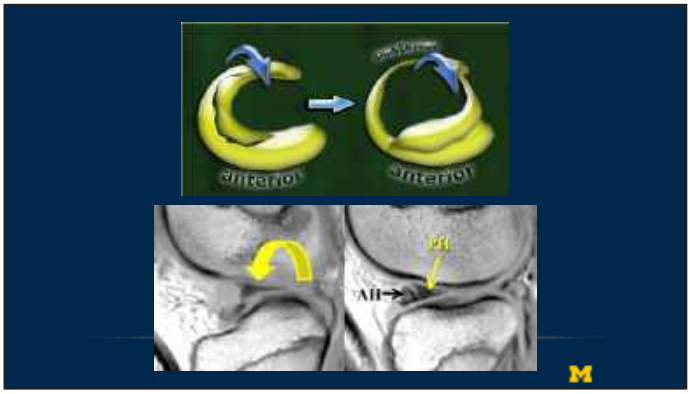




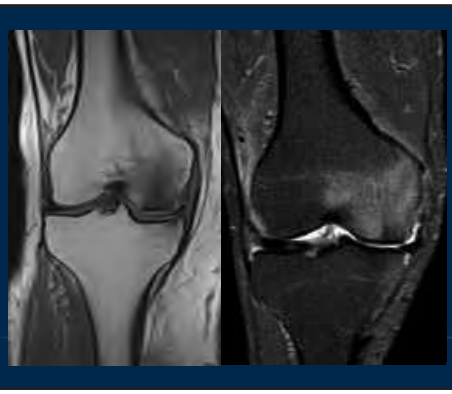
DOUBLE DELTA SIGN (DOUBLE ANTERIOR HORN OR FAST FORWARD SIGN) W/ GHOST MENISCUS POST. HORN







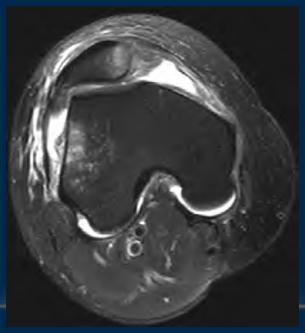
RADIAL TEAR (POST. ROOT)



SIFK (SONK)

- Subchondral insufficiency fracture of the knee (SIF/SIFK)
- Spontaneous osteonecrosis of the knee (Ahlbäck disease) is misnomer
- Subchondral insufficiency fracture that progressed to subchondral collapse
- M:F 1:3 & usually over 55
- Almost always unilateral & usually medial femoral condyle
- Usually associated with meniscal tear, often medial meniscal posterior root with extrusion*

*Roberson DD, et al. J Bone Joint Surg. 2009; 91-B 190-5
Hussain ZB, et al. Clin Sports Med Update
Yasuda T, et al. Int J Rheum Dis. 2017
Gorbachova T, et al. AJR Am J Roentgenol. 2019; 213(5):963-82



TRANSIENT LATERAL PATELLAR DISLOCATION

- Accounts for ~3% of all knee injuries & commonly in sports
- MC from twisting motion, w knee in flexion & femur rotating internally on a fixed foot (valgus-flexion-external rotation)
- Lateral displacement of patella on Merchants/sunrise view
- Effusion
- Medial retinaculum/MPFL sprain or disruption
- Lateral displacement of patella
- Medial patellar & lateral femoral condyle (ant 1/3rd/ paralleling cortex) kissing contusions

SELF EVALUATION

MRI of the Knee

True/False

1. A Baker's cyst is located between the lateral head gastrocnemius and the semimembranosus.

2. The classic valgus pivot shift ACL injury contusion pattern involves the medial femoral condyle and posterior lateral tibial plateau.

3. The most vascularized portion of the meniscus (red-red zone) is the outer one-third.

4. A Pellegrini-Stieda lesion is an ossified post-traumatic lesion secondary to an LCL injury and begins 2-3 years after injury.

5. The most common technique for ACL reconstruction is using a hamstring allograft.

6. ACL arthrofibrosis ("cyclops lesion") typically occurs 2-8 months after ACL repair and involve ~5% of ACL reconstructions.

7. A subchondral insufficiency fracture of the knee (SIFK) typically involves the medial femoral condyle.

Answer Key: 1. F, 2. F, 3. T, 4. F, 5. F, 6. T, 7. T

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Ultrasound of the Knee

OUTLINE

- US Knee Protocol
- US Knee Anatomy Review
- Normal Knee US

US KNEE PROTOCOL

- Focused Examination
  - e.g. Extensor mechanism, effusion or Baker's cyst
- Complete Examination
  - Anterior
  - Medial
  - Lateral
  - Posterior

US KNEE PROTOCOL

- Anterior Structures:
  - Quadriceps tendon
  - Suprapatellar recess
  - Bursae: Prepatellar, Deep & Superficial Infrapatellar
  - Patellar tendon
  - Fat Pads: Prefemoral, Suprapatellar (Quadriceps) & Hoffa's

US KNEE PROTOCOL

- Medial Structures:
  - Medial collateral ligament (MCL)
  - Pes anserine (pes anserine bursa)
  - Medial meniscus (body)

US KNEE PROTOCOL

- Lateral Structures:
  - Lateral collateral ligamentous complex
    - Iliotibial (IT) band (tract)
    - Fibular collateral ligament (FCL)
    - Biceps femoris tendon
  - Popliteus tendon
  - Lateral meniscus (body)

US KNEE PROTOCOL

- Posterior Structures:
  - Baker's cyst (gastrocnemius-semimembranosus bursa)
  - Neurovascular structures
  - Menisci (posterior horns)

US KNEE PROTOCOL

- Technique:
  - Patient in supine position w/knee slightly flexed (20°–30°), pillow or wedge can be used beneath knee
  - Reduces anisotropy by stretching tendons
  - A linear array transducer of 9-15 MHz is recommended

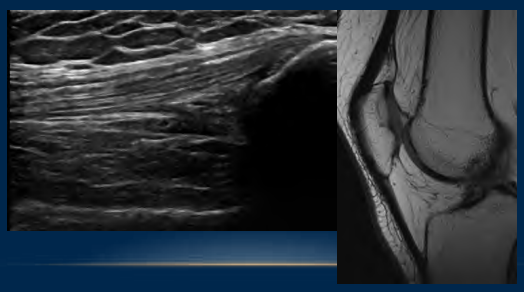
Alves TI, et al. Radiographics 2016; 36(6):1759-1775

ANTERIOR STRUCTURES

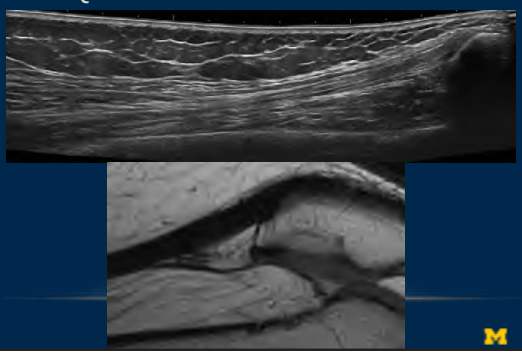
ANTERIOR STRUCTURES

ANTERIOR STRUCTURES

QUADRICEPS TENDON & FAT PADS

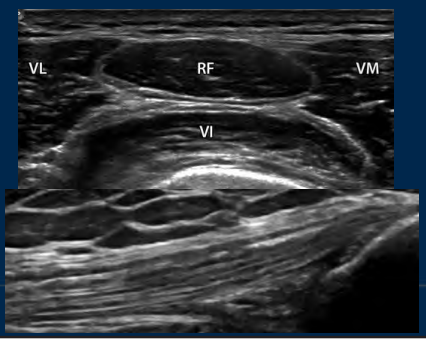


QUADRICEPS TENDON LAX

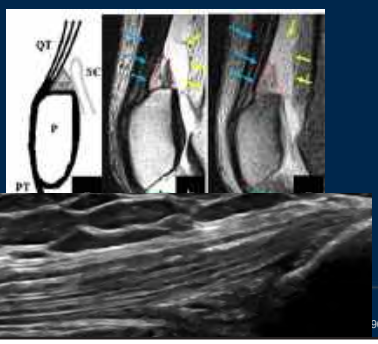


QUADRICEPS TENDON

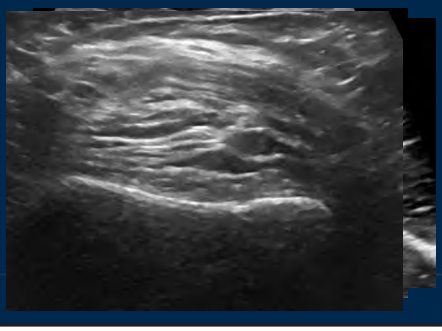
QUADRICEPS TENDON LAYERS



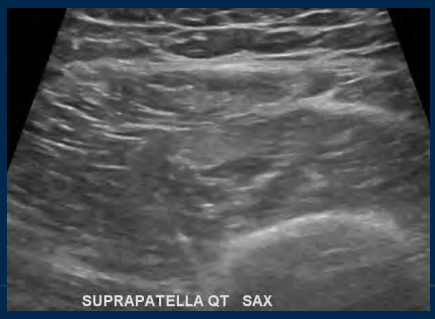
QUADRICEPS TENDON LAYERS



QUADRICEPS TENDON SAX

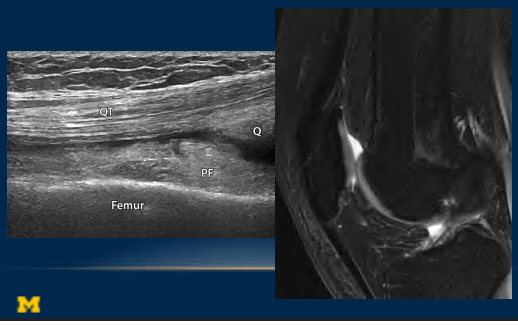


QUADRICEPS TENDON SAX

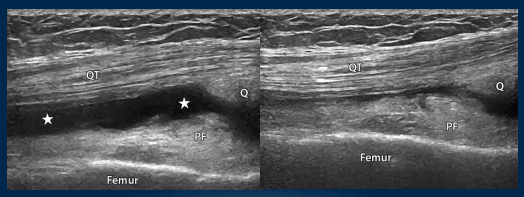


QUADRICEPS TENDON LAYERS

SUPRAPATELLAR RECESS

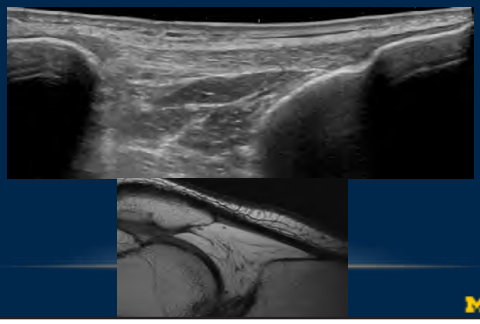


SUPRAPATELLAR RECESS

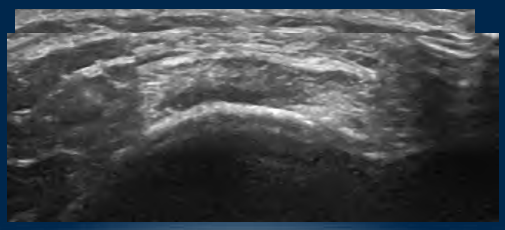


PATELLAR TENDON LAX

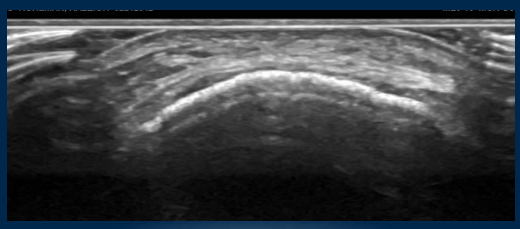
PATELLAR TENDON & HOFFA FAT PAD



PATELLAR TENDON SAX



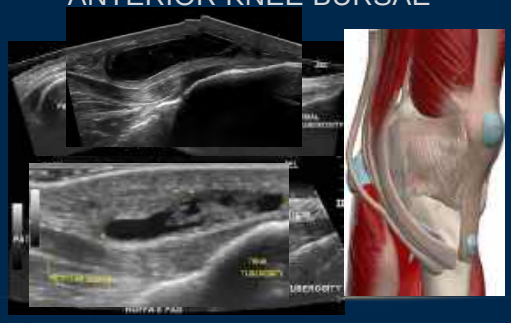
PATELLAR TENDON SAX



ANTERIOR KNEE BURSAE

- Bursae:
  - Prepatellar
  - Deep & Superficial Infrapatellar

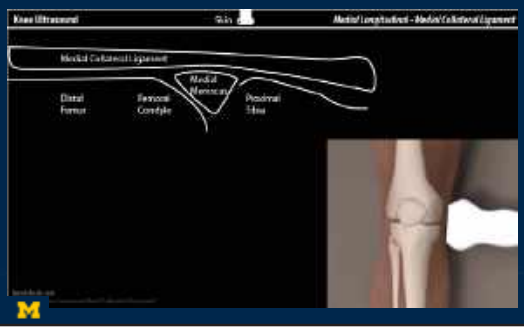
ANTERIOR KNEE BURSAE



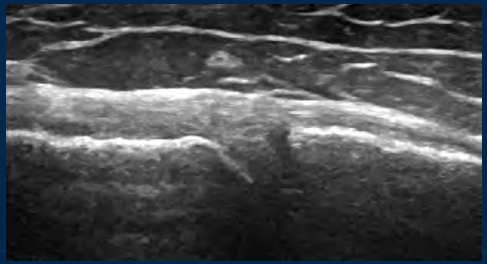
MEDIAL STRUCTURES

MEDIAL STRUCTURES

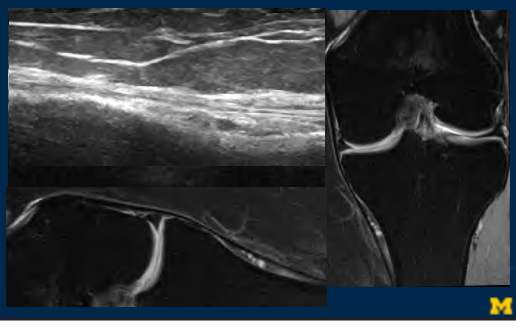
MEDIAL STRUCTURES



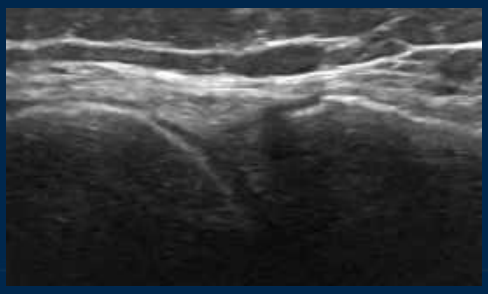
MEDIAL COLLATERAL LIGAMENT



MCL

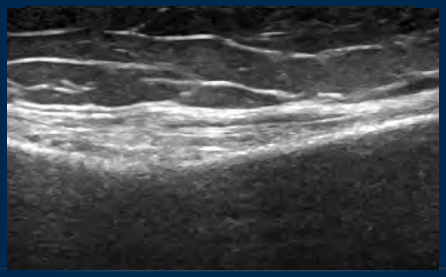


MCL

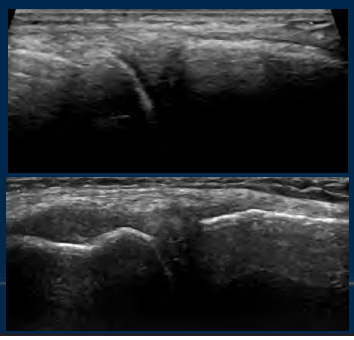


MCL / PES ANSERINE

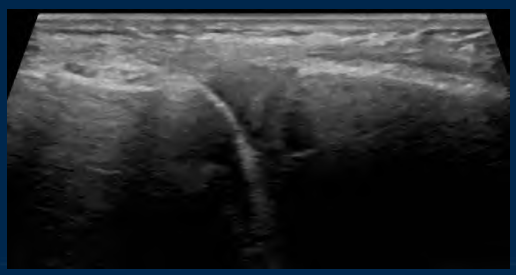
DISTAL MCL / PES ANSERINE



MEDIAL MENISCUS



MEDIAL MENISCUS / MCL

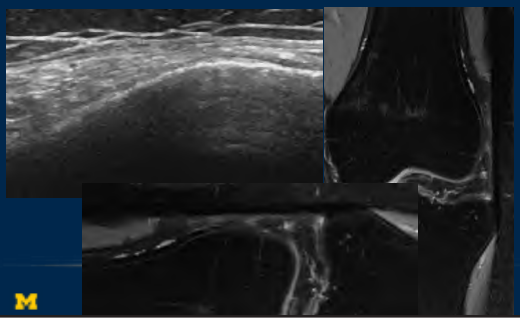


LATERAL STRUCTURES

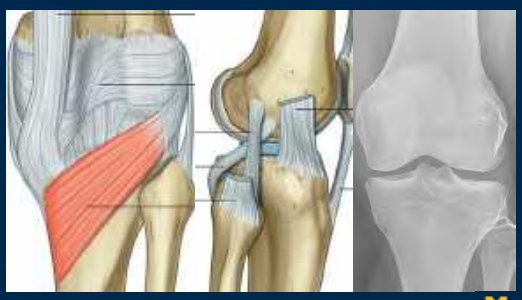
LATERAL STRUCTURES

ILIOTIBIAL BAND / LCL COMPLEX

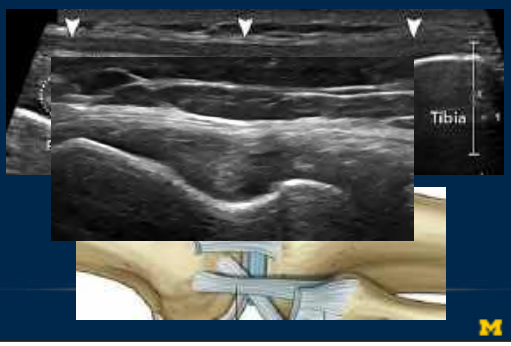
IT BAND (TRACT)



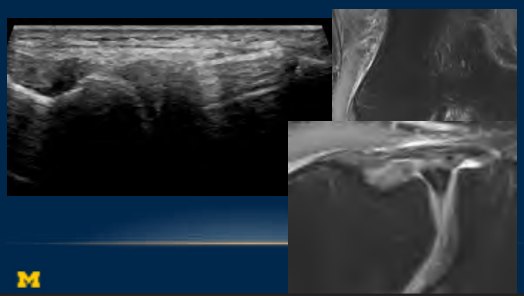
POPLITEUS TENDON



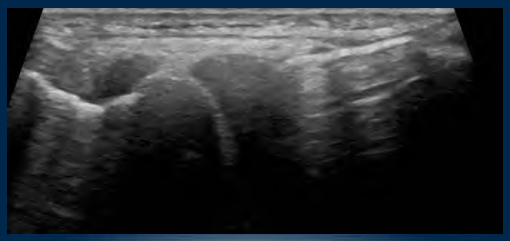
IT BAND / POPLITEUS TENDON



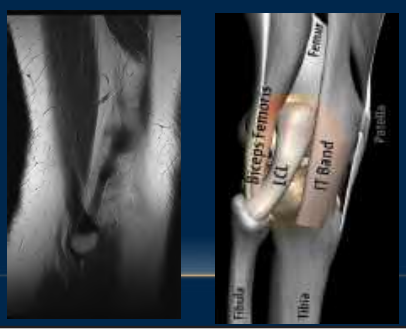
LATERAL MENISCUS



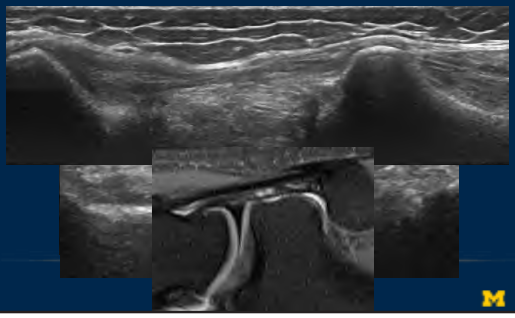
IT BAND / POPLITEUS T. / LAT MEN.



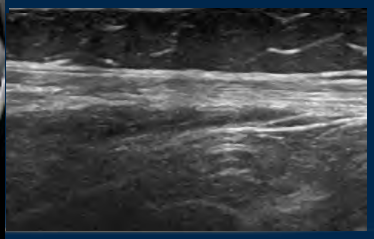
FCL / LCL COMPLEX “V”



FIBULAR COLLATERAL LIGAMENT

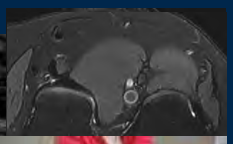


BICEPS FEMORIS



POSTERIOR STRUCTURES

NEUROVASCULAR STRUCTURES



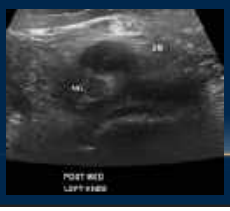
- Slight bend of knee allows filling of the popliteal vein

BAKER'S CYST (GASTROCNEMIUS-SEMIMEMBRANOSUS BURSA)

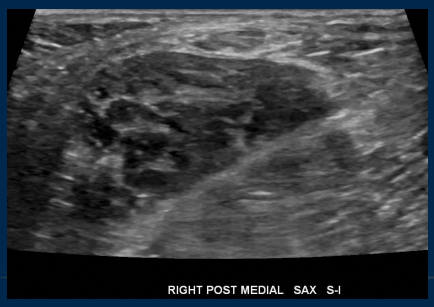
https://essr.org/content-essr/uploads/2016/10/knee.pdf

BAKER'S CYST

- Only if in gastrocnemius-semimembranosus bursa

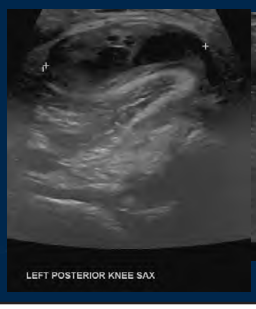


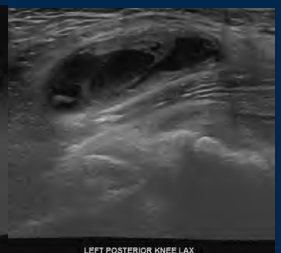
BAKER'S CYST LOCATION SAX



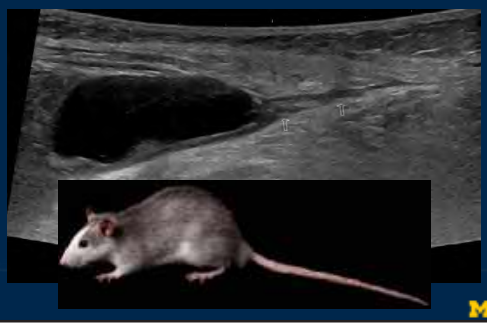
BAKER'S CYST LOCATION LAX

COMPLEX BAKER'S CYST

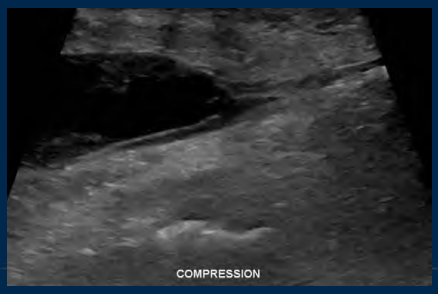




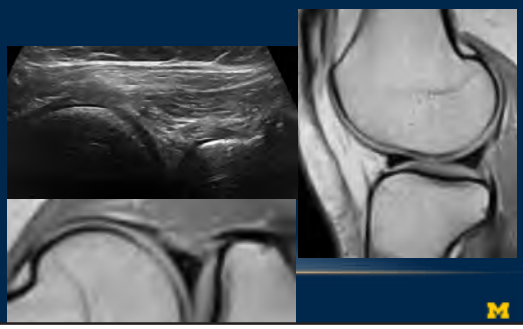
LEAKING BAKER'S CYST



LEAKING BAKER'S CYST



POSTERIOR HORN LAT. MEN.



TAKE HOME POINTS

- Ultrasound is excellent for knee pathology
  - Know limitations
- Understanding anatomy & MSK US basics is critical
  - Baker's cyst location & neck
- Follow protocol (focused vs complete exam)
- Benefits of MSK US
  - Dynamic imaging

THANK YOU

SELF EVALUATION

Ultrasound of the Knee

1. In order from superficial to deep, which of the following is the correct order of the layers of the quadriceps tendon?

a. Vastus lateralis and vastus medialis, rectus femoris, and vastus intermedius
b. Rectus femoris, vastus lateralis and vastus medialis, and vastus intermedius
c. Vastus intermedius, vastus lateralis and vastus medialis, and rectus femoris
d. Rectus femoris, vastus intermedius, and vastus lateralis and vastus medialis

2. T/F - The pes anserine is made up of the sartorius, gracilis, and semitendinosus tendons.

3. T/F - The fibular (lateral) collateral ligament and biceps femoris tendon form a conjoined tendon at the fibular head.

4. T/F - A Baker's cyst is located between the lateral head gastrocnemius and the semimembranosus.

5. T/F - In order to evaluate the anterior knee structures including the quadriceps tendon, the knee should be flexed 90 degrees to reduce anisotropy.

6. T/F - The popliteus tendon can be imaged along the medial knee.

7. T/F - The ultrasound knee protocol should always include the entire knee.

Answer Key: 1. B, 2. T, 3. T, 4. F, 5. F, 6. F, 7. F

FACULTY

Wende N. Gibbs, MD

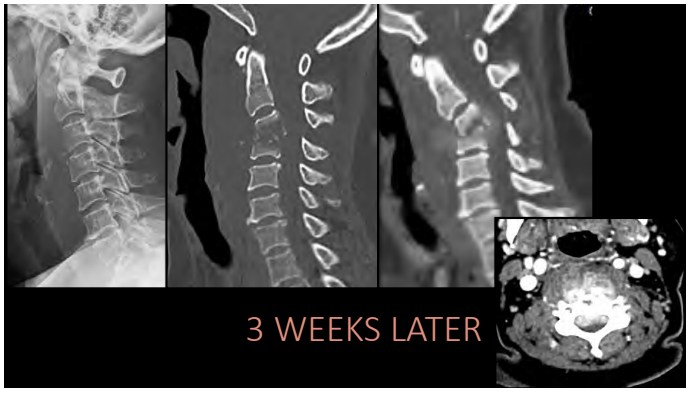
Wende N. Gibbs, MD is a neuroradiologist and the director of spine imaging and intervention at Barrow Neurological Institute. She is certified in diagnostic radiology and neuroradiology by the American Board of Radiology. Dr. Gibbs is an expert in diagnostic and interventional spine radiology, with distinct interests in spine oncology and pain management. She is the president-elect of the American Society of Spine Radiology and the Western Neuroradiological Society and serves as the chair of education for the American Society of Neuroradiology.

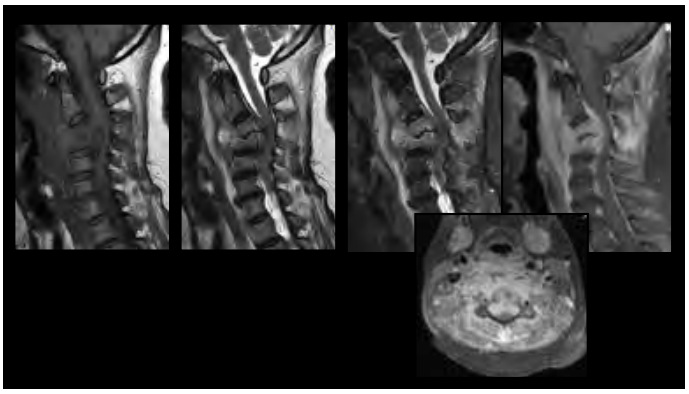
Dr. Gibbs earned her medical degree from the University of California, Irvine. While there, she also completed a one-year National Institutes of Health (NIH)/General Clinical Research Center (GCRC) research fellowship evaluating novel magnetic resonance imaging (MRI) contrast agents for the detection of metastatic lymph nodes in patients with head and neck cancer. She completed her residency in diagnostic radiology at Baylor University Medical Center in Dallas and a two-year neuroradiology fellowship at Barrow Neurological Institute.

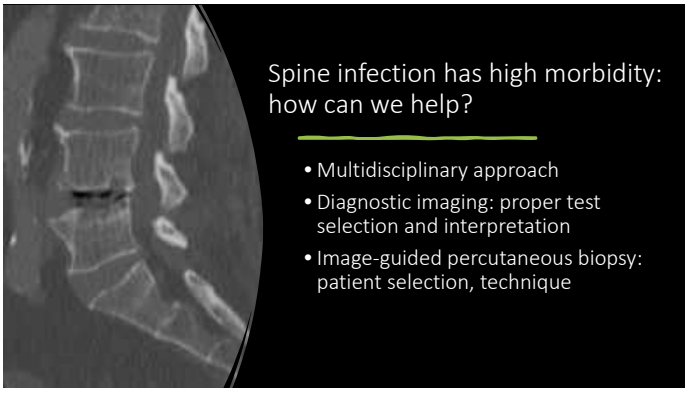
Dr. Gibbs has authored multiple book chapters, peer-reviewed journal articles, and award-winning abstracts. She serves on the editorial boards of three journals and is the podcast editor and host of *Radiographic*, the educational journal of the Radiological Society of North America. Dr. Gibbs also works on several multidisciplinary spinal surgery committees, including the North American Spine Society, and is one of the original hosts of the weekly Virtual Global Spine Conference. Dr. Gibbs is passionate about patient safety, communication, ethics, education, and exploring artificial intelligence.

You may contact Dr. Gibbs with any questions or comments by email at wendengibbs@gmail.com.

Spine Infection and Mimics
Wende N. Gibbs, MD







What is the best imaging test?

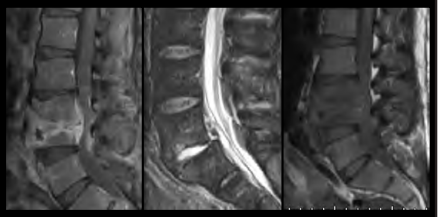
MRI approximately 96% sensitive/93% specific/94% accurate

PET-CT is similar, but less available, more radiation

Talbott J et al. Imaging-Based Approach to Extradural Infections of the Spine. Sem US, CT & MRI, 2018.

What are the key features of infection?

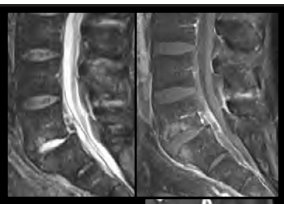
- Paraspinal/epidural inflammatory SI (98% sensitive)
- Disc enhancement 95%
- Disc: T2 hyperintense (fluid signal) 93%
- Endplate erosion 84%
- Lost intranuclear cleft* 83%



Ledermann P, Schweitzer M, Morrison W, Carrino J. MR Imaging Findings in Spinal Infections: Rules or Myths? Radiology, 2003.

What are the key features of infection?

- Paraspinal/epidural soft tissue with inflammatory signal intensity
- Disc enhancement
- Disc: T2 hyperintense (fluid (very!) signal)
- Endplate erosion
- Lost intranuclear cleft

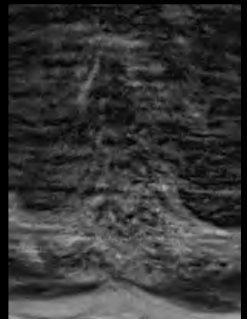


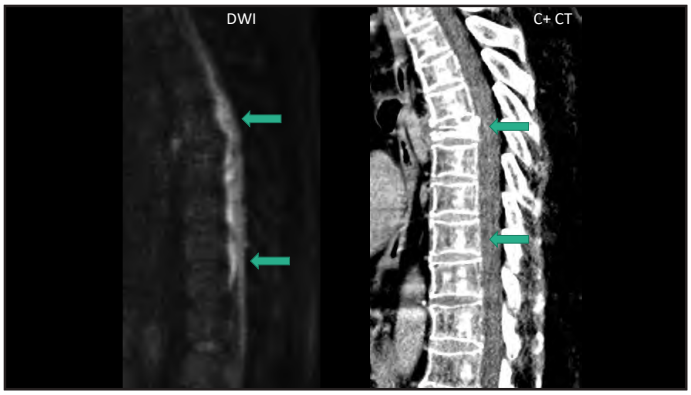
Enhancement?

What if we can't get MRI?

75-year-old call weekend transfer from rehab for acute onset severe back pain, urinary incontinence, leg weakness, on Plavix

Couldn't get MRI on arrival



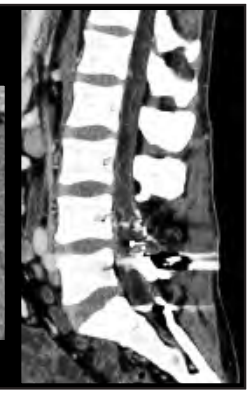


What if we can't get MRI?

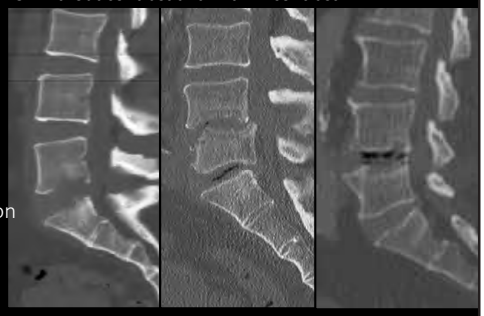
39-year-old with HIV, drug abuse, cauda equina syndrome

- PACEMAKER
- INR 4

CT with contrast



CT without contrast and with IV contrast



- Endplate destruction
- Demineralization
- Air in disc space??
- Phlegmon/abscess

Are x-rays useful? When?

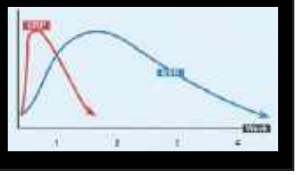
- Acute: normal
- Subacute (1-3 wks.'): endplate irregularity, height loss
- Chronic: sclerosis, collapse, deformity
- Not useful until late

INTERVENTION: Image-guided percutaneous biopsy

- How do we select the right patient?
- Stop antibiotics?
- Hold anticoagulants?
- Need sedation?
- What is the best sample?

How do we select the right patient?

- All patients should get blood cultures and ESR/CRP immediately
- Positive blood culture – no biopsy (IDSA guidelines)
- Normal CRP virtually excludes pyogenic infection, and track treatment
- Waiting two days for blood culture result eliminates 20% of (unnecessary) biopsies



Peckham M, et al. Defining Disc Biopsy timing in Relation to Blood Culture Results for Inpatients with Suspected Discitis- Osteomyelitis. JVIR, 2021.

Berbari E, et al. 2015 IDSA Guidelines for Diagnosis and Treatment of Native Vertebral Osteomyelitis in Adults.

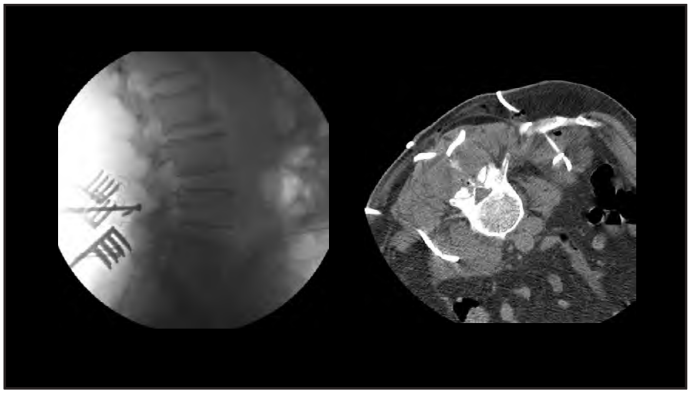
- Hold antibiotics?
- Don't hold anticoagulants
- Moderate sedation preferred but not required
- Best sample: End plate and disc

McNamara A, et al. Yield of Image-Guided Needle Biopsy for Infectious Discitis: A systematic Review and Meta-Analysis. AJNR, 2017.

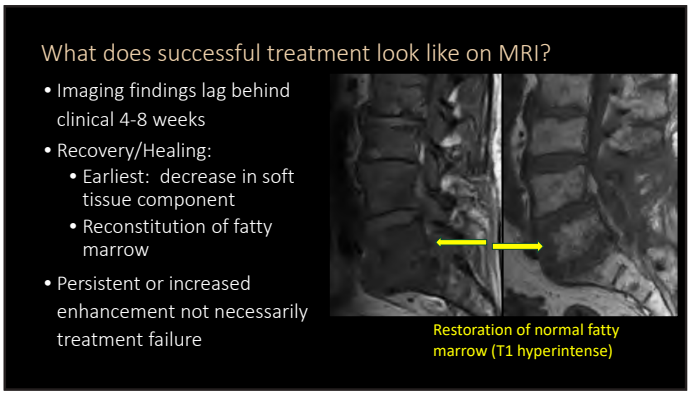
Chang C, et al. Image-Guided Biopsy in Acute Diskitis-Osteomyelitis: A Systematic Review and Meta-Analysis. AJR, 2023.

FOLLOWUP

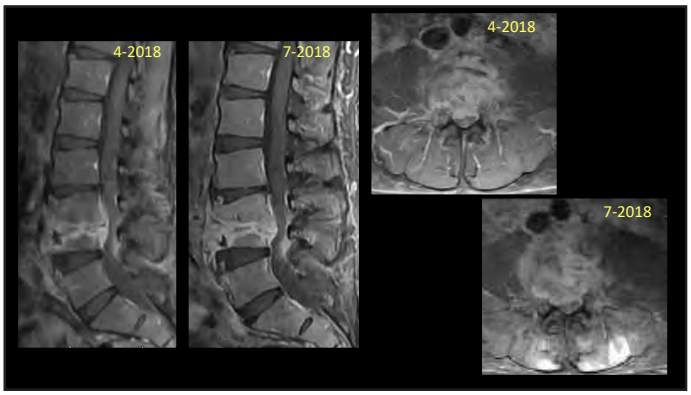

76-year-old man with increasing back pain, new urinary incontinence, leg weakness
Abnormal Neuro exam
Imaging: epidural abscess
Neurosurgical consultation

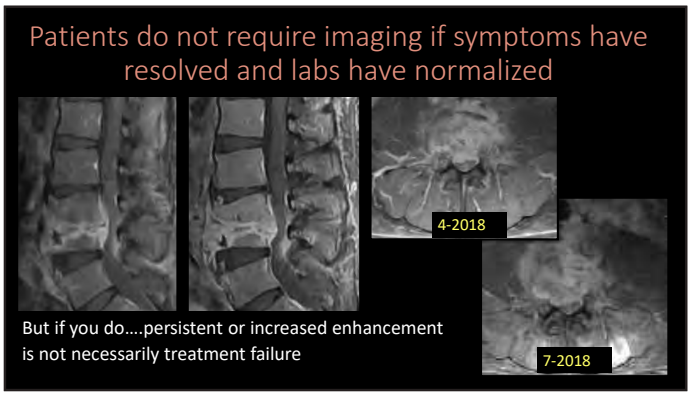


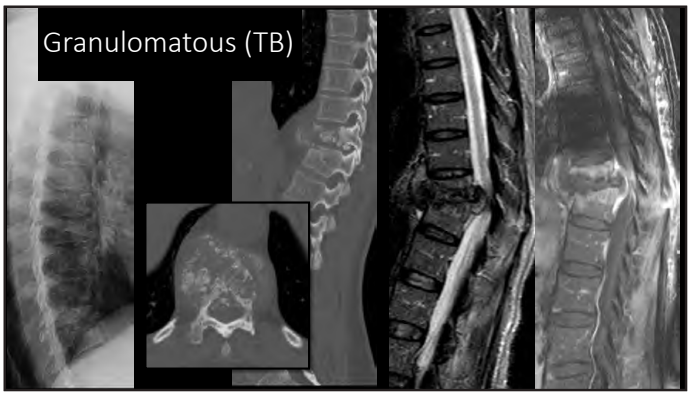

Pre-treatment

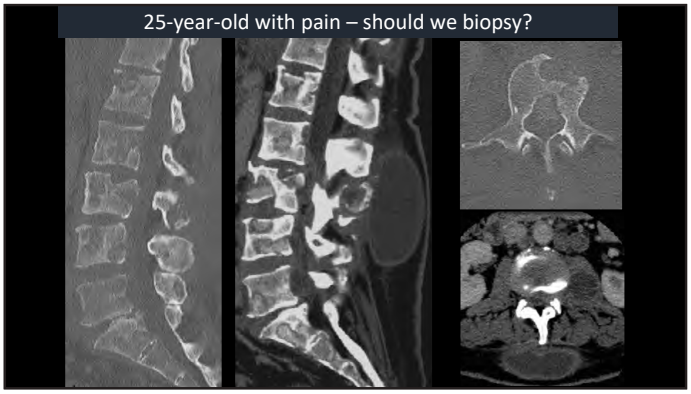

What does successful treatment look like on MRI?
• Imaging findings lag behind clinical 4-8 weeks
• Recovery/Healing:
• Earliest: decrease in soft tissue component
• Reconstitution of fatty marrow
• Persistent or increased enhancement not necessarily treatment failure
Restoration of normal fatty marrow (T1 hyperintense)


40-year-old with increasing back pain, injects heroin and testosterone


4-2018
7-2018
4-2018
7-2018

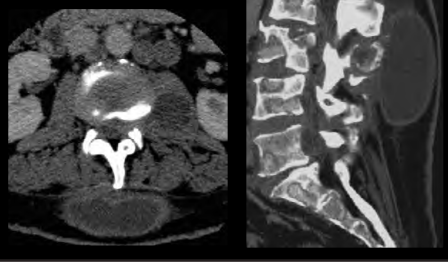

Patients do not require imaging if symptoms have resolved and labs have normalized
4-2018
But if you do….persistent or increased enhancement is not necessarily treatment failure
7-2018


Granulomatous (TB)



Tuberculous spondylitis in immunocompromised patient

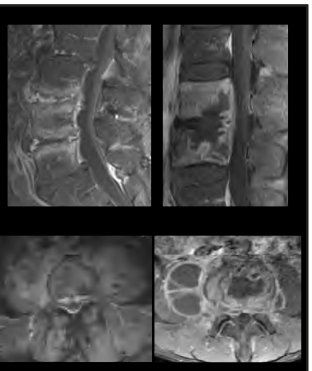
- Cold abscesses



Tuberculous Spondylitis

- Hematogenous
- Subchondral bone adjacent to endplate
- Subligamentous extension, skip lesions
- Discs spared early
- Caseating granulomas in marrow

	Pyogenic	Tuberculous
Clinical	• Acute onset, days to months • Sharp pain, spiking fevers • Older, diabetic, IV drug user, immunocompromised • Elevated ESR, CRP, WBC	• Indolent, months to 2-3 years • Dull, achy pain, low grade fever, night sweats • HIV, endemic areas, diabetic • Elevated to a lesser degree
Imaging	Primarily disc destruction	Primarily osseous destruction
Disc	T2 hyperintense, enhancing, abscess	Often spared until late disease
Vertebral body enhancement	Homogeneous, diffuse	Heterogeneous, focal
Intraosseous abscess	Rare	Common
Deformity	Kyphosis	• Greater degree of kyphosis, Gibbus deformity
Paraspinous soft tissue	Ill-defined enhancement	• Abscess with well-defined margin • Loculated abscess • Calcifications
Levels	Typically 2 VB and disc	• 2 or more levels • Skip lesions (sublig spread)
Location	Lumbar	Thoracic

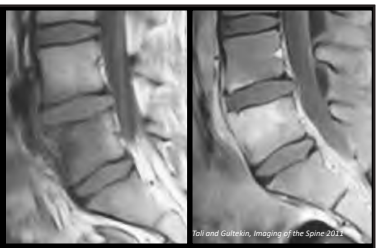


- Preserved vertebral body morphology
- Not disc centered
- No endplate erosions

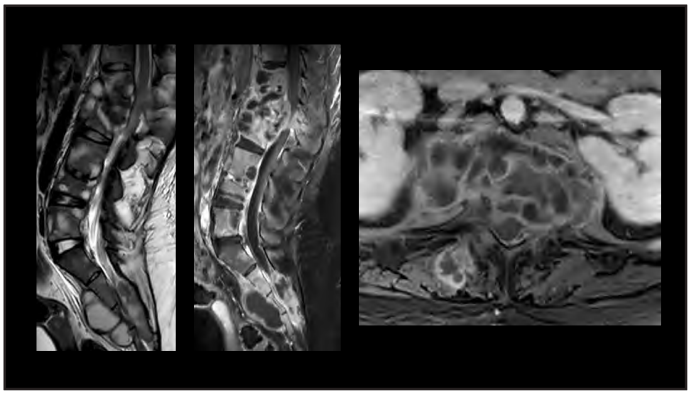
Bozgeyik, et al, Clinical Imaging 2014

Brucella spondylitis

- Zoonotic: GI, respiratory, or abrasion in dairy workers, farmers, vets
- Unpasturized milk
- 500,000 cases worldwide, in US most in CA, TX

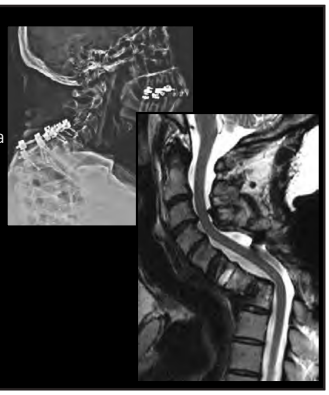


Toll and Gultekin, Imaging of the Spine 2011



Coccidioidomycosis

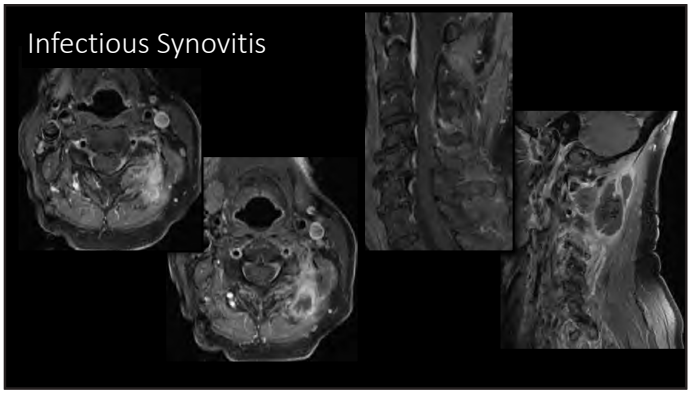
- Dimorphic fungus
- Endemic to SW US, Central &S America
- Inhalation, lung disease
- Disseminated disease
  - Meningitis, osteomyelitis, cutaneous
  - 10% of disseminated is spine
  - Hematogenous from lung
- Populations at high risk
  - African American, Filipino
  - Elderly, young, immunocompromised

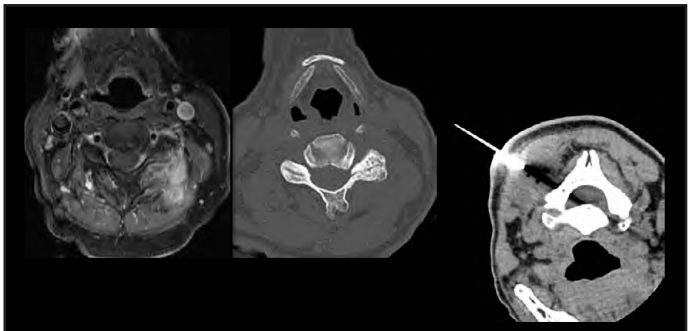


Coccidioidomycosis

- Permeative or punched out lesions
- Discs spared
- Heterogeneous enhancement
- Epidural extension

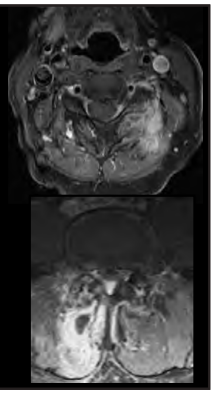
Infectious Synovitis





Facet synovitis

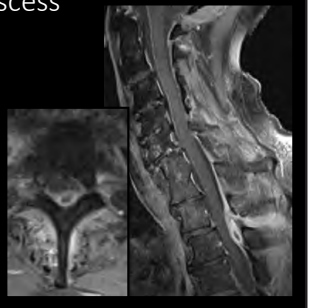
- 4-20% of spine infection
- Hematogenous spread > iatrogenic
- Presents more acutely, unilateral, >80% febrile
- Causative organism found in 75% (aspiration + blood culture 90%)
- Paraspinal and epidural abscess 25-60%

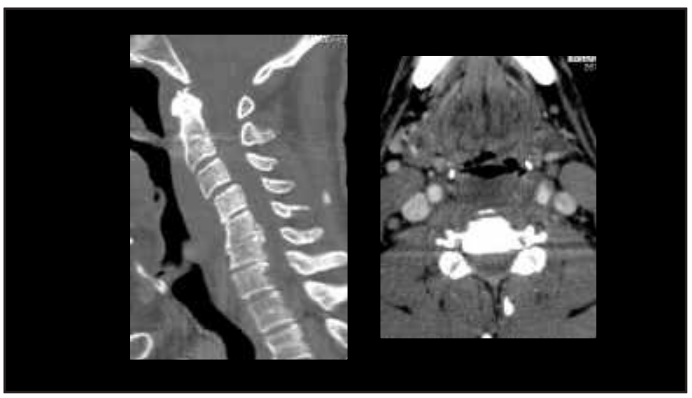


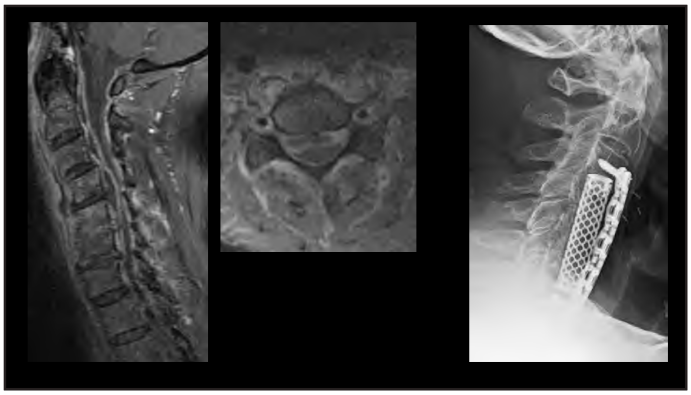
Complications

Complications: Epidural Abscess

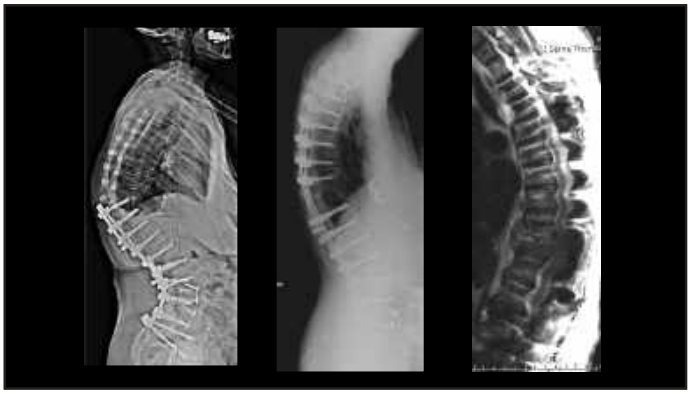
- High morbidity / mortality (18-30%)
- Para- or quadriplegia frequent
- Neurologic deficit greater than expected for degree of compression
  - Arterial occlusion, venous thrombosis, vasculitis
- Treatment
  - Phlegmon: conservative (?)
  - Abscess: surgical decompression (?)



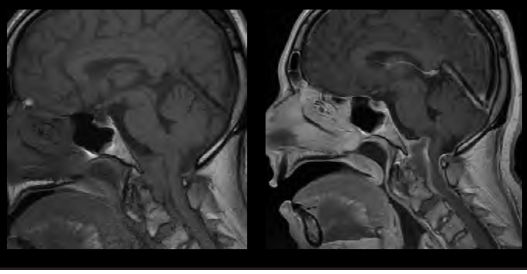




Complications: Instability and deformity



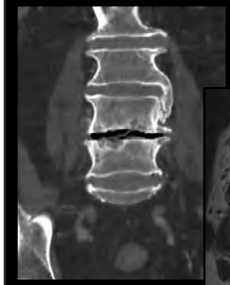
70-year-old with increasing weakness, concern for tumor or infection- should we biopsy?



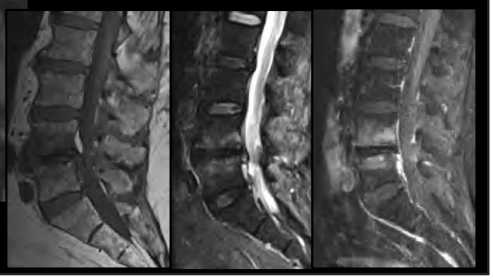
Retro-odontoid Pseudotumor

Not just pannus

- Progressive soft tissue proliferation due to micromotion at C1-2
- Rheumatoid: inflammation of synovial membrane > overgrowth cartilage> ST
- Non-RA: Crystal deposition ds, degeneration, trauma, congenital
- RA in general younger
- Non-RA: lower cervical altered biomechanics, C2-3-disc herniation, more often compressive myelopathy
- Both can have odontoid erosions

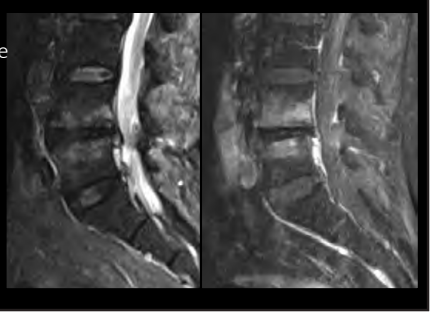


75-year-old with back pain



Mimics: Fibrovascular Type 1 Endplate changes

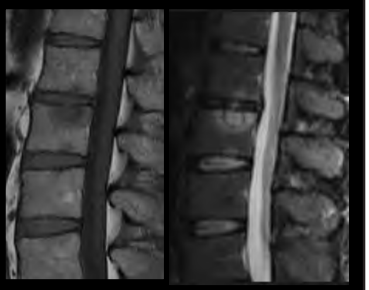
- Endplates can enhance
- Marrow edema
  - Defined
  - Transition
- Vacuum disc *
- T2 hypointense disc

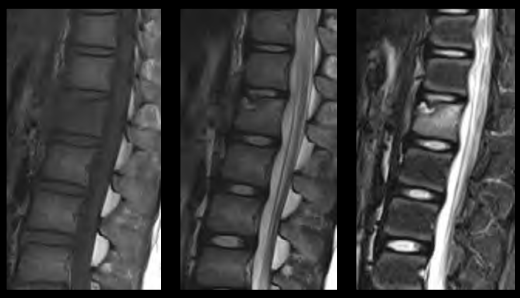


45-year-old runner with severe focal pain

Mimics : Acute Schmorl node

- Acute can be symptomatic
- Marrow edema, enhancement
- Well-defined, concentric T2 hyperintense ring
- 1 endplate, no other disc involvement

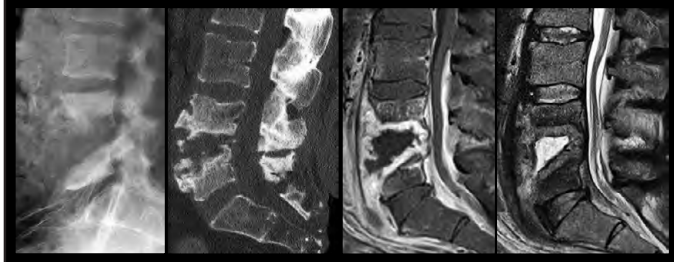




65-year-old with back pain

Case courtesy of William Morrison

65-year-old with back pain

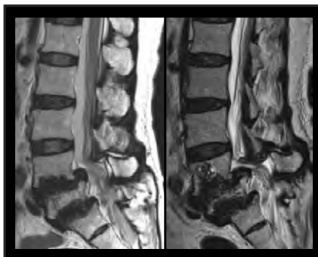


Mimics: Spinal Neuroarthropathy

- Progressive destruction in response to repeated trauma in setting of diminished (protective) sensation
- Traumatic spinal cord injury
- Diabetes mellitus, syringomyelia, syphilis
- Variable length of presentation after inciting injury
- Spondylolisthesis, joint debris, disorganization, peripheral disc enhancement, paraspinal mass

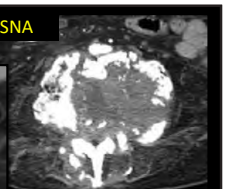
Dense (sclerosis)
Degeneration
Destruction
Deformity
Debris

Ledbetter et al. Radiographics 2016



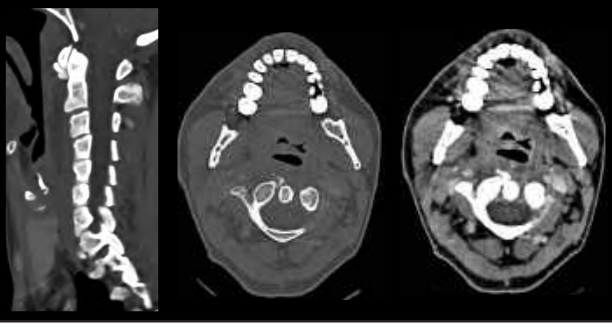
Courtesy of Giulia Cavalli

SNA



TB

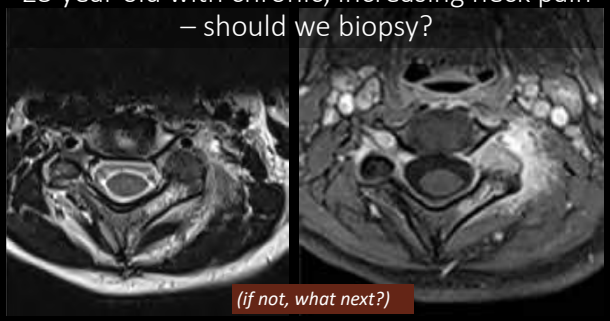
40-year-old with neck pain and dysphagia



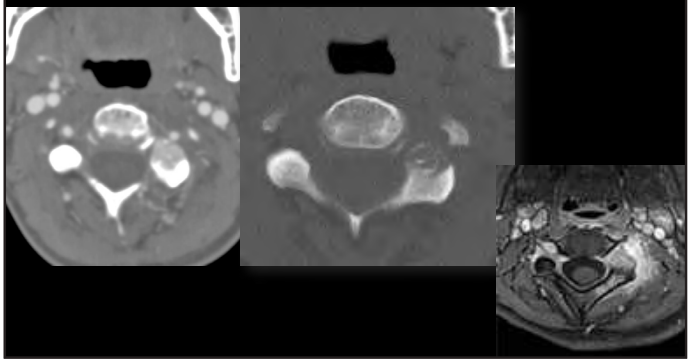
Mimics: Calcific Tendonitis Longus Coli

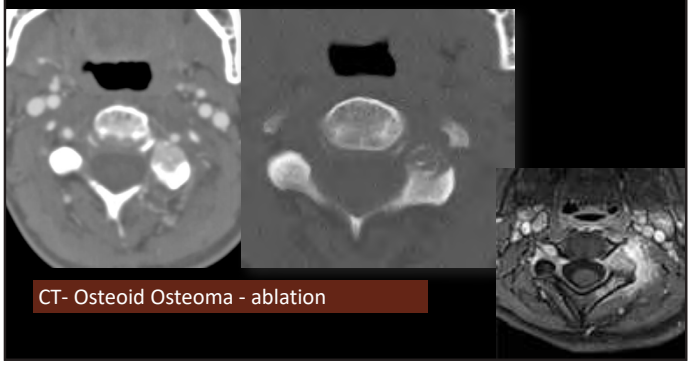
- Inflammatory/granulomatous response to calcium hydroxyapatite crystals in the longus coli tendon
- Fever, dysphagia, neck pain
- Elevated WBC and ESR
- Minimal marginal enhancement of effusion
- No bone destruction

25 year old with chronic, increasing neck pain – should we biopsy?



(if not, what next?)





CT- Osteoid Osteoma - ablation

Barrow Neurological Institute

SELF EVALUATION

Spine Infection and Mimics

True/False

1. Stable volume of marrow and soft tissue enhancement after treatment is considered a reliable sign of treatment failure.

2. Surveillance x-rays after successful treatment of discitis osteomyelitis are commonly performed.

3. Air within the disc space is a reassuring sign that endplate signal abnormality is likely due to degenerative change rather than infection.

4. Facet synovitis is rare, hard to diagnose, and less morbid than discitis osteomyelitis.

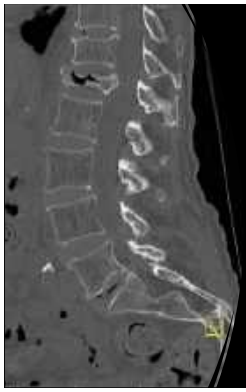
5. PET scans are substantially less sensitive and specific for spinal infection than MRI.

Answer Key: 1. F, 2. T, 3. F, 4. F, 5. F

Degenerative and Postoperative Spine
Wende N. Gibbs, MD

Degenerative & Postoperative Spine

- Degenerative
- Not Degenerative
- Early Complications
- Longer term Failure



Role of Spine Imaging

- Identification of undiagnosed pathology and systemic disease
- High prevalence of asymptomatic, age-related findings
- Significance of findings depends upon the pain/dysfunction syndrome (do we know?)
- CT and MRI may be insensitive to dynamic lesions

Degenerative (and not degenerative) spine

67-year-old with leg pain and weakness

67-year-old with leg pain and weakness

Neurogenic Claudication: leg pain, numbness, weakness after standing for prolonged period

Lumbar stenosis

- Decompression for neurogenic claudication /stenosis is the most common spine surgery in older individuals
- Vascular congestion from compression initiates inflammatory reaction, blood-nerve barrier disruption, Wallerian degeneration
- Disruption in CSF flow (nutrient supply to cauda equina)

Treatment

- SPORT Trial: level II evidence showing that laminectomy and fusion provides better results than non-operative approaches
- Surgical principles
  - Too little surgery – failed back; too much- possible instability
  - Minimally invasive techniques
  - Posterior tension band – keep as intact as possible

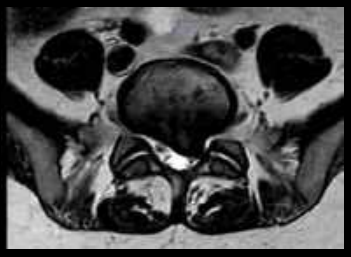
Ghogawala Z, Resnick DK, Glassman SD, Dziura J, Shaffrey CI, Mummaneni PV. Randomized controlled trials for degenerative lumbar spondylolisthesis: which patients benefit from lumbar fusion? J Neurosurg Spine. 2017

Lumbar stenosis

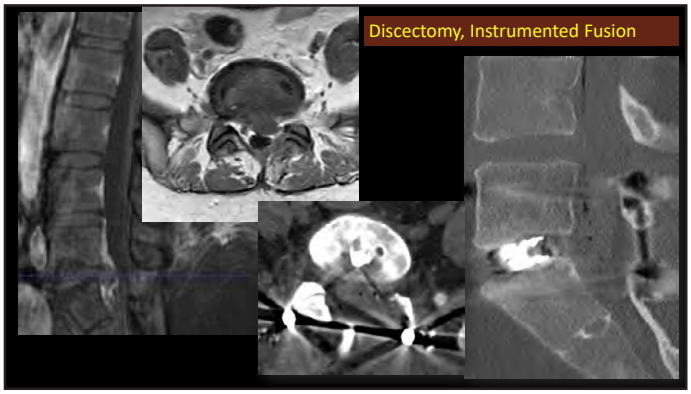
- Poor correlation between quantitative measure of canal or dural sac size and symptoms
- Dynamic lesions may be seen only in axial load & extension - recumbent imaging less sensitive

Kushchayev, Insights in Imaging 2018
Park HJ et al. Clinical correlation of a new practical MRI method for assessing central lumbar spinal stenosis. Br J Radiol 2013

42-year-old with left leg radiculopathy



Failed back syndrome: same symptoms persisting or recurring after surgery

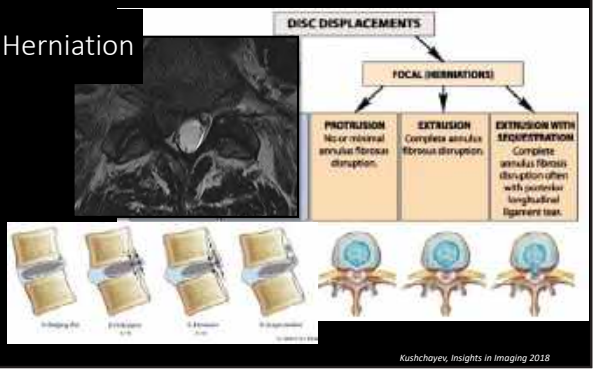


Surgery for Back Pain/Radiculopathy Why and How?

- SPORT Trial: level II evidence showing that laminectomy and fusion is superior to non-operative management for pain, neuro symptoms
- Surgical principles
  - Too little surgery – failed back;
  - Too much - possible instability
  - Posterior tension band – keep as intact as possible

Ghogawala Z, Resnick DK, Glassman SD, et al. J Neurosurg Spine. 2017

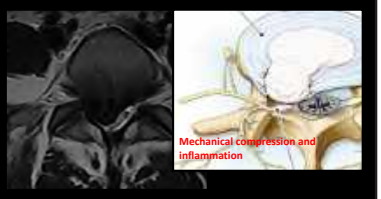
Disc Herniation



Kushchayev, Insights in Imaging 2018

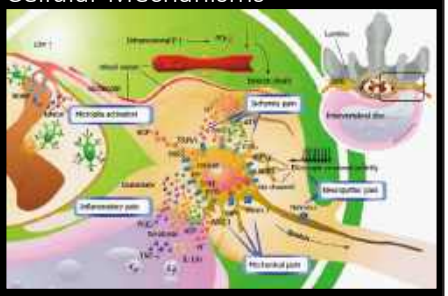
Disc Herniation

- Degradation of disc matrix
- Can no longer bear axial load
- Posterior annulus structural failure
- Herniation
- Mechanical compression and induced inflammatory response produce pain



Radicular Pain: Cellular Mechanisms

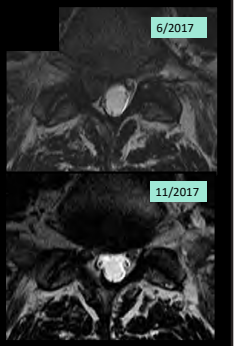
- Nociceptive and inflammatory pain
  - Compression
    - Hypoperfusion
    - Hypoxia
    - Increased pressure
    - Demyelination
  - Chemical radiculitis
- Neuropathic pain
- Central Sensitization



Lin et al. World J Anesthesia, 2014

Disc Herniation: Canal Stenosis (Myelopathy and Radicular Pain)

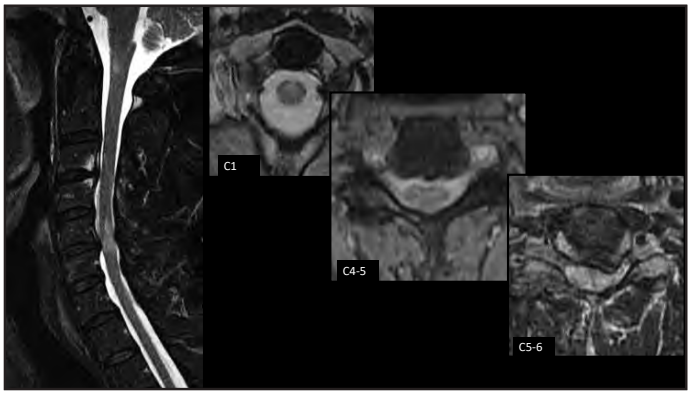
- Many patients do not need surgery
- Discs decrease or resolve
  - 33% at 6 weeks, 65% at 6 months *(Emch, Modic 2011)*
- Initial management: rest, oral pain meds, oral steroids, physical therapy
- Failed conservative management, 4 wks.: Epidural steroid injections
- Goals:
  - Reduce pain and restore function to enable PT
  - Get back to work

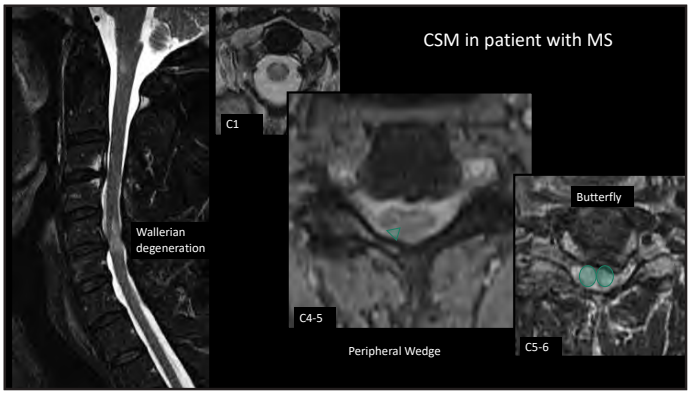


When it comes to herniation, not all levels are the same…

65-year-old healthy woman with increasingly frequent falls

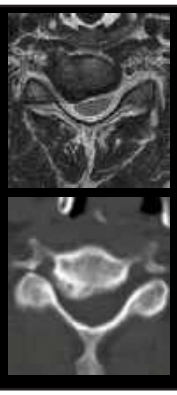
Referred to Neurosurgeon for Tumor or Infectious/Inflammatory





Cervical Stenosis

- Cervical discs have less well defined nuclear/annular structure, no discrete annulus posteriorly
- Function less to distribute axial load
- T2 signal loss not good predictor of pain
- Radicular pain due to disc herniation is less common (due to foraminal stenosis from uncovertebral and facet hypertrophy (osseous))
- Most commonly C6 and C7



Degenerative Cervical Myelopathy

Cervical Spondylotic myelopathy

Degenerative Disc Disease

Ossification of the Posterior Longitudinal Ligament

Decreased hand dexterity

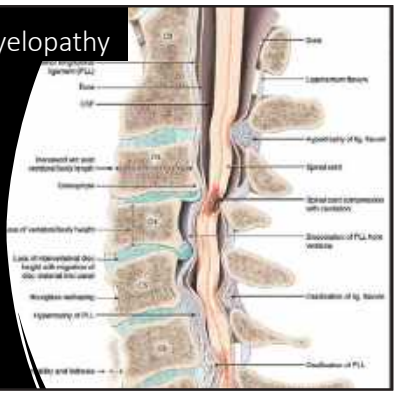
Gait imbalance

Sensorimotor disturbance

Nouri A, Tetreault L, Singh A, et al. Degenerative Cervical Myelopathy: Epidemiology, Genetics, and Pathogenesis. Spine 2015;40:E675.

Cervical Spondylotic Myelopathy

- Most common spinal cord disorder in > 55 years old
- Symptoms begin when canal compromise approximately >50%
- Three components
  - static mechanical
  - dynamic mechanical
  - spinal cord ischemia



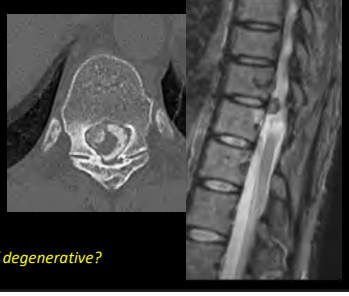
40 y.o with increasing lower extremity weakness and back pain

Surgery?

Calcified Thoracic Disc

- Thoracic stabilization makes these more rare (association with trauma)
- Symptomatic
- Calcification adheres to and erodes dura- intradural disc
- CSF leak
- 30 % surgical complications

Okay, kind of degenerative?



Calcified thoracic disc: surgical approach

Successful!

Post Op

Part of calcified disc left attached to dura

Degenerative?

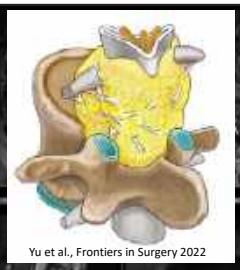
48-year-old with back and leg pain

Is this degenerative stenosis?
What is the treatment?

Epidural Lipomatosis

- Overgrowth of fat in canal
- Causes
  - High BMI
  - Exogenous steroids (T spine)
- Treatment
  - Conservative (stop meds, weight loss)
  - Surgical (acute, severe, failure of conservative)

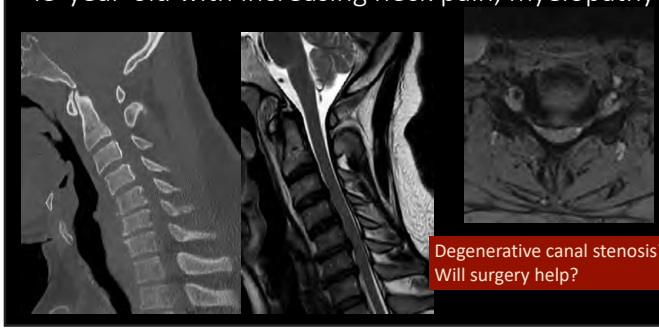
Underreported and Underestimated…



Yu et al., Frontiers in Surgery 2022

Decompression can help (but last resort…)

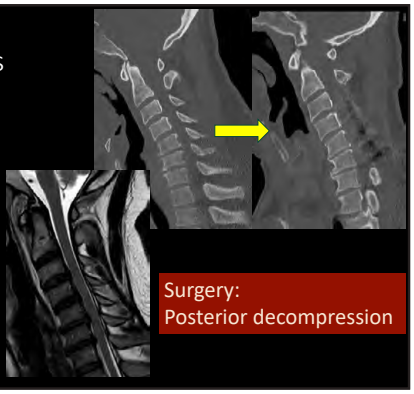
45-year-old with increasing neck pain, myelopathy



Degenerative canal stenosis?
Will surgery help?

Congenital Stenosis

- Shorter pedicle length
- Several levels (rather than focal)
- Primary importance is earlier symptoms with degenerative changes (present younger)
- Increased risk of cord injury even with minor trauma

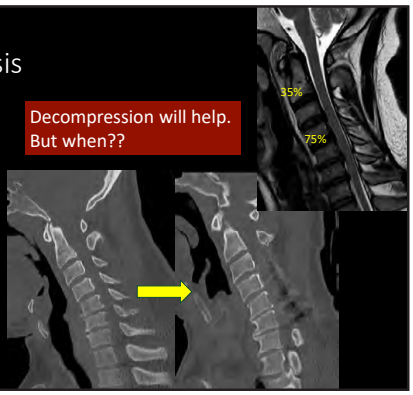


Surgery:
Posterior decompression

Congenital Stenosis

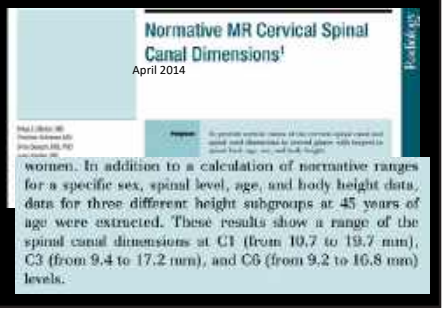
- Shorter pedicle length
- Several levels (rather than focal)
- Primary importance is earlier symptoms with degenerative changes (present younger)
- Increased risk of cord injury even with minor trauma

Decompression will help.
But when??



Canal Stenosis - Cervical

Measurement?

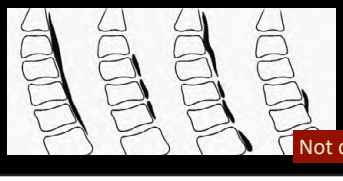


56-year-old with neck pain

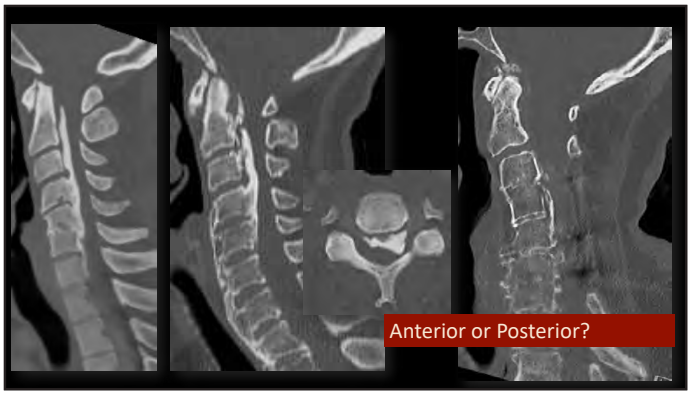
Degenerative? Will surgery help?

Ossification of the Posterior Longitudinal Ligament

- Gradual onset myelopathy, radiculopathy
- Increased risk of cord injury even in minor trauma: compression AND ankylosis



Not degenerative. Surgery will help



52 y.o man with chronic but increasing neck pain, stiffness

Diffuse Idiopathic Skeletal Hyperostosis (DISH)

- Abnormal bone formation at ligamentous, tendinous insertions of spine – etiology unknown
- Non (or minimally?) inflammatory
- Back/neck pain , stiffness, limited motion, dysphagia
- Usually older men with comorbidities (e.g. diabetes, obesity, metabolic syndrome)

Not degenerative

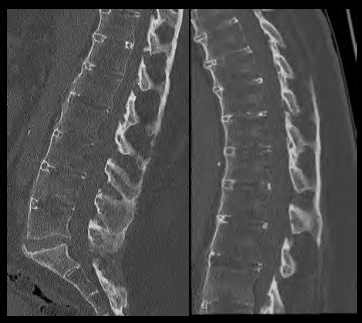
- Bulky, (sometimes) "flowing" anterior osteophytes
- Horizontally oriented – non marginal
- Disk spaces preserved

Early- ossification at site of anterior longitudinal ligament at mid vertebral body (non-marginal)

Ankylosing Spondylitis syndesmophytes (ossification of sharpy fibers of annulus)

Why does it matter?

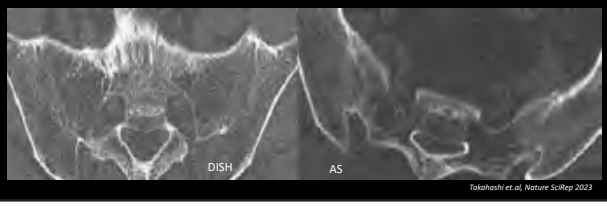
- Increased risk of fracture 4x (ankylosed spine AND weakened bone)
- Some symptoms do need surgery – dysphagia
- Non op treatment similar: PT, NSAIDS but also bisphosphonates
- *It continues to grow….*



DISH v Ankylosing Spondylitis v Degeneration

DISH versus Ankylosing Spondylitis

- Sacroiliac joints?? Both can fuse
- AS: edema and erosions



Takahashi et.al, Nature SciRep 2023

Why does it matter?

- Important to identify all ankylosed spines- altered biomechanics greatly increases severity in even minor trauma
- The reason for ankylosis is important for treatment, prognosis
- DISH and AS and Degenerative disc disease can coexist
- DISH and AS can have fused SI joints (look for edema/inflammatory changes)

Back to degeneration…

Canal Stenosis/Claudication and Radiculopathy

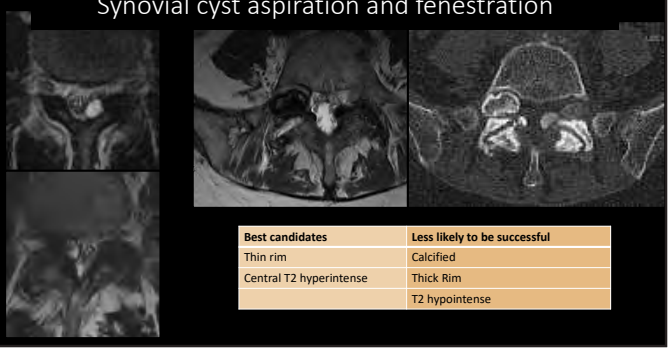
Canal Stenosis/Claudication and Radiculopathy

Synovial Cyst: herniation of the synovium through the facet capsule.

CT-guided synovial cyst aspiration and fenestration

- High technical success rate: 98%, 64 pts (*Shah et al. AJNR 2018*)
- First post-procedure follow up: 88% complete or partial response
- Mean follow up 49 months:
  - 56% complete/partial response, no surgery
  - 44% surgery

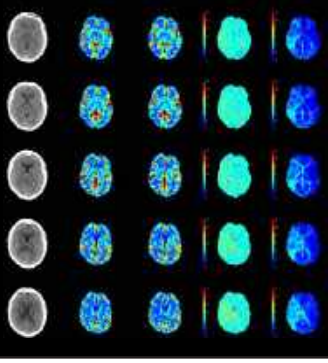
Synovial cyst aspiration and fenestration

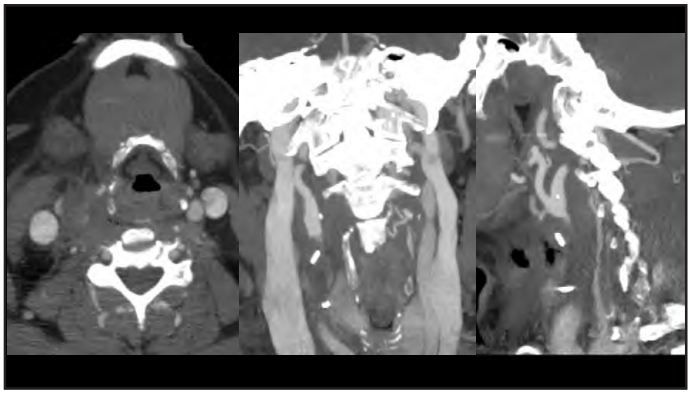


Best candidates	Less likely to be successful
Thin rim	Calcified
Central T2 hyperintense	Thick Rim
	T2 hypointense

These patients get surgery: what can go wrong?

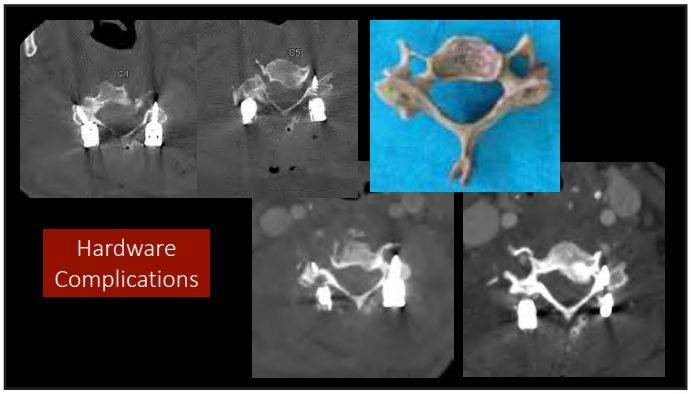
45-year-old with stroke symptoms; anterior cervical discectomy and fusion yesterday



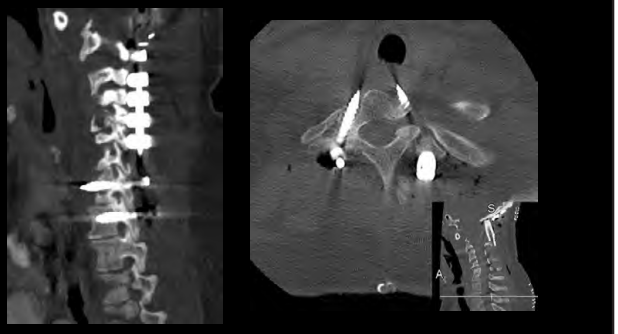


Stroke in ACDF patients with carotid stenosis

Retraction/compression
Dislodge atherosclerotic plaque

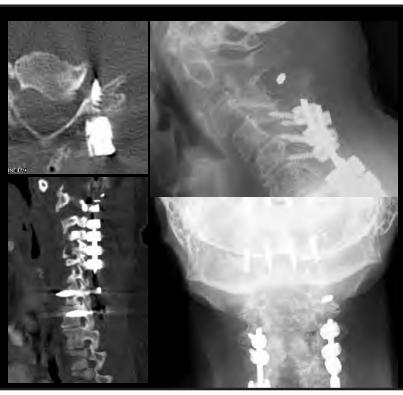


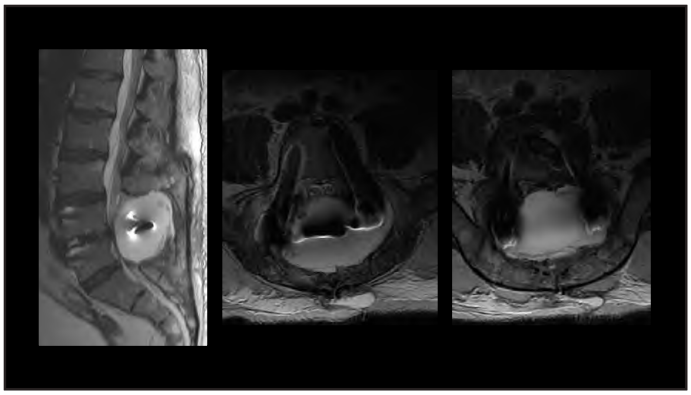
Hardware Complications



Hardware Complications

- Vascular injury
- Nerve irritation
- Prevertebral extension
- Floating parts



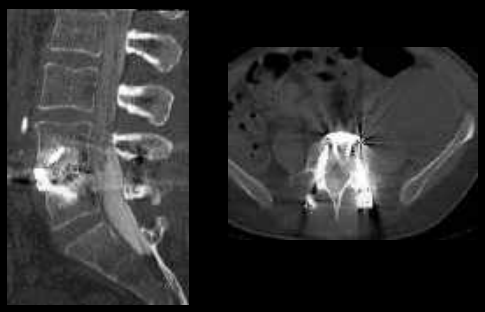


Dural tear/ Pseudomeningocele

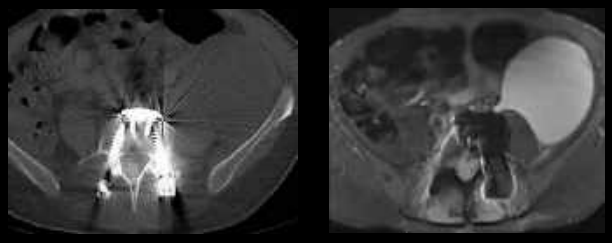
- Dural tear 12-16% (most detected during surgery)
- Risks: long or complicated surgery, OPLL, calcified disc, thoracic disc, dural ectasia, prior radiation
- SX
  - CSF hypotension-like headache
  - Back pain
  - Radiculopathy
- Signs
  - Fluctuant bulge

Young woman two weeks post op with orthostatic headache

Case of Alex Mameghani

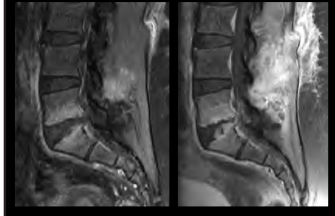


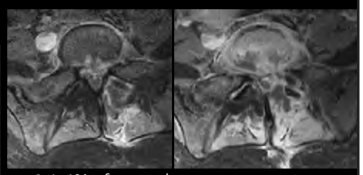
Case of Alex Mameghani



Case of Alex Mameghani

Post op spondylodiscitis

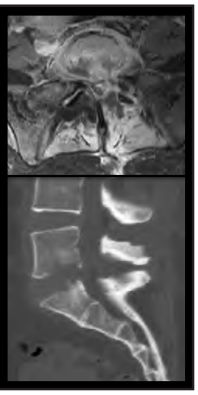




- 0.1-4% of procedures
- S. epidermiditis, S. aureus
- Septicemia, implant migration subsidence, pseudoarthrosis, instability

Post Operative Spondylodiscitis

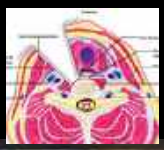
- More common with instrumentation
- Postop days 4-28
- Rising CRP past 96 hours is characteristic
- Normal postoperative findings
  - T2 hyperintense disc
  - Linear disc enhancement
  - Nerve root enhancement
- Abnormal findings
  - Enhancing paravertebral or epidural soft tissue
  - Loss of subchondral endplate definition, erosions



Longer Term Failure: Weeks to Months

65-year-old with deformity and pain – dorsal decompression 8 years ago

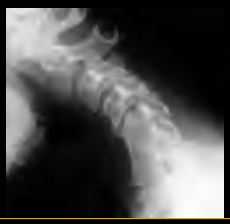
Cervical surgical approaches



Iatrogenic (postoperative) cervical kyphosis

- Anterior approach
  - Pseudoarthrosis
- Posterior Approach
  - Loss of tension band
- Natural History
  - Muscle denervation
  - Progression
  - Lumbar lordosis (back pain)




- 64% of load bearing posterior column
- Disruption moves most to anterior

Why does it matter?

- Cord draped over kyphosis
- Stretched (longitudinal tension)
- Compression of vessels and ischemia
- Neural injury with minor trauma
- Malacia and atrophy

- Axis shifts anteriorly
- Muscles bear load

Neck pain and dysphagia six weeks after surgery

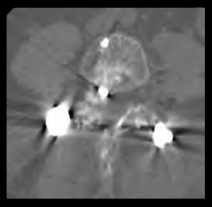
Graft migration

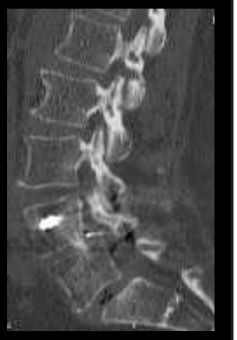
Cervical corpectomy complications

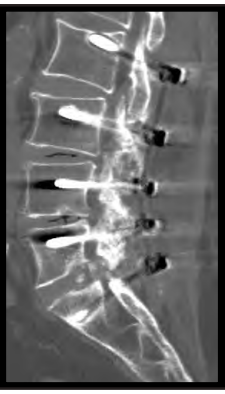

- Dural tear
- Nerve root palsy
- Infection
- Migration

Back pain and radiculopathy one year after surgery

Graft migration

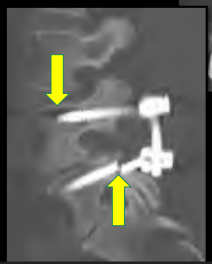




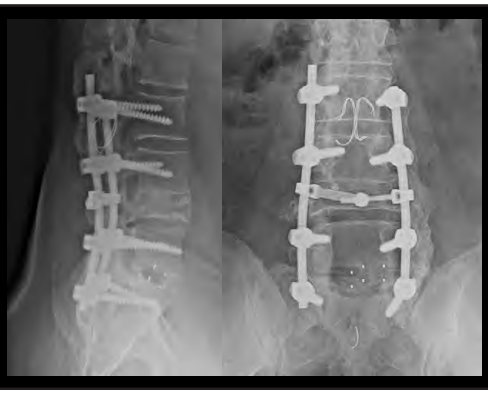


Screw Loosening

- Relatively common (5%)
- Rim at least 2mm
- Retraction of hardware
- Infection



Gradually increasing low back pain



6 months later

Broken rods

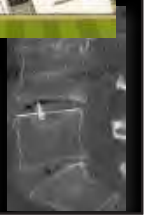
"Failed Back Syndrome"

- Symptoms not alleviated by surgery or recurring after the surgery
  - IF properly diagnosed and treated
- 10-40%
- Foraminal Stenosis 25-30%
- Disc 20%
- Pseudoarthrosis 14%

Surgery 2 years ago with increasing neck pain

Subsidence

- Settling into the body (>3mm)
- 10-20% of cases
- Loss of disc height, recurrent radicular symptoms



Kushchayev, Insights in Imaging 2018

Increasing back pain 1.5 years after surgery

Pseudoarthrosis

- Failure to obtain solid osseous fusion by one year (due to persistent motion)
- Pseudoarthrosis itself can result in pain
- increased stress on hardware which will fail – break or pull out or break the bone

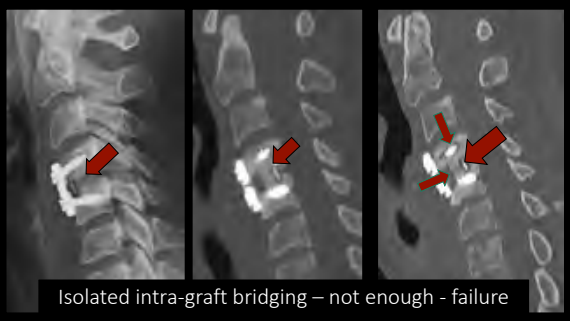
Pseudoarthrosis: what are the signs?

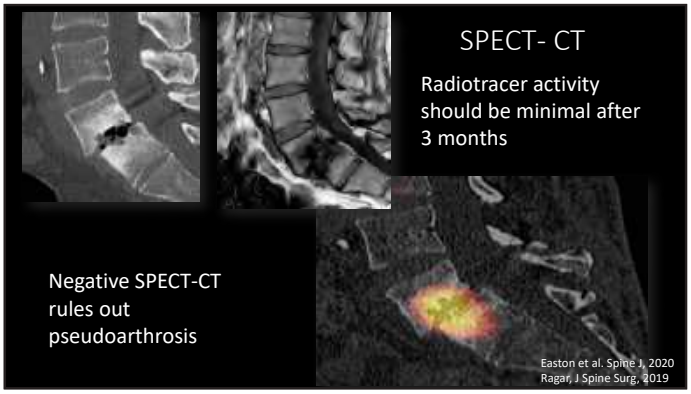
- Flexion extension: motion or more than 3 degrees of intersegmental position change
- Lucency around implant
- Loss of disc space height
- Fracture of implant, vertebral body
- Sclerotic change in the graft or adjacent vertebral endplates
- Endplate edema on MR longer than 6 months

Pseudoarthrosis: what are the signs?

- Horizontal lucency through graft with or without endplate sclerosis
- New vacuum disc
- *And watch out when there is only intragraft bridging*

Benson et al., Neuroradiology 2022





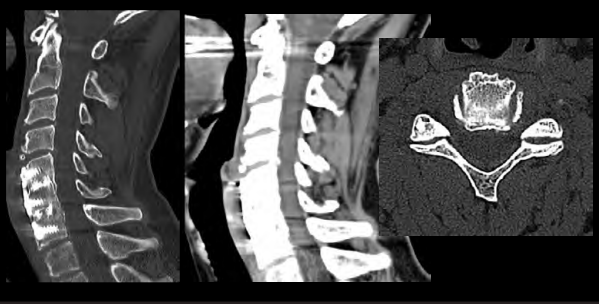
Pseudoarthrosis

- Common 5-35% (Reop rate less than 2%)
- Normal fusion: Bridging trabecular bone inside and out of graft 6-9 months
- Posterolateral fusions can take longer than interbody (9-12 months)
- Risk factors smoking, long segment instrumentation (one level rare, 4 levels 50%)
- Typically presents 3 years, but can be 10, *even if prior solid fusion*

Bottom line:

- If a patient has persistent symptoms, and it is a year out, consider failure of fusion
- BUT: treatment depends on symptoms
- AND: sometimes fusion can take longer… but it does happen

50-yo with 3 months of increasing neck and left shoulder pain



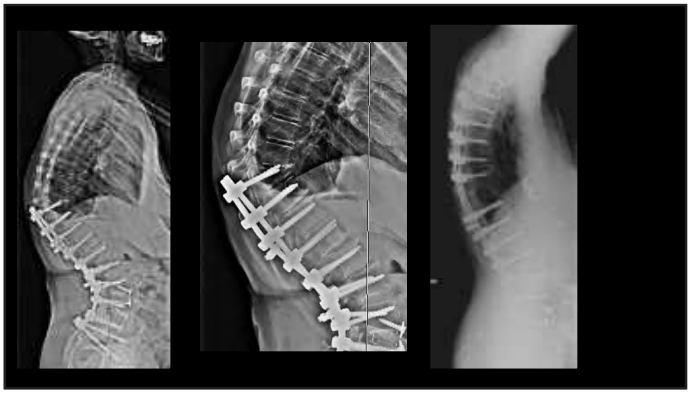
Adjacent Segment Degeneration

- "Accelerated"?
- Altered biomechanics
- Asymptomatic (AS Degeneration) is more common radiographic finding than symptomatic (AS Disease)
- Mostly lumbar spine and superior to fusion
- Any time we have abnormal fusion/biomechanics
- Can't call this without priors!

Retro-odontoid Pseudotumor

- Atlantoaxial instability (abnormal motion) > stress > tear and repair of ligaments > fibrocartilaginous metaplasia and fibrovascular ingrowth
- Lower cervical immobility, C2-3 disc herniation, more often compressive myelopathy -> *a form of "accelerated degeneration"*
- Process is arrested, often regresses after fusion

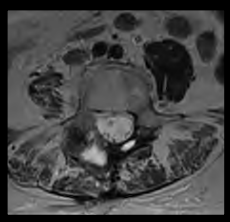
45 yo with popping sensation and then pain



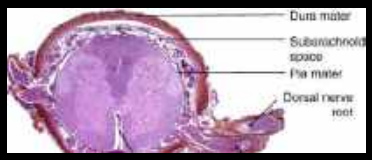
Proximal Junctional Kyphosis/Failure

- PJK:
  - radiologic finding
  - 10-20 degrees
  - Follow up
- PJF:
  - structural failure- bone or ligament
  - Surgical
  - Extension of hardware

Back pain and increasing radiculopathy 10 years after surgery



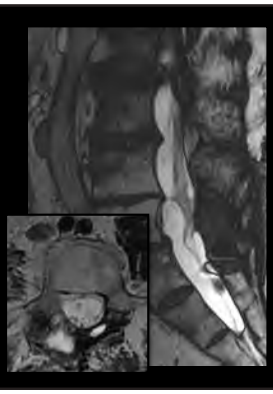
Arachnoiditis

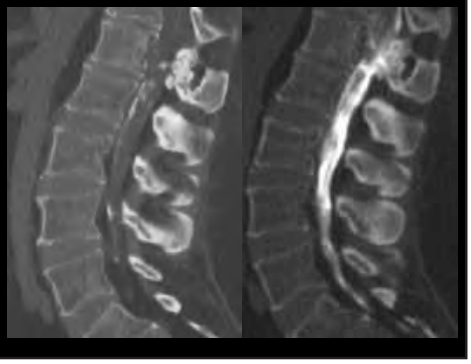


- Persistent inflammation of the arachnoid- granulomatous reaction, fibrosis, adhesions
- Nerve root atrophy
- CSF flow disruption (syrinx)

Arachnoiditis

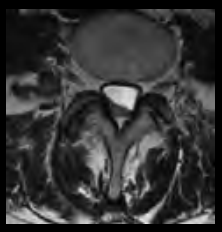
- Chronic, insidious, debilitating
- Diagnosis based on symptoms and imaging
- Clumped or peripheral adhered to dura
- Arachnoiditis ossificans
- TX: Pain control, meds, stimulator
- Surgery: detether





Arachnoiditis: A few additional clues

- Abnormal nerve contour (85%)
- Thickened or nodular roots (89%)
- Enhancing roots (61%)
- Characteristic pain on lumbar puncture or myelogram (but you have to keep going…)



Parenti et al. Clin Neuro 2020

Degenerative & Postoperative Spine

- Degenerative
- Not Degenerative
- Early Complications
- Longer term Failure

WendeNGibbs@gmail.com

@WendeNGibbs

SELF EVALUATION

Degenerative and Postoperative Spine

True/False

1. Degenerative cervical cord compression is a frequent cause of falls in individuals over 55 years old.

2. OPLL is the most common degenerative cause of canal stenosis.

3. Calcified discs are most commonly found in the cervical spine.

4. Epidural fat may cause thoracolumbar canal narrowing, but it is a painless, benign process.

5. DISH and Ankylosing spondylitis may both cause sacroiliac joint fusion.

Answer Key: 1. T, 2. F, 3. F, 4. F, 5. T

MICHIGAN MEDICINE
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MRI of the Shoulder

OBJECTIVES

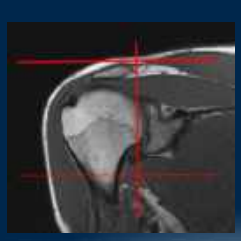
- Learn the Protocol for MRI Shoulder
- Review Selected Shoulder Anatomy
- Review Shoulder MRI Cases

SHOULDER MRI PROTOCOL

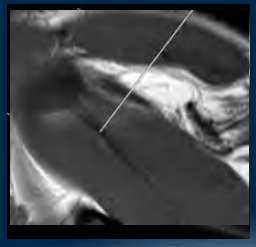

SHOULDER MRI PROTOCOL

- AX PD FAT SAT
- COR *Oblique* T2 FAT SAT
- COR *Oblique* T1 or PD NON FAT SAT (*optional*)
- SAG *Oblique* T1 NON FAT SAT
- SAG *Oblique* PD FAT SAT

AXIAL SEQUENCE (PD FS)

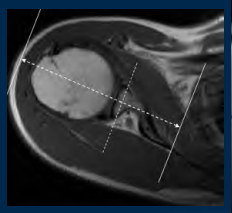



COR OBL SEQUENCE (T2 FS)
COR T1 OR PD (OPTIONAL)




Parallel to the supraspinatus muscle/tendon or scapular body

SAG OBL SEQUENCE (PD FS & T1)

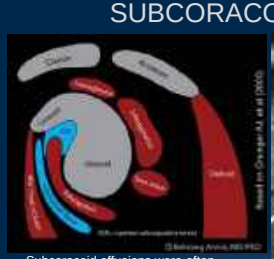


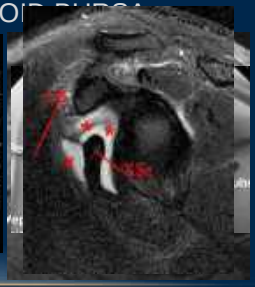

Perpendicular to supraspinatus or scapular body (parallel to glenoid)

Subacromial-su

Images courtesy of Dr. Michael Stadnick & Radsource.
https://radsource.us/subcoracoid-bursa/

SUBSCAPULARIS RECESS VS SUBCORACOI

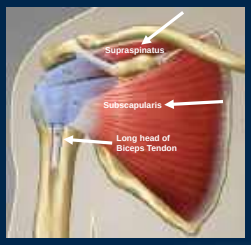


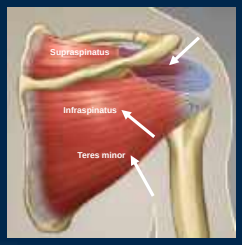


- Subcoracoid effusions were often associated with anterior rotator cuff tears, including tears of the rotator interval

Grainger AJ, et al. AJR Am J Roentgenol. 2000; 174(5):1377-1380

S.I.t.S.



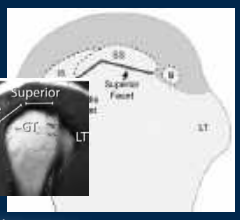


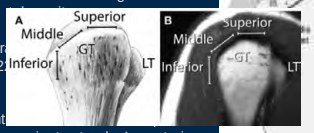
Anterior Posterior

Images courtesy of Carolyn Nowak, Ann Arbor, MI.
Jacobson JA. Radiology 2011; 260(1)6-16

NORMAL SHOULDER ANATOMY

- Supraspinatus tendon measures ~ 23 mm in AP width
  - inserts on both superior & middle facets of greater



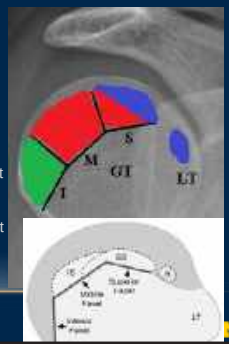


- Infr
  ~ 2
  -
- Ant
  supraspinatus tendon's posterior fibers at a junctional zone (~10 mm)

Image courtesy of Carolyn Nowak, Ann Arbor, MI.
Jacobson JA. Radiology 2011; 260(1)6-16
Kalia V, et al. Am J Roentgenol. 2018; 211(3)538-547
Huang BK, et al. Magn Reson Imaging Clin N Am. 2012; 20(2):163-172, ix

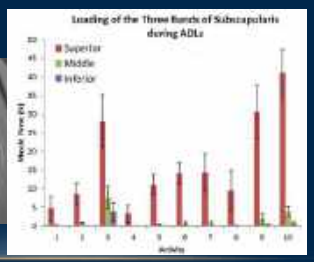
VARIABLE SHOULDER ANATOMY

- Supraspinatus tendon (blue) is triangular in shape
  ~ 12.6 mm in AP width
  - inserts on highest point of superior facet of greater tuberosity & superior aspect of lesser tuberosity
- Infraspinatus tendon (red) is slight trapezoidal in shape
  ~ 32.7 mm in AP width
  - inserts on anterolateral aspect of superior facet & all of middle facet of greater tuberosity



Mochizuki T, et al. J Bone Joint Surg Am. 2008; 90(5):962-969

SUBSCAPULARIS TENDON



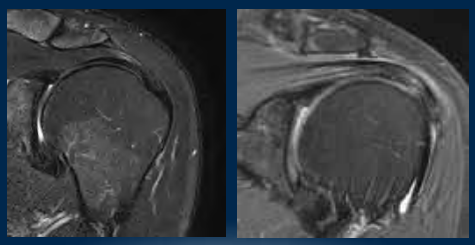
Gausden EB, et al. J Shoulder Elbow Surg. 2017; 26(2):331-336

Image courtesy of Dr. Michael Stadnick & Radsource.
https://radsource.us/off-track-shoulder-lesions/

RTC PATHOLOGY BASICS

- TENDINOSIS
  - Thickened & focally or diffusely heterogeneous hyperintense PD/T2 (non-fluid) signal
- PARTIAL-THICKNESS TEAR
  - Intrasubstance, articular-sided, & bursal-sided
- FULL-THICKNESS TEAR
  - Bursal to articular surface regardless of size or shape
  - Non-displaced or retracted
  - Complete or incomplete (full- or partial-width)

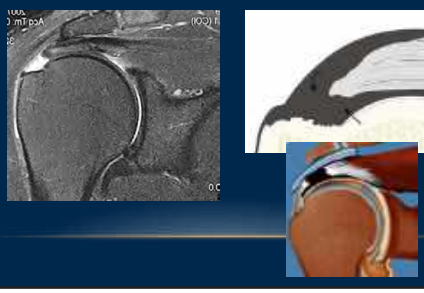
RTC TENDINOSIS



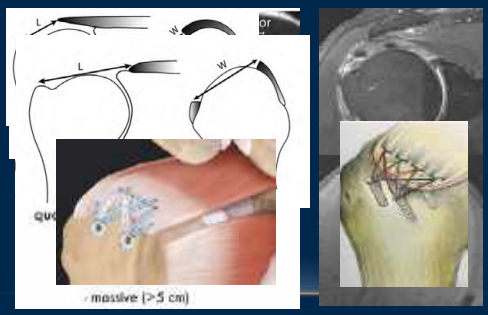
Llopis, E., et al. (2021). Rotator Cuff. In: Hodler, J., Kubik-Huch, R.A., von Schulthess, G.K. (eds) Musculoskeletal Diseases 2021-2024. IDKD Springer Series. Springer, Cham

FULL-THICKNESS TEAR

FULL-THICKNESS RETRACTED SUPRASPINATUS TEAR



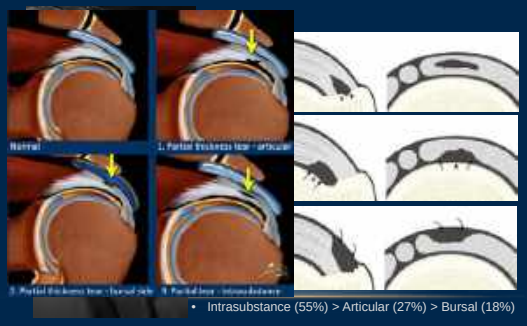
ROTATOR CUFF TEAR SIZES



Llopis, E., et al. (2021). Rotator Cuff. In: Hodler, J., Kubik-Huch, R.A., von Schulthess, G.K. (eds) Musculoskeletal Diseases 2021-2024. IDKD Springer Series. Springer, Cham
Davidson J, et al. Arthroscopy 2010; 26(3):417-424

MASSIVE RETRACTED FTT W/ RTC ARTHROPATHY

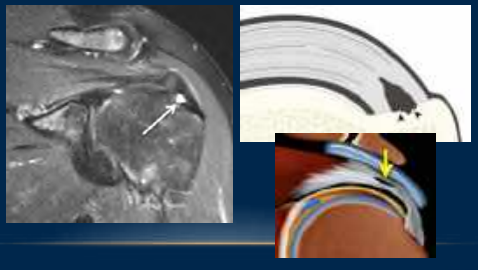
PARTIAL-THICKNESS TEARS



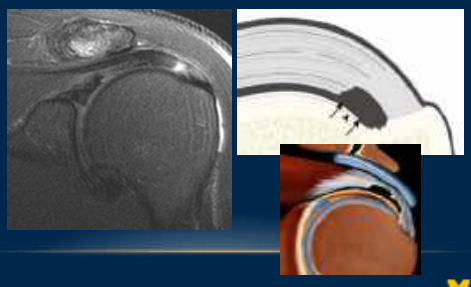
- Intrasubstance (55%) > Articular (27%) > Bursal (18%)

Jacobson JA. Fundamentals of musculoskeletal ultrasound. 3rd ed. Philadelphia: Elsevier; 2018
Matthewson G, et al. Adv Orthop. 2015; 2015:458786

INTRASUBSTANCE PTT SUPRA



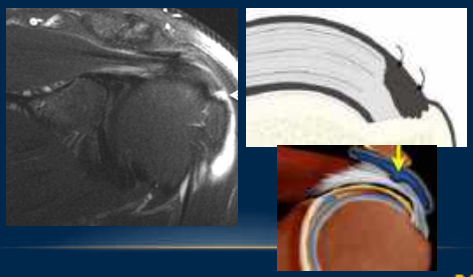
ARTICULAR-SIDED PTT SUPRA



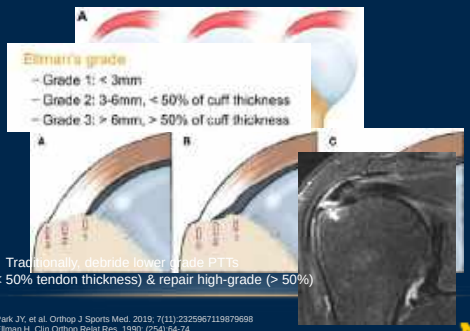
LONG-AXIS SUPRA COMPRESS

SHORT-AXIS SUPRA COMPRESS

BURSAL-SIDED PTT SUPRA



GRADING PARTIAL-THICKNESS TEARS

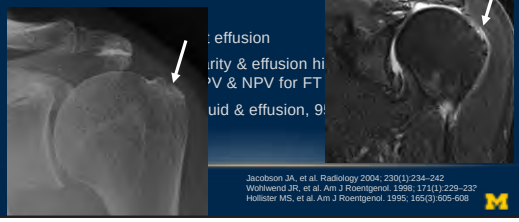


- Traditionally, debride lower grade PTTs (< 50% tendon thickness) & repair high-grade (> 50%)

Park JY, et al. Orthop J Sports Med. 2019; 7(11):2325967119879698
Ellman H. Clin Orthop Relat Res. 1990; (254):64-74
Strauss et al. Arthroscopy 2011; 27:568-580

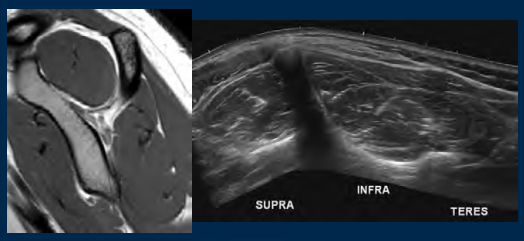
INDIRECT SIGNS OF RTC TEARS

- Indirect signs of rotator cuff tears:
  - Cortical irregularity of subjacent greater tuberosity footprint
    - If present, 75% have RTC tears/
  - effusion
  - rity & effusion hi
  - V & NPV for FT
  - uid & effusion, 9



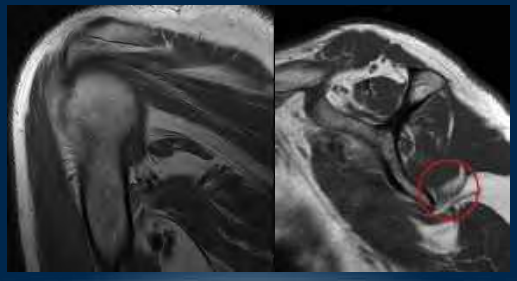
Jacobson JA, et al. Radiology 2004; 230(1):234-242
Wohlwend JR, et al. Am J Roentgenol. 1998; 171(1):229-232
Hollister MS, et al. Am J Roentgenol. 1995; 165(3):605-608

ROTATOR CUFF MUSCLES



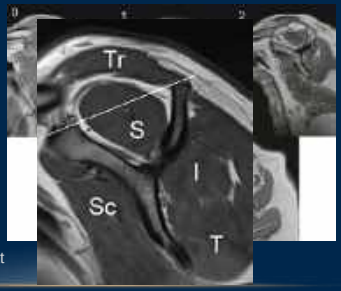
- Compare others to teres minor
- Infraspinatus muscle degeneration associated w/ higher retear rates & poor clinical outcomes following arthroscopic RTC repair

Park JS, et al. Am J Sports Med. 2015; 43(10):2386-2392
Chalmers PN, et al. Arthroscopy 2018; 34(5):1393-1400
Lawrence RL. Skeletal Radiol. 2023; 52(4):695-703



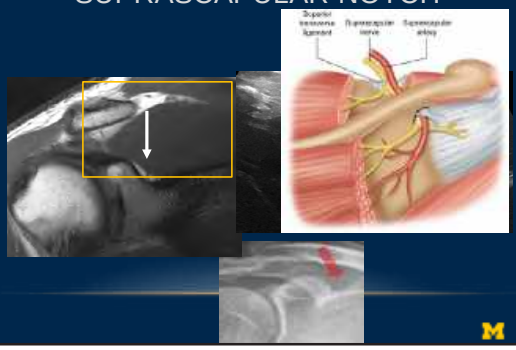
GOUTALLIER CLASSIFICATION

- Grade 0: normal
- Grade 1: some fatty streaks
- Grade 2: <50% fatty muscle atrophy (> muscle than fat)
- Grade 3: 50% fatty muscle atrophy
- Grade 4: >50% fatty muscle atrophy (> fat than muscle)
- Tangent Sign

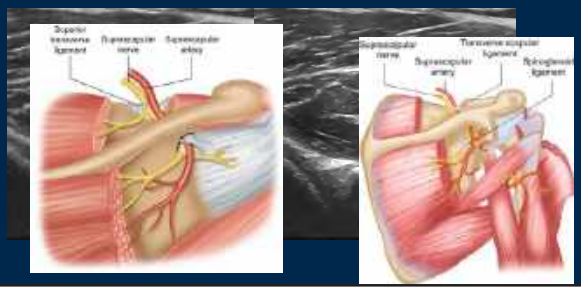


Lawrence RL. Skeletal Radiol. 2023; 52(4):695-703

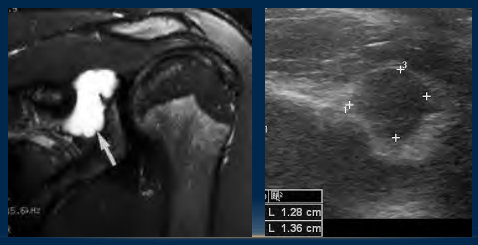
SUPRASCAPULAR NOTCH



SPINOGLENOID NOTCH



SPINOGLENOID NOTCH GANGLION



- Differential Diagnosis: Paralabral cyst

TAKE HOME POINTS

- Protocol & sequences
- Important anatomic landmarks and relationships
  - Bursae, greater tuberosity facets, ligaments, etc.
- Basics of rotator cuff pathology, classifications, etc.
  - What the orthopaedic surgeon needs to know

THANK YOU

SELF EVALUATION

MRI of the Shoulder

1. Fluid seen within which location is often associated specifically with anterior rotator cuff tears, including tears of the rotator interval?

a. Subscapularis recess
b. Subcoracoid recess
c. Long head biceps tendon sheath
d. Subcoracoid bursa

2. Which band of the subscapularis tendon bears the highest percentage of load during activities of daily living, especially in the presence of a supraspinatus tear, and is therefore more likely to have tendinopathy?

a. Superior
b. Middle
c. Inferior
d. Load is distributed evenly between the 3

3. According to the DeOrio and Cofield classification, a 'large' full-thickness rotator cuff tear is defined as the following…

a. 1-3 cm
b. Involving 2 tendons
c. 3-5 cm
d. >5 cm

4. Which of the following shows the correct order for the most common types of partial-thickness rotator cuff tears?

a. Bursal>Articular>Instrasubstance
b. Instrasubstance>Articular>Bursal
c. Articular>Bursal>Instrasubstance
d. Intrasubstance>Bursal>Articular

5. Fatty degeneration in which one of the following rotator cuff muscles is associated with higher retears and poor clinical outcomes following arthroscopic rotator cuff repair?

a. Subscapularis
b. Supraspinatus
c. Infraspinatus
d. Teres minor

6. T/F - At the level of the spinoglenoid notch, the suprascapular nerve has the branches to innervate both the supraspinatus and infraspinatus muscles.

7. T/F - The Goutallier classification is used for rotator cuff tear sizes.

Answer Key: 1. D, 2. A, 3. C, 4. B, 5. C, 6. F, 7. F

MICHIGAN MEDICINE
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Ultrasound of the Shoulder

OUTLINE

- Background & Benefits of MSK US
- Selected Shoulder Anatomy Review
- US Shoulder Protocol
- Normal Shoulder US

MSK US

- Use of MSK US has significantly increased over the past two decades
  - Especially US evaluation of shoulder for pain & rotator cuff pathology

Lee MH, et al. Radiographics 2016; 36(6):1606-1627

BENEFITS OF US OVER MRI

- Dynamic assessment while interacting directly with patient
- Higher spatial resolution than MRI & excellent in imaging superficial structures
- Real-time Doppler analysis & allows comparing with contralateral side
- Ease of accessibility & lower cost of US when compared to MRI
- Ability to perform US in patients with contraindications to MRI

Alves TI, et al. Radiographics 2016; 36(6):1759-1775

NORMAL SHOULDER ANATOMY

Image courtesy of "BodyParts3D, © The Database Center for Life Science licensed under CC Attribution-Share Alike 2.1 Japan."

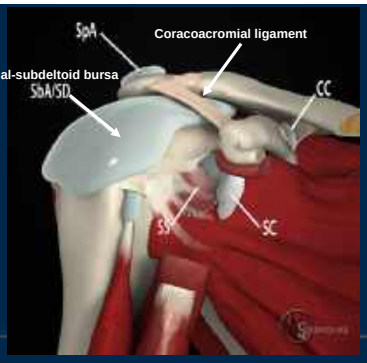
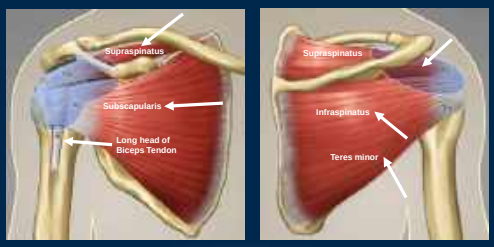


Image courtesy of Dr. Michael Stadnick & Radsource. https://radsource.us/subcoracoid-bursa/

S.I.t.S.



Anterior Posterior

Images courtesy of Carolyn Nowak, Ann Arbor, MI. Jacobson JA. Radiology 2011; 260(1):6-16

Image courtesy of Dr. Robin Smithuis & Radiology Assistant.
https://radiologyassistant.nl/musculoskeletal/shoulder/mri-anatomy

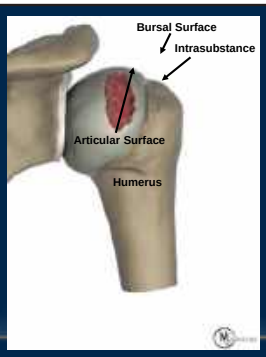


Image courtesy of Dr. Michael Stadnick & Radsource.
https://radsource.us/off-track-shoulder-lesions/

Image courtesy of Dr. Scott Moses & Fpnotebook.com
https://fpnotebook.com/ortho/Rad/ShldrUltrsnd.htm

US SHOULDER PROTOCOL

- Long head of biceps tendon
- Subscapularis tendon
  - Subcoracoid impingement
- AC joint
  - Subacromial impingement

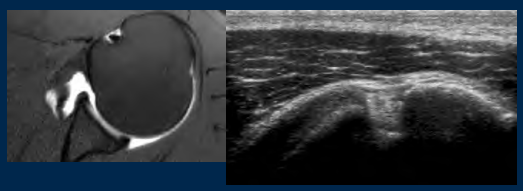
US SHOULDER PROTOCOL

- Supraspinatus tendon
- Infraspinatus tendon (& Teres minor tendon)
- GH jt, Posterior glenoid labrum
- Spinoglenoid notch
- Rotator cuff muscle bellies

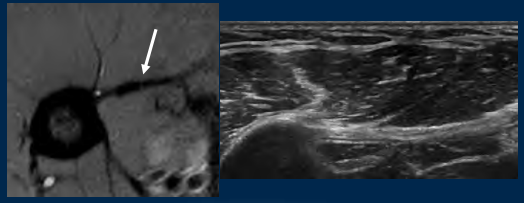
LONG HEAD OF BICEPS TENDON SAX

Image courtesy of Dr. Jon Jacobson
http://www.med.umich.edu/radiology/mskus/index.html

LONG HEAD OF BICEPS TENDON SAX



LONG HEAD OF BICEPS TENDON SAX



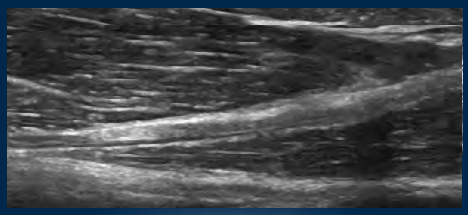
Pectoralis Major Tendon

LONG HEAD OF BICEPS TENDON SAX

LONG HEAD OF BICEPS TENDON LAX

Image courtesy of Dr. Jon Jacobson
http://www.med.umich.edu/radiology/mskus/index.html

LONG HEAD OF BICEPS TENDON LAX



LONG HEAD OF BICEPS TENDON LAX

SUBSCAPULARIS LAX (TO TENDON)

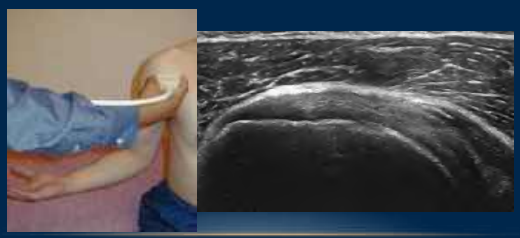
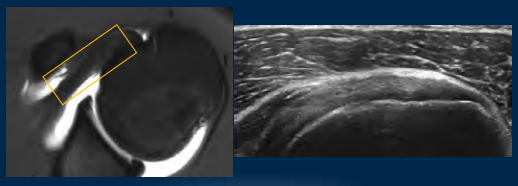
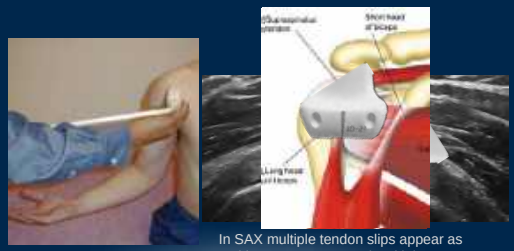


Image courtesy of Dr. Jon Jacobson
http://www.med.umich.edu/radiology/mskus/index.html

SUBSCAPULARIS LAX (TO TENDON)



SUBSCAPULARIS SAX (TO TENDON)

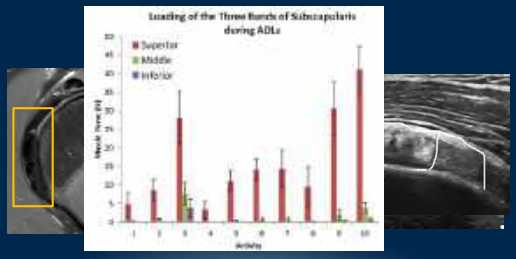


In SAX multiple tendon slips appear as multi-pennate pattern w/ multiple hyperechoic bundles

Image courtesy of Dr. Jon Jacobson
http://www.med.umich.edu/radiology/mskus/index.html

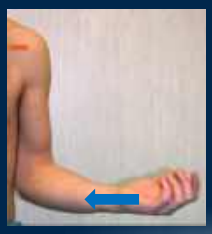
Seibold JC, et al. Radiographics 1999; 19(3):685-705
Vivek K, et al. Am J Roentgenol 2018; 211(3):538-547

SUBSCAPULARIS SAX



Gausden EB, et al. J Shoulder Elbow Surg 2017; 26(2):331-336

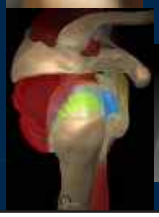
SUBCORACOID IMPINGEMENT & LHBT SUBLUXATION



Images courtesy of the European Society of Musculoskeletal Radiology.
https://essr.org/content-essr/uploads/2016/10/shoulder.pdf

SUBCORACOID IMPINGEMENT & LHBT SUBLUXATION

AC JOINT



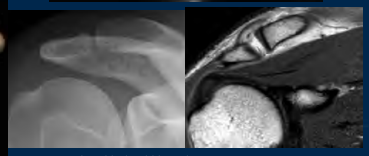
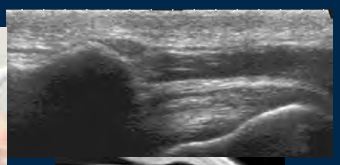
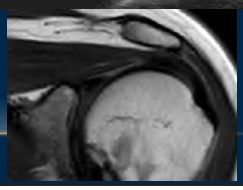


Image courtesy of Dr. Michael Stadnick & Radsource.
https://radsource.us/rotator-cuff-pitfalls/

SUBACROMIAL IMPINGEMENT

SUBACROMIAL IMPINGEMENT





Jacobson JA. Radiology 2011; 260(1)6-16

SUBACROMIAL IMPINGEMENT

Jacobson JA. Radiology 2011; 260(1)6-16

SUPRASPINATUS TENDON

Crass

Modified Crass

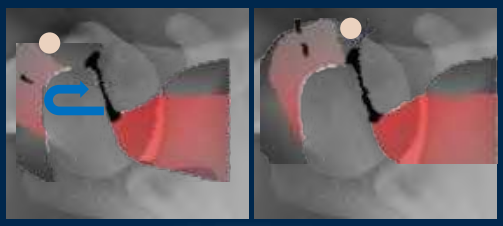
Images courtesy of the European Society of Musculoskeletal Radiology.
https://essr.org/content-essr/uploads/2016/10/shoulder.pdf

SUPRASPINATUS TENDON

Neutral

Internal Rotation

SUPRASPINATUS TENDON

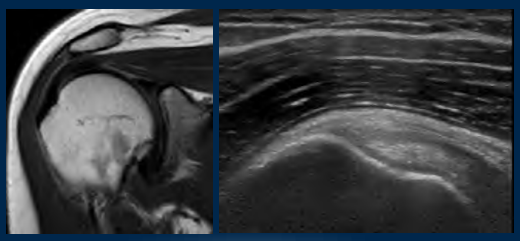


Neutral Internal Rotation

SUPRASPINATUS TENDON LAX

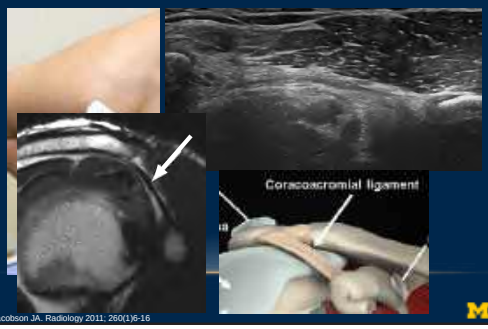
Jacobson JA. Radiology 2011; 260(1)6-16

SUPRASPINATUS LAX



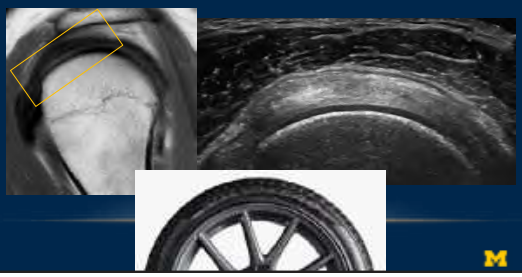
SUPRASPINATUS LAX

SUPRASPINATUS SAX



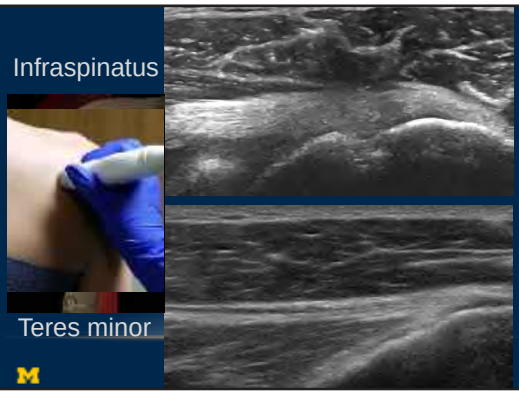
Jacobson JA. Radiology 2011; 260(1)6-16

SUPRASPINATUS SAX



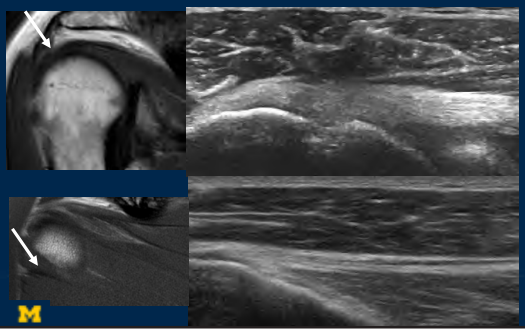
SUPRASPINATUS SAX

Infraspinatus



Teres minor

INFRASPINATUS & TERES MINOR LAX



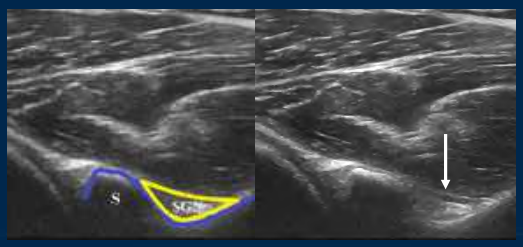
INFRASPINATUS LAX

POST SUP GLENOID LABRUM

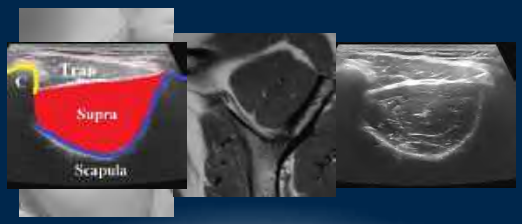
Image courtesy of Dr. Robin Smithuis & Radi
https://radiologyassistant.nl/musculoskeletal/

POST SUP GLENOID LABRUM

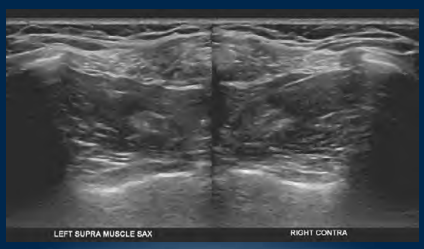
SPINOGLENOID NOTCH



SUPRASPINATUS MUSCLE



SUPRASPINATUS MUSCLE



ROTATOR CUFF MUSCLES

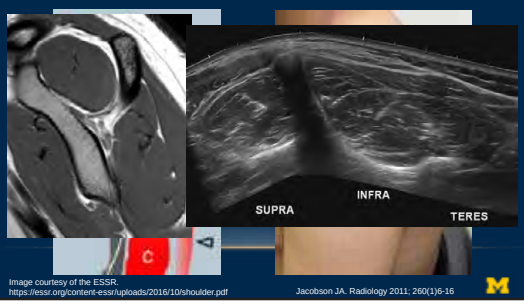


Image courtesy of the ESSR
https://essr.org/content-essr/uploads/2016/10/shoulder.pdf

Jacobson JA. Radiology 2011; 260(1)6-16

TAKE HOME POINTS

- Ultrasound is excellent for rotator cuff evaluation
- Understanding anatomy is critical
- Follow protocol
- Benefits of MSK US
  - Dynamic imaging for impingement & biceps subluxation

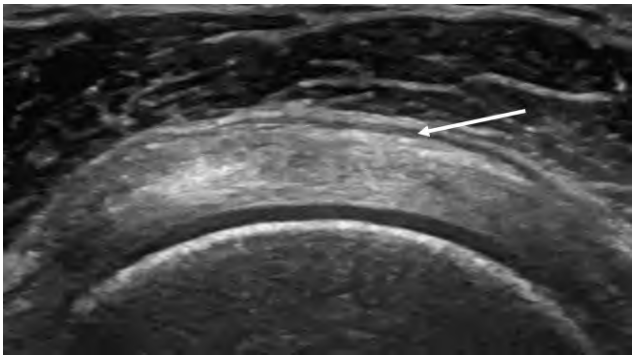
THANK YOU

UNIVERSITY OF MICHIGAN

SELF EVALUATION

Ultrasound of the Shoulder

1. In this short-axis view of the supraspinatus tendon, the arrow is pointing to which structure?



a. Peribursal fat
b. Subacromial-subdeltoid bursa
c. Articular cartilage
d. Supraspinatus tendon

2. T/F - Internal and external rotation of the shoulder is the dynamic maneuver used to evaluate for subacromial impingement.

3. Which band of the subscapularis tendon bears the highest percentage of load during activities of daily living and is therefore more likely to have tendinopathy?

a. Superior
b. Middle
c. Inferior
d. Load is distributed evenly between the 3 bands

4. Fatty degeneration in which one of the following rotator cuff muscles is associated with higher retear rates and poor clinical outcomes following arthroscopic rotator cuff repair?

a. Subscapularis
b. Supraspinatus
c. Infraspinatus
d. Teres minor

5. T/F - The modified crass position puts the shoulder in internal rotation.

6. T/F - The glenoid labrum can be clearly and entirely visualized by ultrasound?

7. T/F - The pectoralis minor tendon divides the long head biceps tendon from the muscle belly?

Answer Key: 1. B, 2. F, 3. A, 4. C, 5. T, 6. F, 7. F

Carole C. Foos, CPA

Carole C. Foos, CPA, of Cincinnati, Ohio, is a partner in OJM Group, a physician focused financial planning and asset management firm and a Certified Public Accountant offering tax analysis and tax planning services to the firm's clients. Ms. Foos has over 25 years experience in accounting, tax planning and financial consulting and is a co-author of numerous books for physicians, including *Wealth Management Made Simple* and *Wealth Planning for the Modern Physician: Residency to Retirement*. Ms. Foos has authored numerous articles and presented many lectures, webcasts, and podcasts on tax planning and wealth management.

You may contact Ms. Foos with any questions or comments at (513) 309–3946 or by email at carole@ojmgroup.com.

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Maximizing Practice Profitability: Metrics, Analyses, and Strategies

Carole C. Foos, CPA

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Maximizing Practice Profitability: Metrics, Analyses, and Strategies

PRESENTED BY:

Carole Foos, CPA
OJM Group Partner

Introduction

- Understanding Key Financial Ratios
- Improving Cash Flow Management
- Maximizing Profitability through Financial Analysis
- Implementing Strategies for Success

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UNDERSTANDING KEY FINANCIAL RATIOS

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Current Ratio

- Measures practice's ability to cover short-term liabilities with short–term assets
- Divide current assets (cash, A/R, inventory) by current liabilities (A/P, accrued expenses, short-term debt)
- Ratio of 1 or higher indicates ability to pay short-term obligations
  - <1 may signal liquidity issues
  - Ratio of 1.5 – 2.0 is considered healthy for a medical practice generally
  - Makes sense to benchmark your ratio against industry / specialty averages

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Current Ratio

- Factors Affecting Current Ratio
  - A/R Management - collection % and days in A/R
  - Inventory management – excess ties up working capital; too little impacts revenue
  - A/P Management – extending payment with vendors can improve current ratio
- Trend Analysis
  - Monitor changes over time to identify trends and financial challenges
- Compare with industry benchmarks
- Use in decision making
  - Determine need for additional financing
  - Evaluate impact of investment decisions
  - Identify areas for operational improvements

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Working Capital

- Indicates practice's liquidity and short-term financial health
- Difference between practice's current assets and current liabilities
- Regularly calculating ensures enough funds to cover expenses such as salary, rent, utilities, supplies
- Identifying surplus or deficit in WC allows owners to proactively maintain or improve liquidity
- Essential when planning for growth or expansion
- Mitigates financial risks associated with liquidity
- Monitor changes in WC over time to identify trends
- Calculation can help optimize cash flow management
  - Determine when to accelerate A/R, improve billing / collections
  - Negotiate better terms with suppliers or extend payment deadlines
  - Streamline inventory management

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Days in Receivables / Payables

- Days in Receivables indicates time it takes from patient service to collection
- Days in Payables = receipt of product or service to date of payment
- Improving Days in Receivables
  - Accurate and timely billing / accurate coding
  - Verify insurance information up front
  - Review claim rejections / re-processing
  - Spotlight problem payers
  - Regularly review and update billing codes
  - Monitor claim status and follow up
  - Implement clear and consistent patient collection policies
  - Train staff to effectively communicate with patients
  - Utilize technology solutions such as RCM software or outsourced billing, processing and collections
  - Use analytics to identify trends and patterns
  - Benchmark against industry standards
  - Establish relationships with payers / insurance companies
  - Stay informed about reimbursement policy changes

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IMPROVING CASH FLOW MANAGEMENT

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Cash Flow Statement

- Provides sources and uses of cash over a specific period from
  - Operations
  - Investing
  - Financing
- Operating Cash Flow (OCF)
  - Assess ability to generate cash from core business operations (patient care)
  - Positive OCF = GOOD!!
  - Monitor trends to identify fluctuations, seasonal patterns that could impact working capital
- Investing Cash Flow
  - Evaluate investments in assets such as medical equipment, facilities, technology
  - Assess impact of capital expenditures on growth objectives and long-term strategy
  - Use it to evaluate timing and magnitude of investment activities

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Cash Flow Statement

- Financing Cash Flow
  - Understand sources and uses of external financing (loans, lines of credit, capital contributions)
  - Evaluate impact of financing on overall cash position and debt levels
  - Monitor changes in debt repayments, dividends, or equity transactions
- Net Cash Flow and Cash Balance
  - Calculate net increase or decrease to determine whether practice generated or consumed cash for the period
  - Monitor changes in cash balance to ensure liquidity
  - Maintain a target cash reserve for emergencies / contingencies
- Cash Flow Ratios
  - OCF / Total Revenue and OCF/Total Debt
  - Compare to industry benchmarks
- Cash Flow Forecasting
  - Use historical data to forecast future flows and for budgeting

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MAXIMIZING PRACTICE PROFITABILITY

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Revenue and Expense Trends

- Revenue Trends
  - Total Revenue
  - Revenue Sources
  - Revenue Mix
  - Revenue Growth Rate
  - Revenue per Patient Visit
- Expense Trends
  - Total Expenses
  - Expense Categories
  - Expense Ratios
  - Expense Trend Analysis
  - Expense Control Measures
- KPI's
  - Operating margin to assess profitability from core operations
  - Profitability ratios
  - Provider productivity
  - Patient retention and acquisition
- Benchmark against industry, peers, historical
- Budget Variance Analysis

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Operating Margin

- Percentage of revenue remaining after deducting operating expenses excluding interest, taxes and non-operating items
- Provides insight into efficiency and profitability
  - Indicates efficiency in various areas such as patient consultations, diagnostic tests, treatments and procedures
  - Higher operating margin suggests effective management of expenses relative to revenue
- Cost Management
  - Higher operating margin suggests better cost management
- Operational Efficiency
  - Efficiently run practices can optimize revenue while minimizing expenses
  - Efficiency in patient and staff scheduling, workflows, and revenue cycle management
- Ability to cover fixed costs
- Compare with industry, peer group and historical benchmarks

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Performance Indicators

- Patient Volume
  - Number of patients seen / treated in a specific period
  - Indicator of Demand
  - Potential for Growth
  - Helps assess capacity utilization
  - Identify trends
- Average Revenue per Patient
  - Average revenue per patient encounter
  - Higher average may indicate broader range of services / higher value treatments
  - Cross selling opportunities – screenings, tests, treatments
- Provider Productivity
  - Measures efficiency of each provider
  - Ability to see more patients, diagnose conditions, and perform treatments
  - Identifies high-performing providers so practices can appropriately incentivize, optimize schedules, provide resources

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IMPLEMENTING STRATEGIES FOR SUCCESS

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Implementation

- Regular Monitoring
- Invest in Technology
- Staff Training
- Seek Professional Help

By leveraging key financial ratios and conducting thorough financial analysis, you can significantly enhance your medical practice's efficiency, cash flow management, and profitability. Remember, proactive financial management is essential for the long-term success of your practice.

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PERSONAL WEALTH PLANNING

DIAGNOSTIC vs. TREATMENT

ADVICE & EXPERTISE FOR A FLAT FEE

BUILDING A RELATIONSHIP

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Wealth Strategies for Today's Physician: A Multi-Media Playbook

- New content from OJM: Our first book since 2020!
- Co-authored by OJM Group partners
- Innovative multi-media format includes more than 90 links to videos and podcast episodes that offer unique perspectives and real-world examples
- Videos to be periodically updated by OJM so that the Playbook remains current over time
- Crafted in six informative Strategies that can help physicians protect assets, reduce taxes, invest wisely and build wealth for retirement
- Bonus Strategy for medical practice owners and *doctorpreneurs*

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Schedule a Free Consultation

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SELF EVALUATION

Maximizing Practice Profitability: Metrics, Analyses, and Strategies

True/False

1. Current Ratio is used to measure practice's ability to cover short term liabilities with short term assets.
2. A current ratio of 0.5 indicates strong liquidity.
3. Working capital is the difference between current assets and current liabilities.
4. Accurate coding has no effect on Days in Receivables.
5. Negative operating cash flow indicates a healthy practice.
6. Patient Volume is a performance indicator that provides insight into practice efficiency.
7. Proper utilization of practice management software and financial tools can streamline processes and improve efficiency.

Answer Key: 1. T, 2. F, 3. T, 4. F, 5. F, 6. T, 7. T

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David B. Mandell, JD, MBA is a practicing attorney in The Law Offices of David B. Mandell, PC, and a principal of the doctor focused wealth management firm OJM Group, LLC. He specializes in risk management, asset protection, and financial planning and has authored a number of books for doctors including his latest, Wealth Strategies for Today's Physician: A Multi-Media Playbook. His articles have appeared in over 100 publications, including over 30 medical specialty journals, and he has addressed many of the nation's leading medical conferences.

Mr. Mandell holds a bachelor's degree from Harvard University from which he graduated with honors, a law degree from the UCLA School of Law where he was awarded the "American Jurisprudence Award" for achievement in legal ethics and earned his MBA from UCLA'S Anderson School of Management.

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Legal Protections & Tax Efficiencies for Radiologists

David B. Mandell, JD, MBA

LEGAL PROTECTIONS & TAX EFFICIENCIES FOR RADIOLOGISTS

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DAVID B. MANDELL, JD, MBA
Partner, OJM Group

About Me

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Today's Presentation

- Tax efficiency for radiologists
  - Practice owners and doctorpreneurs
  - Employed
- Asset protection basics for radiologists
  - Background
  - Tools and tactics

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PRACTICE OWNERS & DOCTORPRENEURS

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Doctorpreneurship for radiologists

- *Locums tenens* work
- Moonlighting
- Expert medical witness
- Telemedicine outside primary job
- Consulting to industry
- Paid speaking
- Medical surveys
- Creating a patentable medical device
- Real estate investing/AirBnB
- Launching a startup
- Many others…

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Corporate Structure: Tax-Wise, Choose Your Medicine

- **Proprietorship/General Partnership**
  - No good tax reason – 3.8% ACA tax (Medicare 2.9%) on all income.
- **LLP/LLC taxed as partnership**
  - 3.8% ACA (Medicare 2.9%) tax on all income
  - Flexibility with regard to gains and losses
- **LLC taxed as disregarded entity**
  - No good tax reason; 3.8% ACA (Medicare 2.9%) tax on all income.
- **S Corporation**
  - Spread income between reasonable salary/distributions
  - Save 3.8% ACA (Medicare 2.9%) tax on distributions
  - EXAMPLE: Are you an S acting like a C?
- **C Corporation**
  - Lose the S salary/distribution play
  - Access to some write-off not available to S corps

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What is a Retirement Plan

- Many physicians think of a qualified retirement plan (QRP)
  - Many different types
- At OJM, we see a QRP as one "bucket" in a multi-bucket plan
  - Other benefit plans, after-tax assets, securities/real estate, other asset classes
- Tax diversification is key

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Tax Diversification

ORDINARY INCOME	CAPITAL GAINS	TAX FREE
37.0% FEDERAL + 6.6% STATE + 3.8% ACA	20% FEDERAL + 6.6% STATE + 3.8% ACA	
(47.4% TAX)	(30.4% TAX)	(0% TAX)
WITHDRAWAL: $100,000	WITHDRAWAL: $100,000	WITHDRAWAL: $100,000
LESS TAX: $47,400	LESS TAX: $30,400	LESS TAX: $0
NET AFTER TAX: $52,600	NET AFTER TAX: $69,600	NET AFTER TAX: $100,000

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QRP Ground Rules

- Two different categories
- Asset protection is excellent
- Must cover all eligible employees
- **Full deduction for contributions**
- **Income taxation on withdrawals**
- Penalties on withdrawals before $59^1/_2$
- Funds left in estate taxed up to 70%

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QRP: Defined Contribution Plans

- IRS defines the contribution amount
- 401(k)s, 403(b), and 457 plans
  - $23,500 employee deferral amount
- Profit-sharing plan: $70,000
- A few "catch up" provisions
- Flexibility on funding
  - No penalties for underfunding or termination
- **Proper plan design is key**

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QRP: Defined Benefit Plans

- Actuarially-determined contribution amount
- Clients contributing $200,000+ annually
- Employee costs can be high
- Penalties for underfunding or termination
- *Cash balance plans: special type of DB plan*
  - *Highest deductibility*
  - *Ideal for physician groups*
  - *Highlighted in wall street journal article*
- **Planning design/commitment is key**

The Retirement-Savings Weapon Doctors and Lawyers Use to Build Wealth

Cash balance plans have exploded in popularity and now hold more than $1 trillion of wealth*

*https://www.wsj.com/personal-finance/retirement/cash-balance-plans-retirement-high-earners-71bfed2e?st=ENKDdG&reflink=article_copyURL_share

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Non-Qualified Plan As An Option

- No limitations on contributions – reasonable compensation
- In addition to 401k, profit-sharing, pension
- Owners can vary how much/if they participate
- Employee participation not required
- No tax deduction, tax-free growth and on withdrawal
- **Ideal hedge against future income/capital gains tax increases**

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Assumptions for Case Study

Example taken from Actual OJM Group Client:

- 45-Year-Old Male
- $100,000 Annual Contribution for 10 Years
- Growing at 6.0% annual gross rate of return
- Investment fees of 1.25%
- Assuming taxed at 20% Short Term Rates/80% Long Term Rates
- 37% Federal & 6.0% State
- 20% Long Term Capital Gains & 3.8% ACA Tax
- Distributions at age 65 for 20 years

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Case Study: Non-Qualified Plan: After-Tax Retirement Distribution

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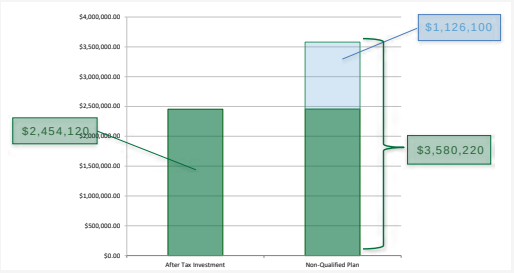

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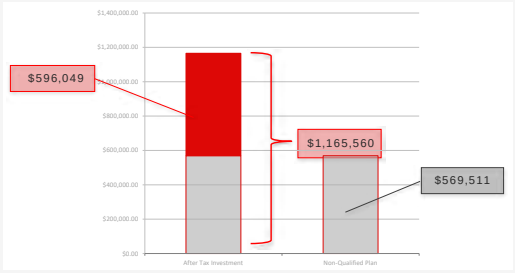
Case Study: Non-Qualified Plan: Taxes and Fees vs. Policy Expenses



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What Largest Firms Do

Percentage of Banks That Own BOLI

Asset Size	Banks	Banks with BOLI	% of Banks with BOLI
Greater than $50 billion	48	38	79%
$10-50 Billion	110	87	79%
$5-10 Billion	128	104	81%
$1-5 Billion	746	624	84%
$750-999 Million	285	224	79%
$500-749 Million	491	372	76%
$250-499 Million	954	690	72%
$100-249 Million	1087	660	61%
<$100 Million	701	254	36%
Totals	**4550**	**3053**	**67%**

Source: S&P Global Market Intelligence

As of September 30, 2024
- Numbers in thousands
- Tier 1 Capital plus Loan Loss Allowance, if applicable

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EMPLOYED PHYSICIAN TAX PLANNING

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Tax Preparation vs. Tax Planning

- Tax preparation
  - Backwards looking
  - Some adjustments/planning, but limited
- Tax planning
  - Forward looking
  - Impactful to practice structure, compensation, benefit plans, investments, tax diversification, personal deductions, charitable gifts, estate planning and more
- What do tax attorneys do?

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Take Advantage of Employer-Sponsored Plans

- 401(k)s, 403(b)s, etc.
- Always qualify for any match

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Techniques to Reduce Your Investment Tax Bill

- Be aware of holding periods.
- Understand any funds' tax cost ratio
- Take advantage of account registration
- Offset gains by realizing losses

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ASSET PROTECTION
FOR ALL RADIOLOGISTS

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Types of Liability Facing Physicians

- Medical malpractice
- Employer liability
  - Sexual harassment ("hostile work environment"); Wrongful termination (protected classes); Violation of fiduciary duty (qualified plans)
- Billing issues
  - Over-billing, improper billing, fraud, violation of anti-kickback rules, Stark rules, etc.
- HIPAA
- Premises liability
- Business deals gone south
- Auto liability for self, children

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What Is Asset Protection?

Multidisciplinary approach to shielding practice and personal assets from future liability

- Multidisciplinary: insurance, legal, financial
- Practice & Personal
- Future Liability
- Diagnostic and treatment model

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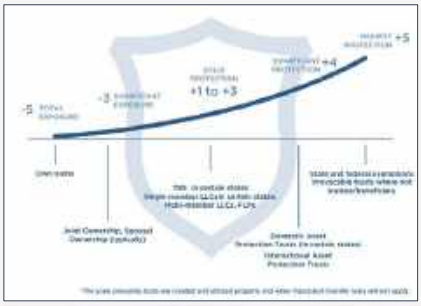
Asset Protection Sliding Scale



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What Are Asset Protection Tools?

- Property & casualty (P&C) insurances – at practice and personally
- State exempt assets
  - Qualified plans, like 401(k)s, profit sharing plans, pensions
  - Homestead
  - Cash Value life insurance or annuities
- Legal tools: limited liability companies (LLCs), trusts, co-ownership forms (TBE)
- Collateralization/debt shields

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About OJM Group

- Unique, fee-based wealth management firm
- Multidisciplinary; three divisions
- Corporate and personal planning
- Goal: Reducing physician financial stress

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How We Work With Physicians

- **Investing**
  - RIA
  - Fiduciary, independent custodian
  - Tax-focused
- **Insurance and Benefits**
  - Life, disability, long term care insurance
  - Through partner firm, P&C coverages
  - Qualified and non-qualified plans
- **Consulting**

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Personal Wealth Planning

- **Diagnostic vs. Treatment**
- **Advice and Expertise for a Flat Fee**
- **Building a Relationship**

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Wealth Planning for the Modern Physician Podcast

- Physician wealth podcast hosted by David Mandell, JD, MBA
- Guests include physicians of all specialties and wealth management industry experts
- Episode 4.1 with Dr. Charles Mandell
- Nearly 100 episodes published to date
- Available on Apple Podcasts, Spotify and other popular podcast platforms
- Video versions of episodes now available on YouTube
- Scan the QR Code to listen and subscribe!

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SELF EVALUATION

Legal Protections & Tax Efficiencies for Radiologists

1. T/F - Using an “S” corporation tax status, one can split income between “reasonable compensation” and distributions, and save 3.8% in Medicare taxes on distributions.

2. T/F - Tax diversification is crucial for all physicians’ long term financial plans.

3. Which of the following are considered “defined contribution” plans?

a. Profit sharing plans
b. 401(k)s
c. 403(b)s
d. All of the above

4. T/F - Non-qualified plans can be offered to only physicians in a practice, employees do not have to participate.

5. The percentage of large U.S. banks using bank-owned life insurance (BOLI) is approximately:

a. 0%
b. 10%
c. 30%
d. 70%

6. Which of the following is NOT a tactic for reducing taxes on investments:

a. Implementing asset protection planning
b. Understanding a funds’ tax cost ratio
c. Taking advantage of account registration
d. Offsetting gains by realizing losses

Answer Key: 1. T, 2. T, 3. D, 4. T, 5. D, 6. A