How to Order and Read MSK X-rays and Imaging Studies

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Objectives

- Go over the different imaging modalities and their use in musculoskeletal imaging
  - Specifically, the role of different imaging modalities in various clinical scenarios
- Discuss the different resources available when trying to decide what to order
- Basic radiograph interpretation with case examples

Radiographs

- Integral in initial work-up for ***trauma***, infection, and arthritis
  - Especially important in characterizing fractures, dislocations, foreign bodies
  - At least 2 views at 90 degrees to each other
- Fluoroscopy
  - Arthrograms
  - Aspirations

Radiographs

Alignment appears to be normal on the PA view of the hand.

Dorsal dislocation of the middle phalanx

Key Point

ALWAYS START WITH AN X-RAY

Computed Tomography (CT)

- Multi-detector CT
  - Can define or exclude a fracture that was equivocal on radiographs
  - Can further define the extent of a fracture line
  - In emergent trauma, this is likely the modality of choice, foregoing plain radiography
  - *Allows for multi-planar and volume rendered images*
- Other uses aside from trauma
  - Hardware complications, infection, inflammatory conditions

graphy (CT)

Question‘

Is the fracture intra- or extra- articular?

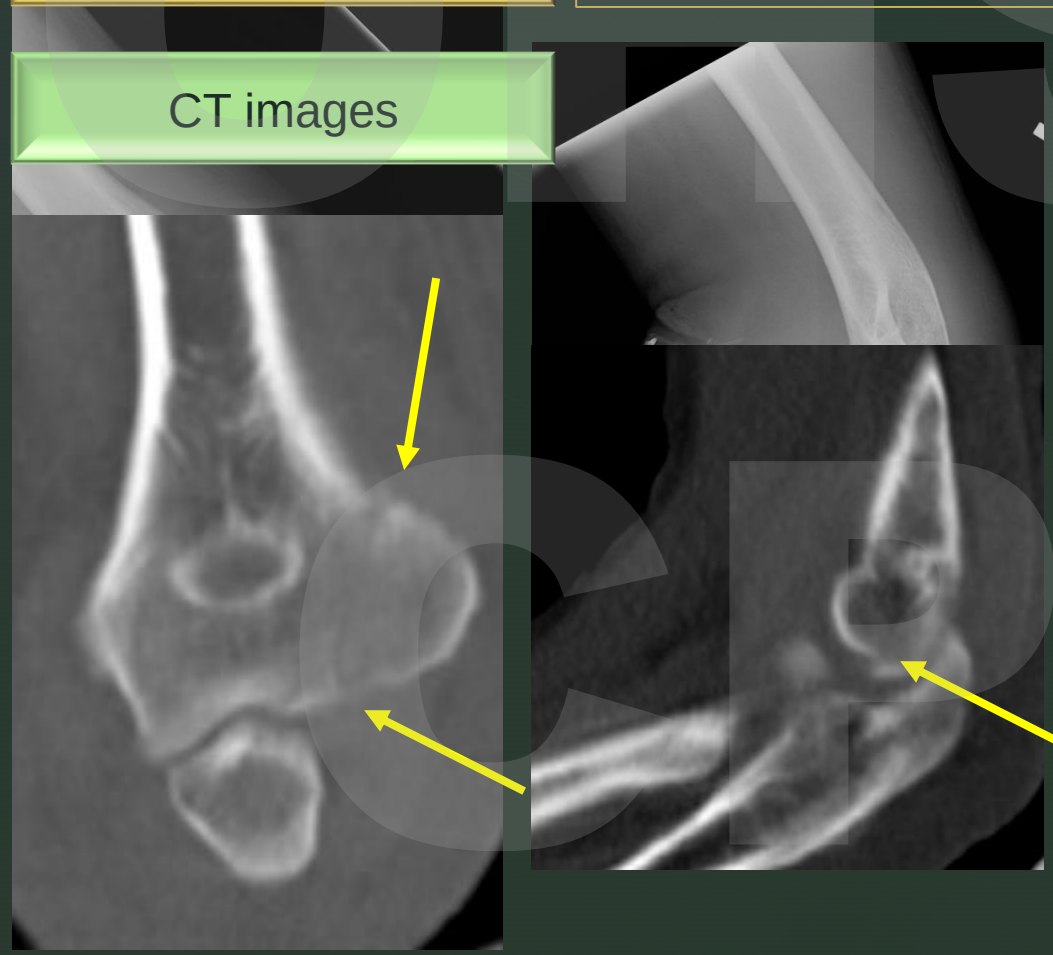
ateral views of the left

Computed Tomography (CT)

Question?

Is the fracture intra- or extra-articular?

CT images



Key Point

CT scans depict fracture planes to a better advantage than radiographs

Ultrasound

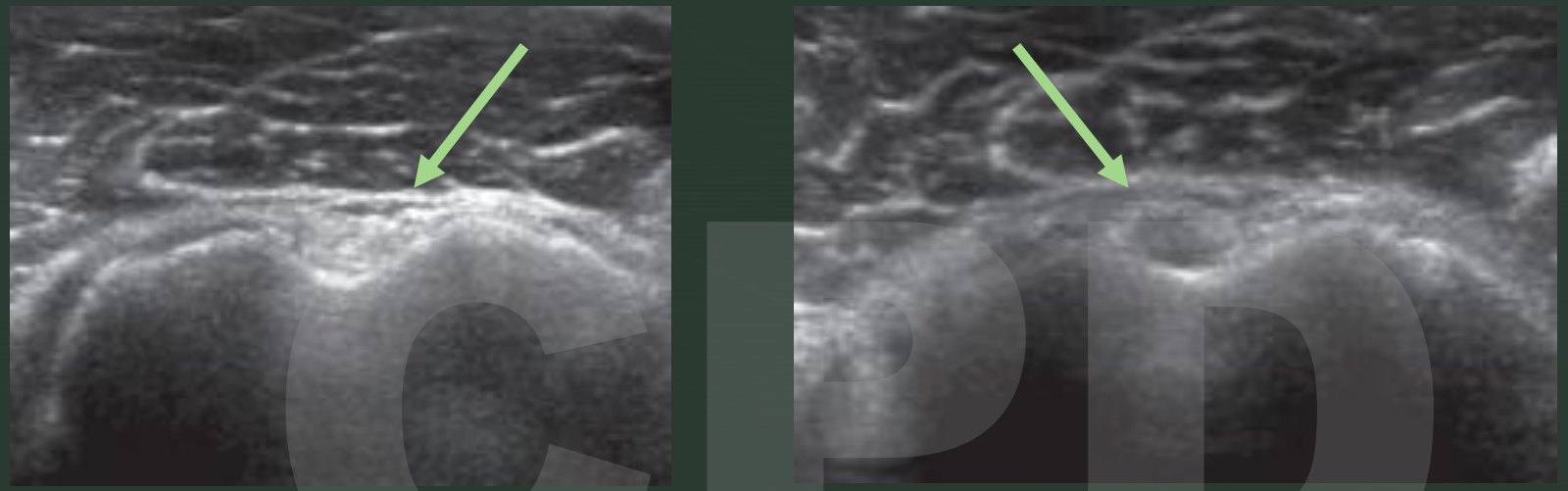
- Utilization has steadily increased since the 1990s (increased by over 200%)
- Capability of *dynamic* imaging
- Good in the evaluation of:
  - Tendon and ligament injuries (i.e., rotator cuff, Achilles, hamstrings)
  - Soft tissue foreign bodies
  - Soft tissue masses +/- biopsies
  - Peripheral nerve studies
  - Synovitis

Ultrasound

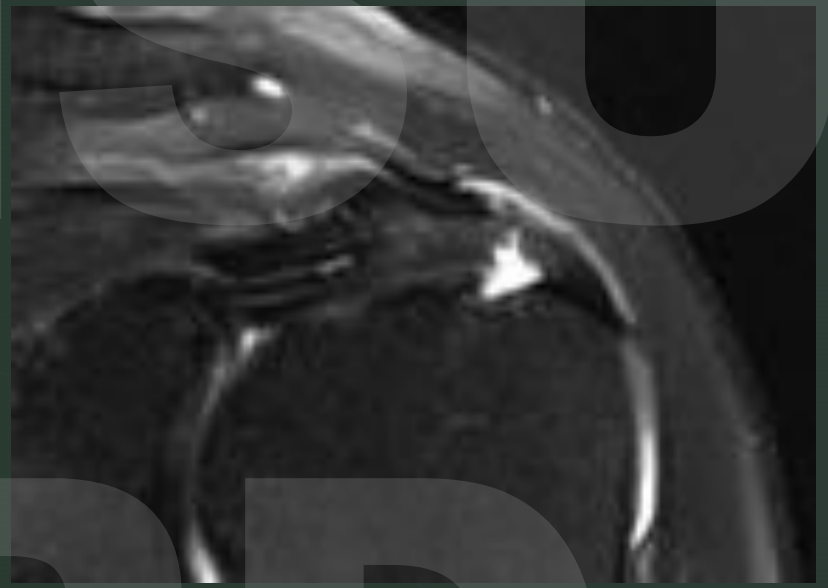
- Limitations:
  - US images are not intuitive
  - Extremely operator dependent modality
  - Steep learning curve
  - Sound waves cannot penetrate bone or gas; limited depth
  - Artifacts mimic pathology
  - No temporal comparison at the time of exam

Ultrasound

Anisotropy of the long head biceps tendon



Ultrasound



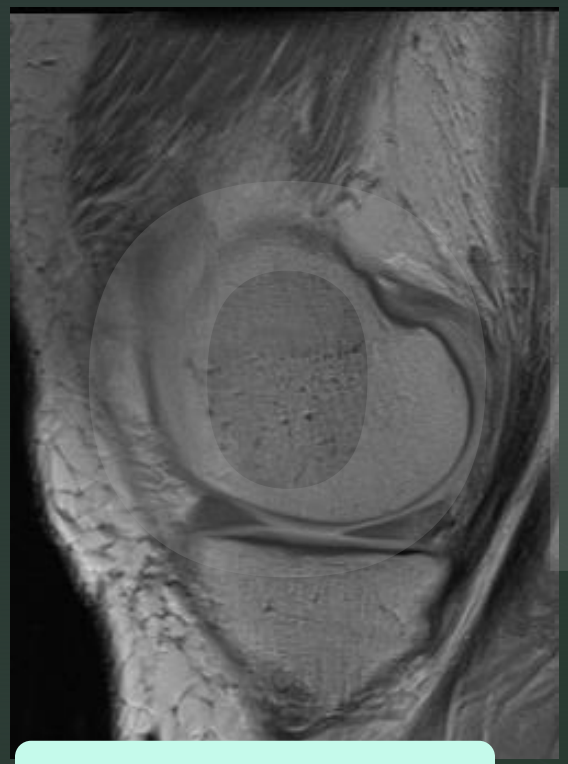
Ultrasound and MRI both show a high grade, partial thickness articular surface sided tear.

Key Point

Ultrasound can do it too! If you know what you are doing.

Magnetic Resonance Imaging (MRI)

- The “Gold-standard” imaging tool in sports medicine
  - Detailed evaluation of the anatomy, specifically the smaller hyaline and fibrocartilage structures
  - Contrast allows for better characterization for potential infectious or malignant processes
    - Not all infections/tumors require contrast…more on that later



Meniscal tears

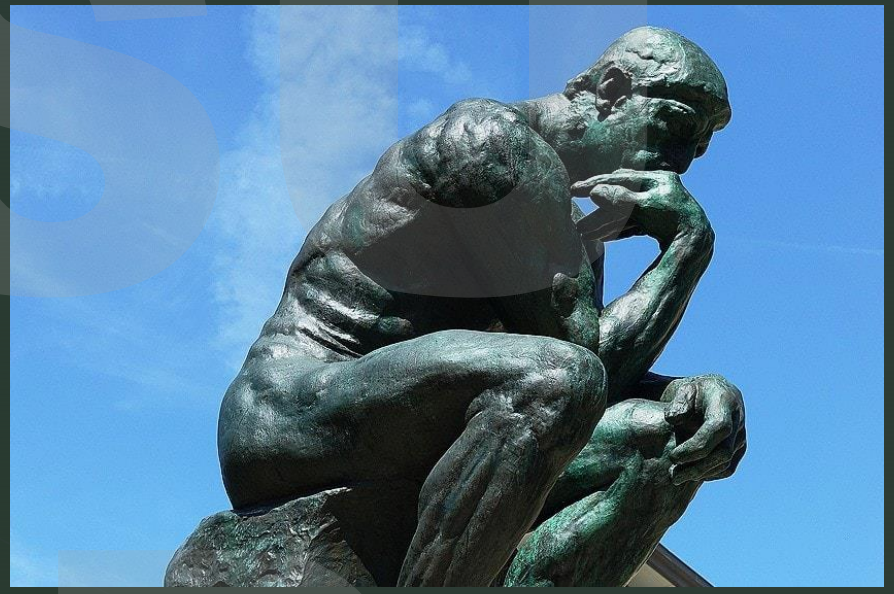
Stress fractures

Ligament tears

Tendon tears

The list goes on…

MRI



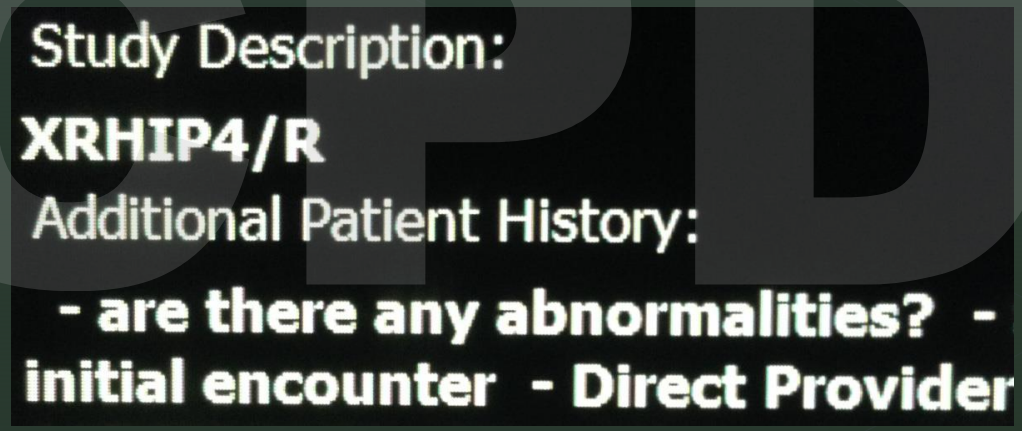
- So which MRI do I pick?
  - Joint/non-joint
  - w/wo
  - Specific sequences
    - Different positioning for elbow, shoulder, ankle to be added to a protocol

MRI

- So which MRI do I pick?

Best resource is the radiologist who will protocol the examination.

- However, this is almost entirely based on the history we are provided.



Nuclear Medicine

- Not the most commonly used modality for MSK imaging
- However, has shown utility in diagnosing:
  - Sports medicine injury
    - Stress fractures
    - Shin splints
    - Fractures not visible by radiograph
    - Acute skeletal muscle injury, rhabdomyolysis
  - Neoplastic disease
    - Metastatic disease (breast, prostate)
  - Infection
    - Hardware

How do I know what to order?

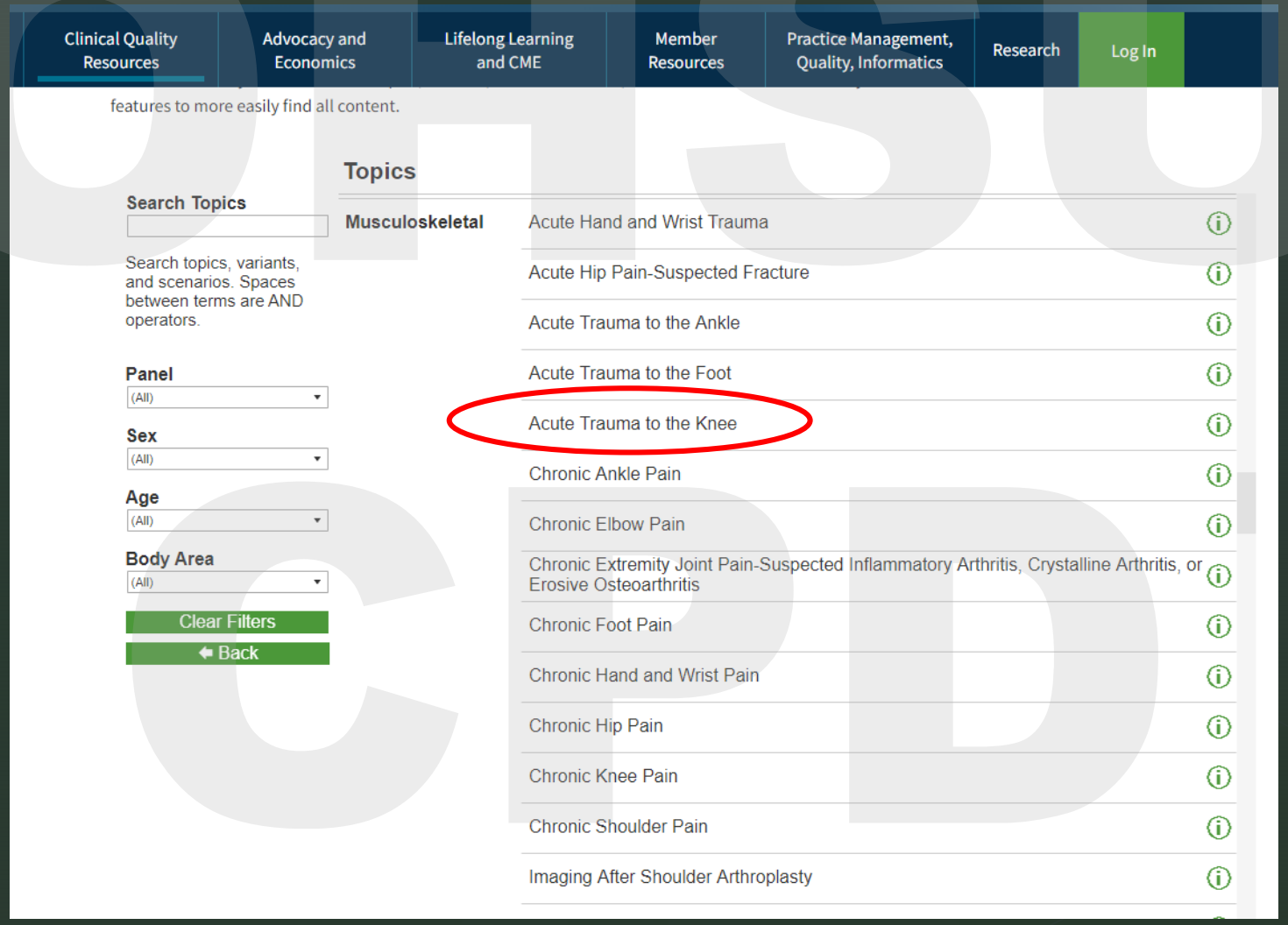
- ACR Appropriateness Criteria
- Consensus panels
- Your local radiologist

ACR Appropriateness Criteria

- American College of Radiology
- Evidence based guidelines to assist referring clinicians to make the most appropriate imaging or treatment choices
- More than 200 topics covered!
- Website:
  - www.acr.org/quality-safety/appropriateness-criteria

ACR Appropriateness Criteria

ACR Appropriateness Criteria



ACR Appropriateness Criteria

Variant 5: **Adult or child 5 years of age or older. Fall or acute twisting trauma to the knee. Tibial plateau fracture on radiographs. Suspect additional bone or soft-tissue injury. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI knee without IV contrast	Usually Appropriate	O
CT knee without IV contrast	Usually Appropriate	☢
Bone scan with SPECT or SPECT/CT knee	Usually Not Appropriate	☢☢☢
CT knee with IV contrast	Usually Not Appropriate	☢
CT knee without and with IV contrast	Usually Not Appropriate	☢
MR arthrography knee	Usually Not Appropriate	O
MRA knee without and with IV contrast	Usually Not Appropriate	O
MRA knee without IV contrast	Usually Not Appropriate	O
MRI knee without and with IV contrast	Usually Not Appropriate	O
US knee	Usually Not Appropriate	O

Variant 6: **Adult or child 5 years of age or older. Acute trauma to the knee. Mechanism unknown. Focal patellar tenderness, effusion, able to walk. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography knee	Usually Appropriate	☢
Bone scan with SPECT or SPECT/CT knee	Usually Not Appropriate	☢☢☢
CT knee with IV contrast	Usually Not Appropriate	☢
CT knee without and with IV contrast	Usually Not Appropriate	☢
CT knee without IV contrast	Usually Not Appropriate	☢
MR arthrography knee	Usually Not Appropriate	O
MRA knee without and with IV contrast	Usually Not Appropriate	O
MRA knee without IV contrast	Usually Not Appropriate	O
MRI knee without and with IV contrast	Usually Not Appropriate	O
MRI knee without IV contrast	Usually Not Appropriate	O
US knee	Usually Not Appropriate	O

ACR Appropriateness Criteria

This lists 62 studies and is 28 pages long…

Acute Trauma to the Knee

Reference	Study Type	Patients/Events	Study Objective(Purpose of Study)	Study Results	Study Quality
60. Rieger M, Mallouhi A, Tauscher T, Lutz M, Jaschke WR. Traumatic arterial injuries of the extremities: initial evaluation with MDCT angiography. AJR Am J Roentgenol. 2006;186(3):656-664.	Observational-Dx	87 patients	Retrospectively assess the accuracy of MDCT angiography as the initial diagnostic technique to describe arterial injury in patients with extremity trauma. Presence of arterial involvement was examined prospectively by a radiologist and retrospectively by 2 independent radiologists.	MDCT angiography yielded high accuracy in detection and characterization of traumatic arterial injuries and in recognizing an underlying dissection. Prospective sensitivity and specificity were 95% and 87%, respectively, and retrospective sensitivity and specificity were 99% and 87%, respectively. MDCT angiography provides significant and reproducible technique for the detection and characterization of arterial injuries.	2
61. Potter HG, Weinstein M, Allen AA, Wickiewicz TL, Helfet DL. Magnetic resonance imaging of the multiple-ligament injured knee. J Orthop Trauma. 2002;16(5):330-339.	Review/Other-Dx	21 patients	Retrospective search was performed to evalu MRA in detecting s neurovascular, and after multiple ligam including knee disl		
62. Tocci SL, Heard WM, Fadale PD, Brody JM, Born C. Magnetic resonance angiography for the evaluation of vascular injury in knee dislocations. J Knee Surg. 2010;23(4):201-207.	Observational-Dx	16 patients	To determine whet prudent and conve an MR angiogram a as an MRI scan, wit and discomfort tha conventional angio		

ACUTE TRAUMA TO THE KNEE

Expert Panel on Musculoskeletal Imaging: Mihra S. Taljanovic, MD, PhD[a]; Eric Y. Chang, MD[b]; Alice S. Ha, MD, MS[c]; Roger J. Bartolotta, MD[d]; Matthew Bucknor, MD[e]; Karen C. Chen, MD[f]; Tetyana Gorbachova, MD[g]; Bharti Khurana, MD[h]; Alan K. Klitzke, MD[i]; Kenneth S. Lee, MD, MBA[j]; Pekka A. Mooar, MD[k]; Jie C. Nguyen, MD, MS[l]; Andrew B. Ross, MD, MPH[m]; Richard D. Shih, MD[n]; Adam D. Singer, MD[o]; Stacy E. Smith, MD[p]; Jonelle M. Thomas, MD, MPH[q]; William J. Yost, MD[r]; Mark J. Kransdorf, MD[s].

Summary of Literature Review

Introduction/Background

Acute bone and soft-tissue injuries to the knee may result from low- or high-energy trauma and are commonly seen in emergency departments as well as in outpatient practices [1]. The most common acute knee injuries result from a direct blow, a fall, or a twisting injury [2,3]. The fracture risk increases with age, likely secondary to decreased bone mineral density, increased frequency of blunt injury, and inability to protect the knee during a fall [3]. An estimated 6.6 million knee injuries presented to emergency departments in the United States from 1999 through 2008, for a rate of 2.29 knee injuries per 1,000 population. Prompt and accurate diagnosis facilitates adequate management and may prevent potential complications [1,4].

After thorough history and clinical examination, radiographs are usually the initial imaging modality in the

ACR Appropriateness Criteria

3 MSK Scenarios using Appropriateness Criteria

- Foot ulcer
- Wrist Pain
- Knee Trauma

3 MSK Scenarios using Appropriateness Criteria

Scenario #1	66 year old male with a history of diabetes, now with a foot ulcer
Question?	What is the likely concern for this patient?
	What do you think the best study(ies) might be?

ACR Appropriateness Criteria

Scenario #1

Clinical Condition: Suspected Osteomyelitis of the Foot in Patients with Diabetes Mellitus

Variant 3: Soft-tissue swelling without neuropathic arthropathy with ulcer.

Radiologic Procedure	Rating	Comments	RRL*
X-ray foot	9	Initial study. Radiographs and MRI are complementary, and both are indicated. The results of initial x-ray examination do not preclude the necessity for additional studies.	☢
MRI foot without and with IV contrast	9	Radiographs and MRI are complementary, and both are indicated. MRI is useful preoperatively to identify the extent of involvement and to map devitalized areas.	O
MRI foot without IV contrast	9	Radiographs and MRI are complementary, and both are indicated.	O
Labeled leukocyte scan foot (In-111 or Tc-99m)	3	May be appropriate in certain circumstances such as if MRI is contraindicated or unavailable.	☢☢☢☢
Tc-99m 3-phase bone scan and labeled leukocyte scan (In-111 or Tc-99m) foot	1		☢☢☢☢
Tc-99m 3-phase bone scan foot	1		☢☢☢
Labeled leukocyte scan (In-111 or Tc-99m) and Tc-99m sulfur colloid marrow scan foot	1		☢☢☢☢
Tc-99m 3-phase bone scan and labeled leukocyte scan (In-111 or Tc-99m) and Tc-99m sulfur colloid marrow scan foot	1		☢☢☢☢
US foot	1		O
CT foot without IV contrast	1		☢
CT foot without and with IV contrast	1		☢
CT foot with IV contrast	1		☢
FDG-PET/CT foot	1		☢☢☢☢

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

*Relative Radiation Level

Osteomyelitis

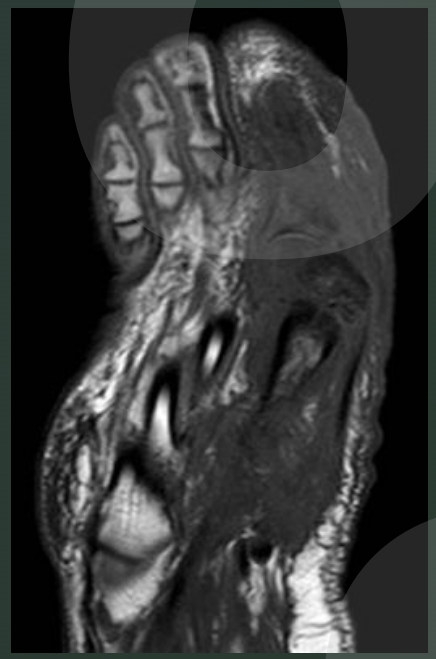
Findings

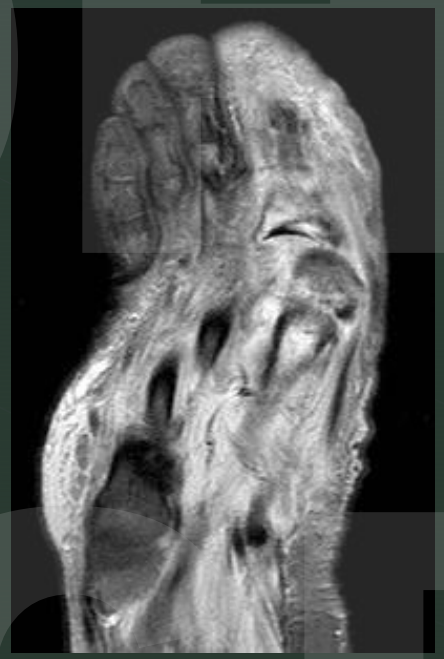
- Osteolysis
- Periosteal reaction
- Osseous fragmentation
- Soft tissue gas

Key Point

So should I get an MRI? It does have an equal rating to x-rays.

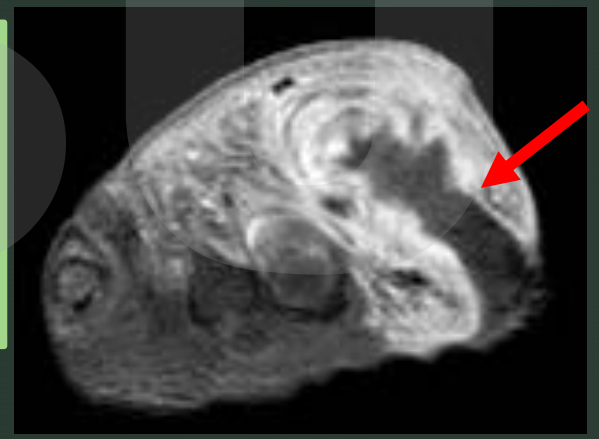
Osteomyelitis





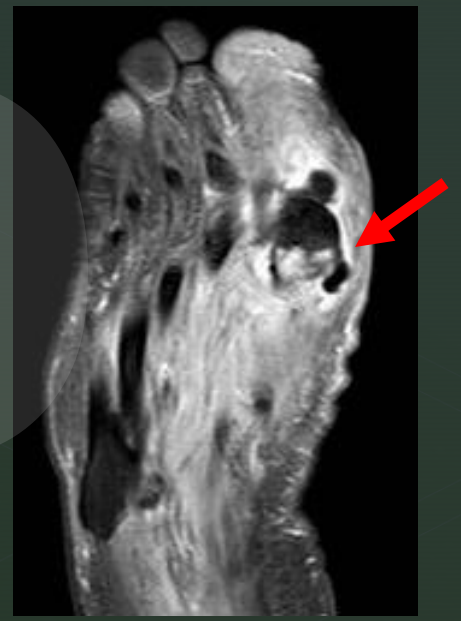
Long-axis T1 and STIR sequences; the long-axis T1 sequence shows T1 marrow replacement, our most sensitive indicator for osteomyelitis

Short and long-axis and T1 fat saturated post-contrast sequences



Key Point

Contrast helps us look for complications of osteomyelitis, such as abscess formation, sinus tracts, devitalized bone



3 MSK Scenarios using Appropriateness Criteria

Scenario #2	54 year old female with chronic bilateral wrist pain, suspect rheumatoid arthritis
Question?	What is the best initial study?

Rheumatoid Arthritis

Scenario #2

New 2016

American College of Radiology
ACR Appropriateness Criteria®
Chronic Extremity Joint Pain–Suspected Inflammatory Arthritis

Variant 1: **Chronic extremity joint pain. Suspect rheumatoid arthritis.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray appendicular skeleton area of interest	9	This procedure is the initial imaging method.	☢
MRI appendicular skeleton area of interest without IV contrast	7	This procedure complements x-ray.	O
MRI appendicular skeleton area of interest without and with IV contrast	7	This procedure complements x-ray.	O
US appendicular skeleton area of interest	7	This procedure complements x-ray.	O
CT appendicular skeleton area of interest without IV contrast	4		Varies
CT appendicular skeleton area of interest with IV contrast	3		Varies
FDG-PET/CT whole body	2		☢☢☢☢
Tc-99m bone scan whole body	2		☢☢☢
CT appendicular skeleton area of interest without and with IV contrast	1		Varies

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

*Relative Radiation Level

Rheumatoid Arthritis

LEFT

RIGHT

Key Findings

- Periarticular erosion
- Fusion of the carpus
- Subluxations at the MCP joints

Other findings that might suggest RA:

Periarticular osteopenia (which is difficult to evaluate for in this case due to the patient's osteoporosis), soft tissue swelling, subchondral cysts

Rheumatoid Arthritis

So…which one do I pick?

American College of Radiology
ACR Appropriateness Criteria®
Chronic Extremity Joint Pain–Suspected Inflammatory Arthritis

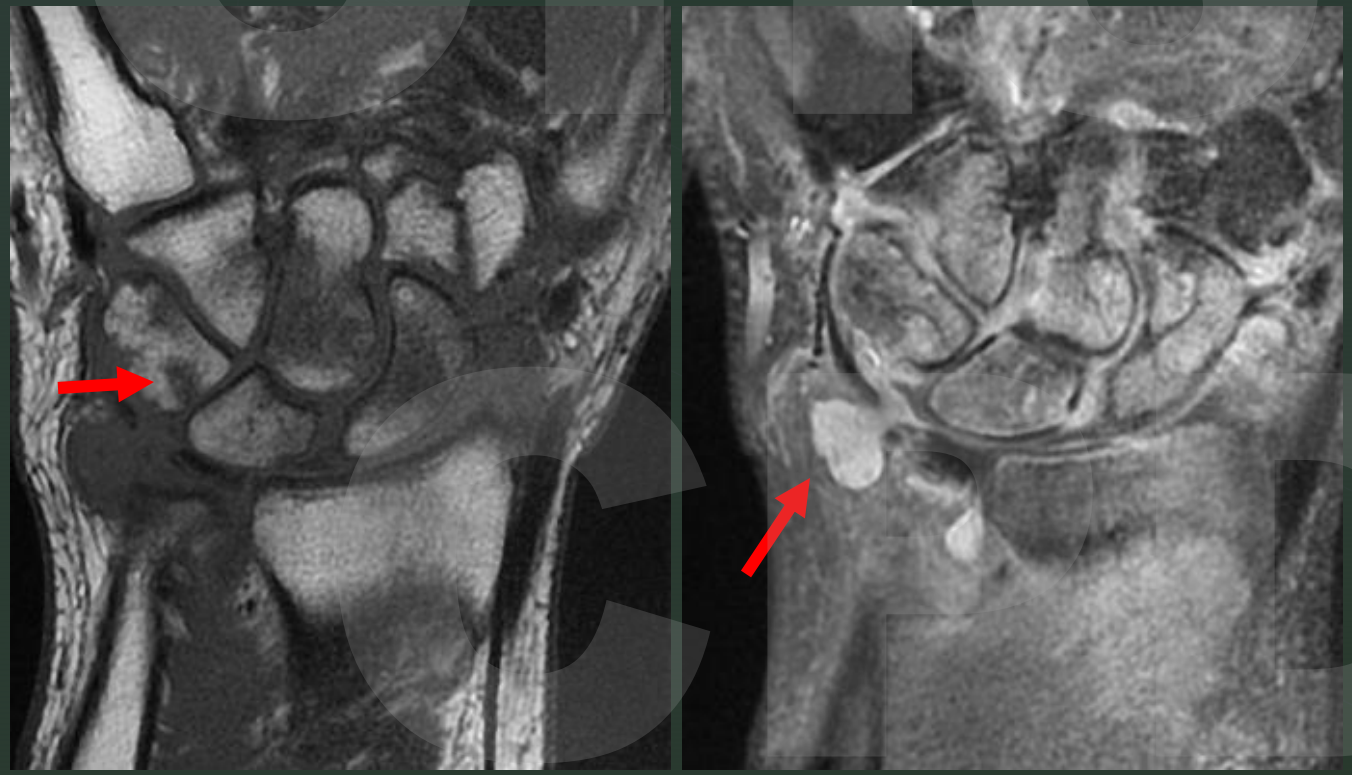
Variant 1: **Chronic extremity joint pain. Suspect rheumatoid arthritis.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray appendicular skeleton area of interest	9	This procedure is the initial imaging method.	☢
MRI appendicular skeleton area of interest without IV contrast	7	This procedure complements x-ray.	O
MRI appendicular skeleton area of interest without and with IV contrast	7	This procedure complements x-ray.	O
US appendicular skeleton area of interest	7	This procedure complements x-ray.	O
CT appendicular skeleton area of interest without IV contrast	4		Varies
CT appendicular skeleton area of interest with IV contrast	3		Varies
FDG-PET/CT whole body	2		☢☢☢☢
Tc-99m bone scan whole body	2		☢☢☢
CT appendicular skeleton area of interest without and with IV contrast	1		Varies

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

*Relative Radiation Level

Rheumatoid Arthritis



Coronal T1 and proton density fat saturated sequences

MRI is a good tool to further evaluate osseous erosions, synovitis and tenosynovitis; contrast for better depiction of synovitis and tenosynvoitis.

Some debate of MRI vs. US

Inflammatory Arthropathy

Question?

Do you think that the imaging recommendations for all inflammatory arthropathies are the same?

American College of Radiology
ACR Appropriateness Criteria®
Chronic Extremity Joint Pain–Suspected Inflammatory Arthritis

Variant 1: **Chronic extremity joint pain. Suspect rheumatoid arthritis.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray appendicular skeleton area of interest	9	This procedure is the initial imaging method.	☢
MRI appendicular skeleton area of interest without IV contrast	7	This procedure complements x-ray.	O
MRI appendicular skeleton area of interest without and with IV contrast	7	This procedure complements x-ray.	O
US appendicular skeleton area of interest	7	This procedure complements x-ray.	O
CT appendicular skeleton area of interest without IV contrast	4		Varies
CT appendicular skeleton area of interest with IV contrast	3		Varies
FDG-PET/CT whole body	2		☢☢☢☢
Tc-99m bone scan whole body	2		☢☢☢
CT appendicular skeleton area of interest without and with IV contrast	1		Varies

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate — *Relative Radiation Level

Rheumatoid Arthritis

Variant 3: **Chronic extremity joint pain. Suspect gout.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray appendicular skeleton area of interest	9	This procedure is the initial imaging method.	☢
CT appendicular skeleton area of interest without IV contrast	7	This refers specifically to dual-energy CT and complements x-ray.	Varies
US appendicular skeleton area of interest	7	This procedure complements x-ray.	O
MRI appendicular skeleton area of interest without IV contrast	6		O
MRI appendicular skeleton area of interest without and with IV contrast	5		O
CT appendicular skeleton area of interest with IV contrast	1		Varies
CT appendicular skeleton area of interest without and with IV contrast	1		Varies
FDG-PET/CT whole body	1		☢☢☢☢
Tc-99m bone scan whole body	1		☢☢☢

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate — *Relative Radiation Level

Gout

3 MSK Scenarios using Appropriateness Criteria

Scenario #3	25 year-old male with knee trauma
Question?	What is the best initial study?
	If you think there is an occult fracture (on x-ray), what is your next study of choice?
	If you think there is a ligament or tendon tear, what is your next study of choice?

Knee Trauma

Clinical Condition: Acute Trauma to the Knee

Variant 5: Adult or child >1 year old. Injury to knee, mechanism unknown. Focal patellar tenderness, effusion, able to walk.

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee	9	Consider this procedure if it was not previously obtained or if patella views were not included.	☢
MRI knee without IV contrast	5		O
US knee	2		O
CT knee without IV contrast	2	The RRL for the adult procedure is ☢.	☢☢
Tc-99m bone scan with SPECT lower extremity	2		☢☢☢
MRI knee without and with IV contrast	1		O
MRA knee without and with IV contrast	1		O
MRA knee without IV contrast	1		O
CT knee with IV contrast	1	The RRL for the adult procedure is ☢.	☢☢
CT knee without and with IV contrast	1	The RRL for the adult procedure is ☢.	☢☢

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate — *Relative Radiation Level

Variant 6: Adult or child >1 year old. Significant trauma to the knee from motor vehicle accident, suspect knee dislocation.

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee	9	This procedure should be an initial examination to assess overall injury. A normal x-ray does not preclude further imaging workup for vascular or ligament injury.	☢
MRI knee without IV contrast	9	This procedure is necessary to evaluate the extent of damage to ligaments and other support structures.	O
MRA knee without and with IV contrast	7	This procedure should be performed in conjunction with MRI of the knee.	O
Arteriography lower extremity	7	The RRL for the adult procedure is ☢☢.	☢☢☢
CTA lower extremity with IV contrast	7	This procedure should be performed in conjunction with trauma CT imaging. The RRL for the adult procedure is ☢☢☢.	☢☢☢☢
MRA knee without IV contrast	3	This procedure should be performed in conjunction with MRI of knee.	O
US knee	2		O
CT knee without IV contrast	2	The RRL for the adult procedure is ☢.	☢☢
Tc-99m bone scan with SPECT lower extremity	2		☢☢☢
MRI knee without and with IV contrast	1		O
CT knee with IV contrast	1	The RRL for the adult procedure is ☢.	☢☢
CT knee without and with IV contrast	1	The RRL for the adult procedure is ☢.	☢☢

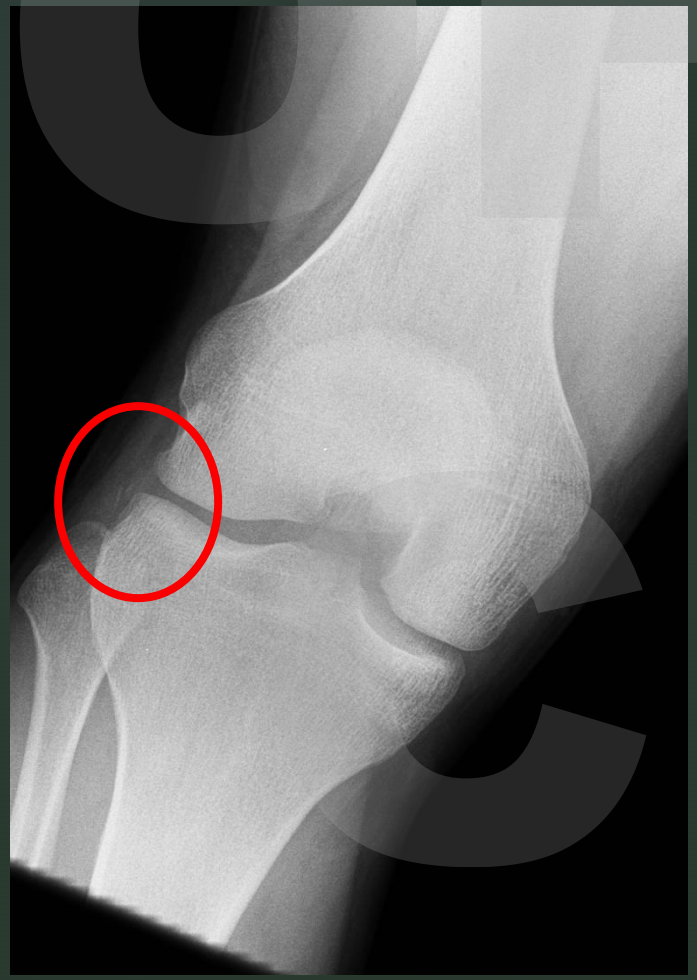
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate — *Relative Radiation Level

Notice the difference between recommendations with the different variants:

i.e., if suspect a knee dislocation

i.e., if there has been MVC

Knee Trauma



AP view of the knee shows a small osseous avulsion at the lateral tibial plateau of the knee.

Question?

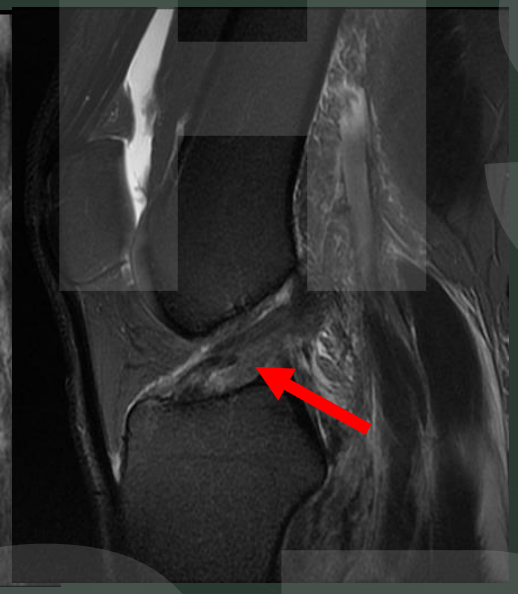
What might this represent?

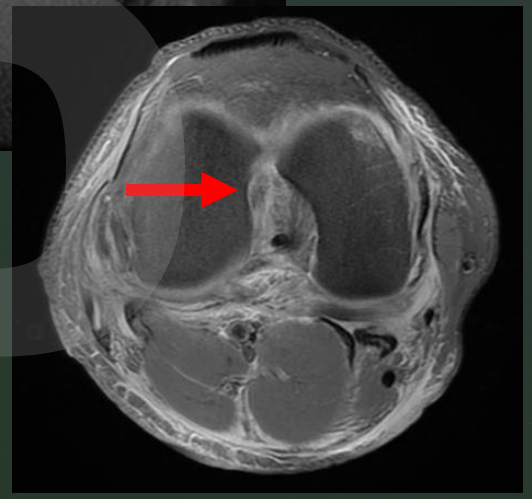
A Segond fracture
75% of cases are associated with an ACL tear

Key Point

Findings in the initial imaging study may dictate or suggest the need for further imaging (and the type of study needed)

Knee Trauma





Sagittal proton density and T2 fat-saturated sequences confirm a disruption at the mid-portion of the ACL

ACL disruptions are often associated with other injuries; in this case, there was also a posterolateral corner injury (popliteus tendon, biceps femoris tendon tear – not shown), further emphasizing the need for MRI

Summary

Radiographs

- Great initial study
- Excellent spatial resolution
- Trauma
- Arthritis
- Infection
- Malignancy
- Foreign bodies

CT

- Better delineate fracture planes
  - Often used for surgical planning
- Software (i.e., DECT) that can play a role in conditions like gout
- Hardware complications

Summary

MRI

- Non-displaced fractures in the elderly
- Bone marrow edema
- Soft tissue injury (i.e., ligaments, tendons)
- Infection, inflammation
- Neoplastic disease

Ultrasound

- Tendon and ligament injury
- Muscle injury
- Foreign bodies
- Dynamic imaging
- Soft tissue tumor biopsy

Ask your local radiologist

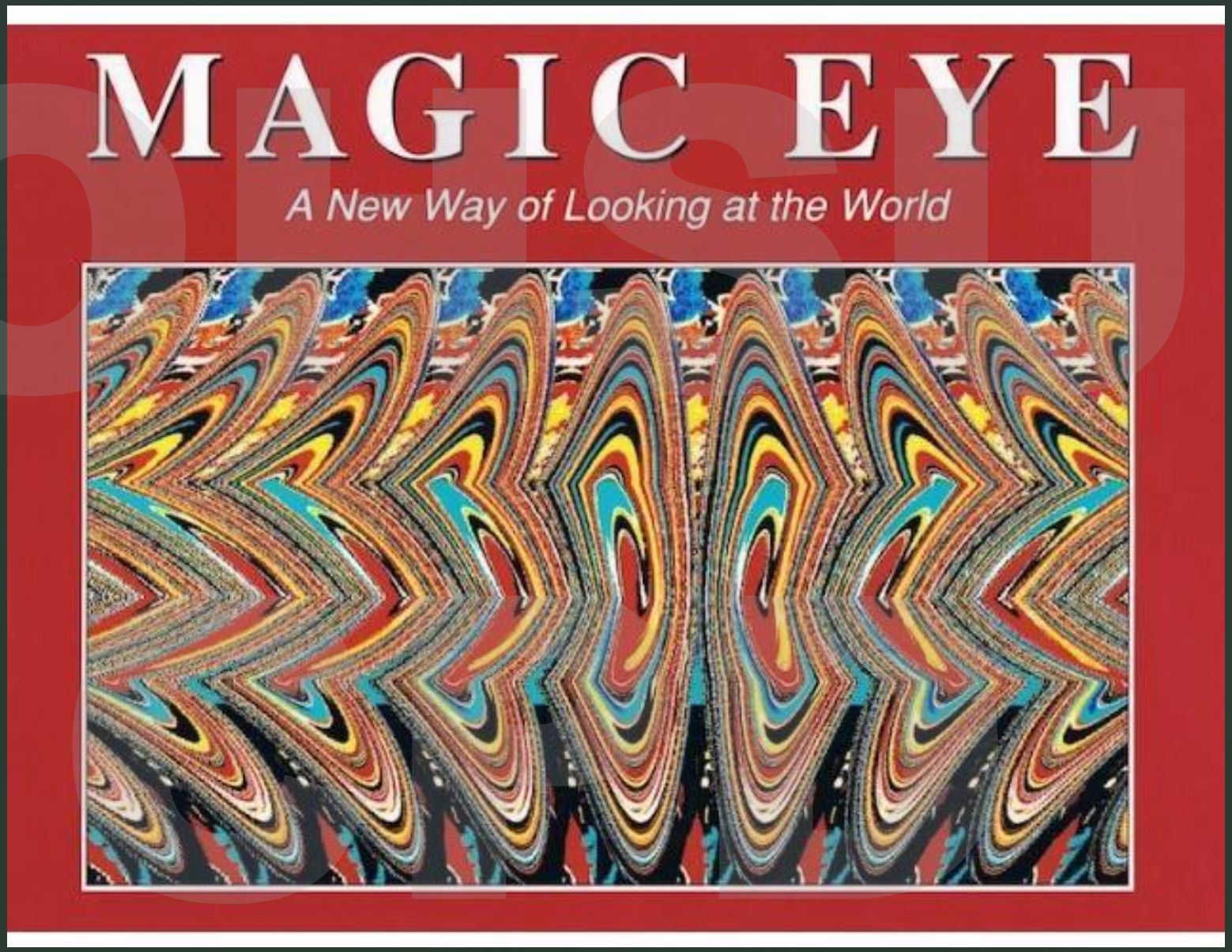
- Does it need contrast?
- Is it even ok to give contrast?
- Contrast allergies
- MRI safety

Transition Time

OHSU

CPD

How to approach a bone x-ray


MAGIC EYE
A New Way of Looking at the World

Systematic Approach

- Patient and Image Data
- Bone and Joint Alignment
- Joint Spacing
- Cortical Alignment/Integrity
- Bone Density/Texture *(Did he just say bone texture?)*
- Soft Tissues

Patient and Image Data

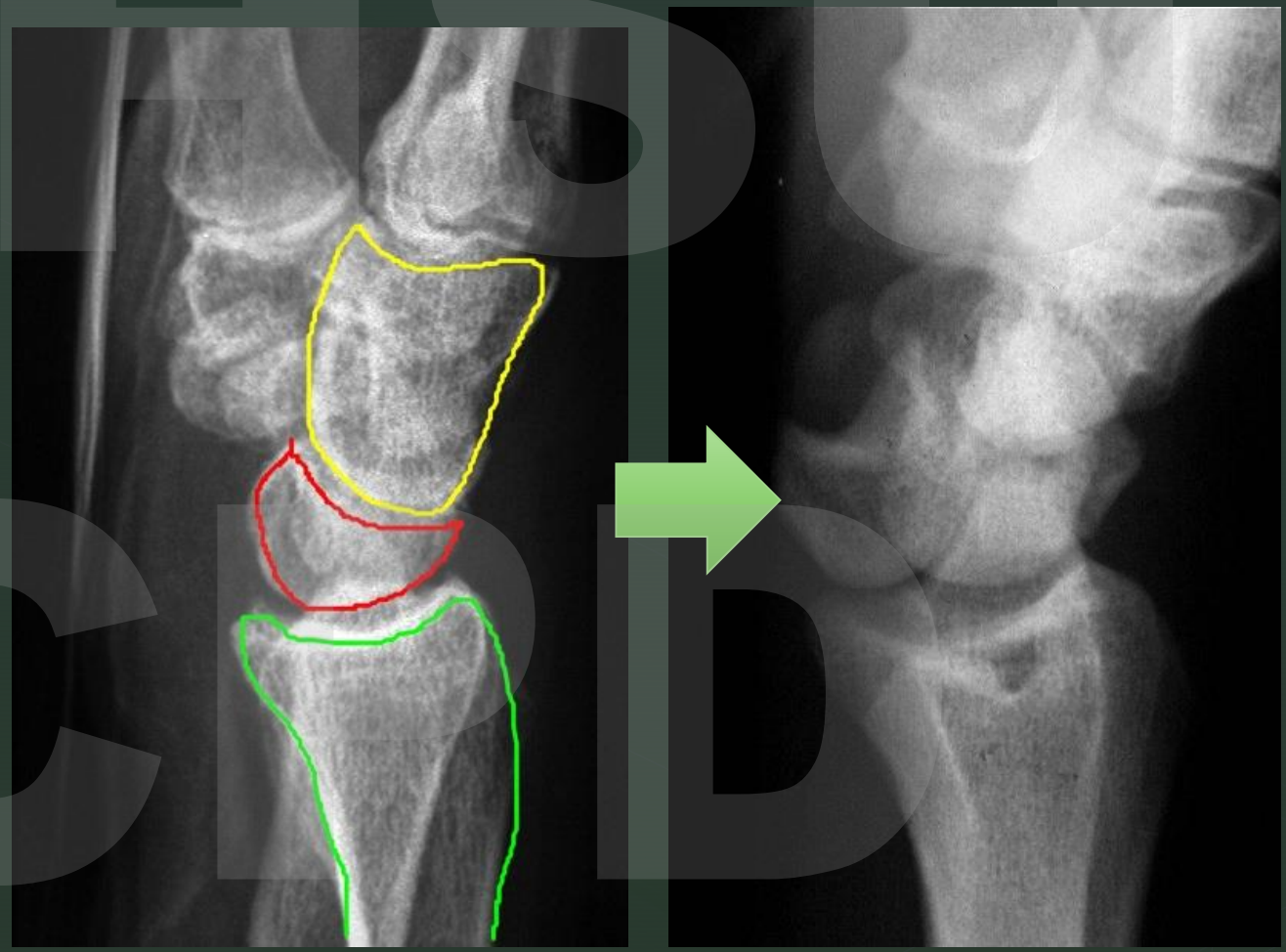
- Age
- Technique

Bone and Joint Alignment

- Malalignment is sometimes just bad positioning

Bone and Joint Alignment

Radius-lunate-capitate should all line up on a lateral view



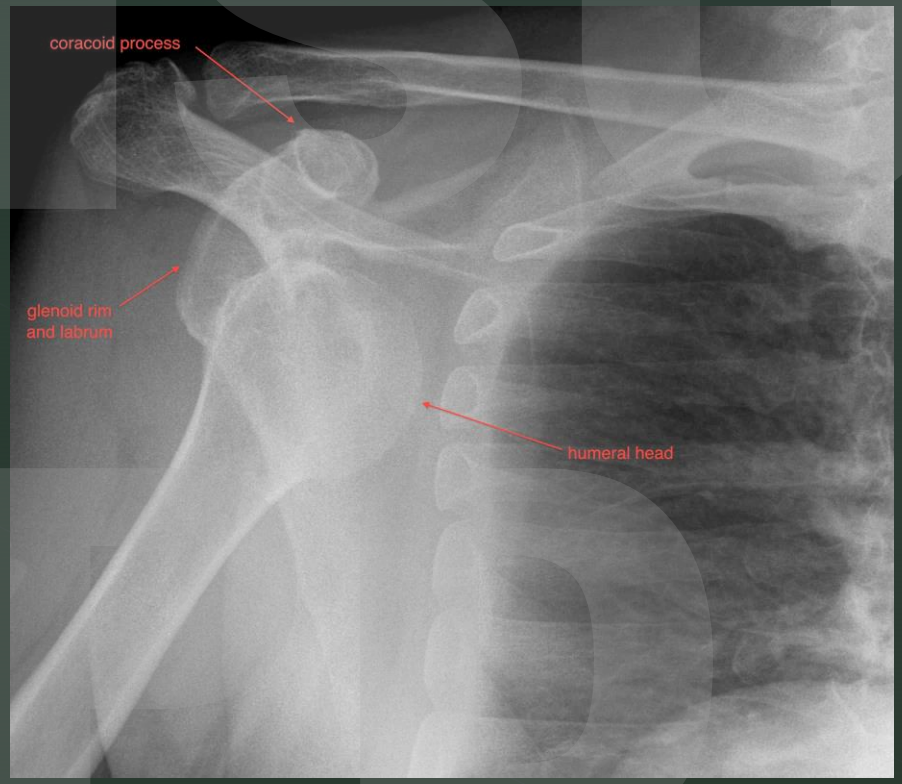
Bone and Joint Alignment

Carpal arcs

or

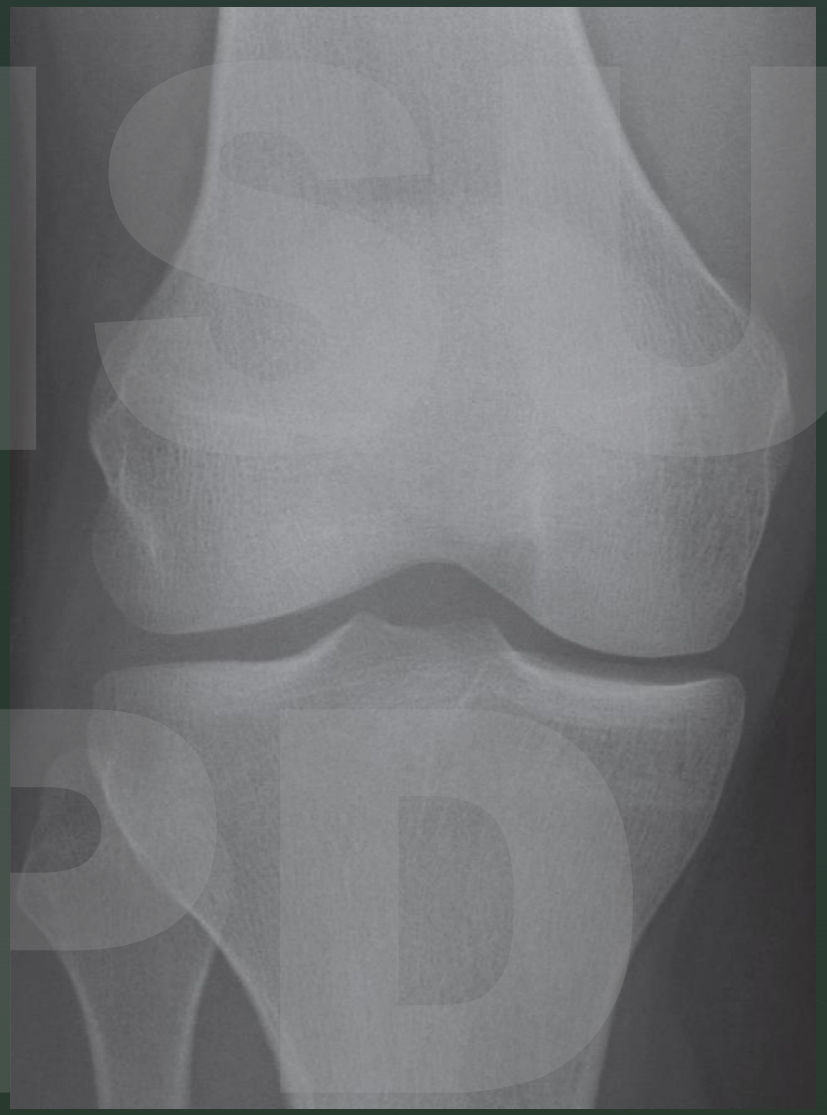
Arcs of Gilula

- Bone and Joint Alignment



Joint Spacing

- Cartilage Loss
- Fracture/Dislocation



Joint Spacing

- Cartilage Loss
- Fracture/Dislocation

Cortical Outline

- Follow the outline of all bones on the exam

Cortical Outline

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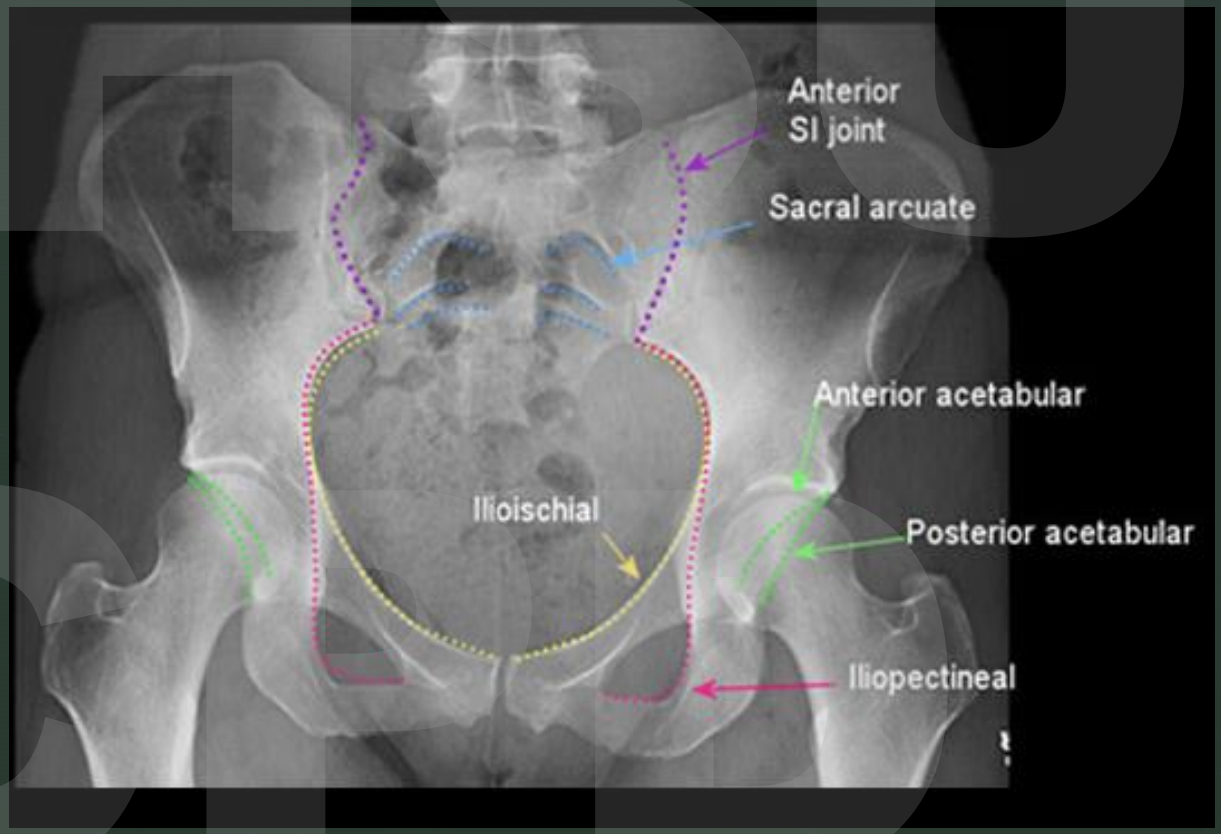
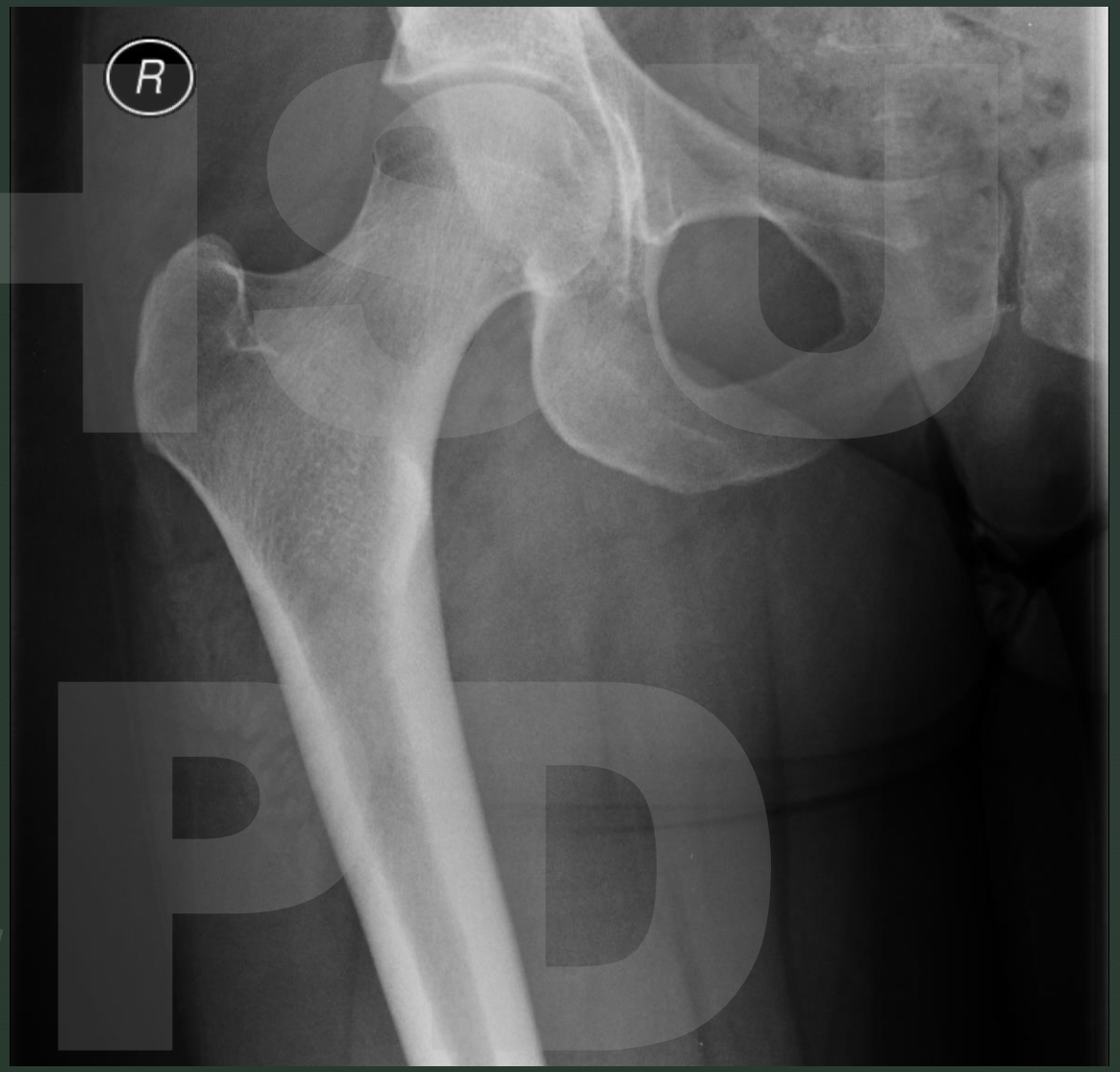
Cortical Outline



Bone Texture

- Normal vs abnormal trabeculae
- Overall mineralization



Bone Texture

- Normal vs abnormal trabeculae
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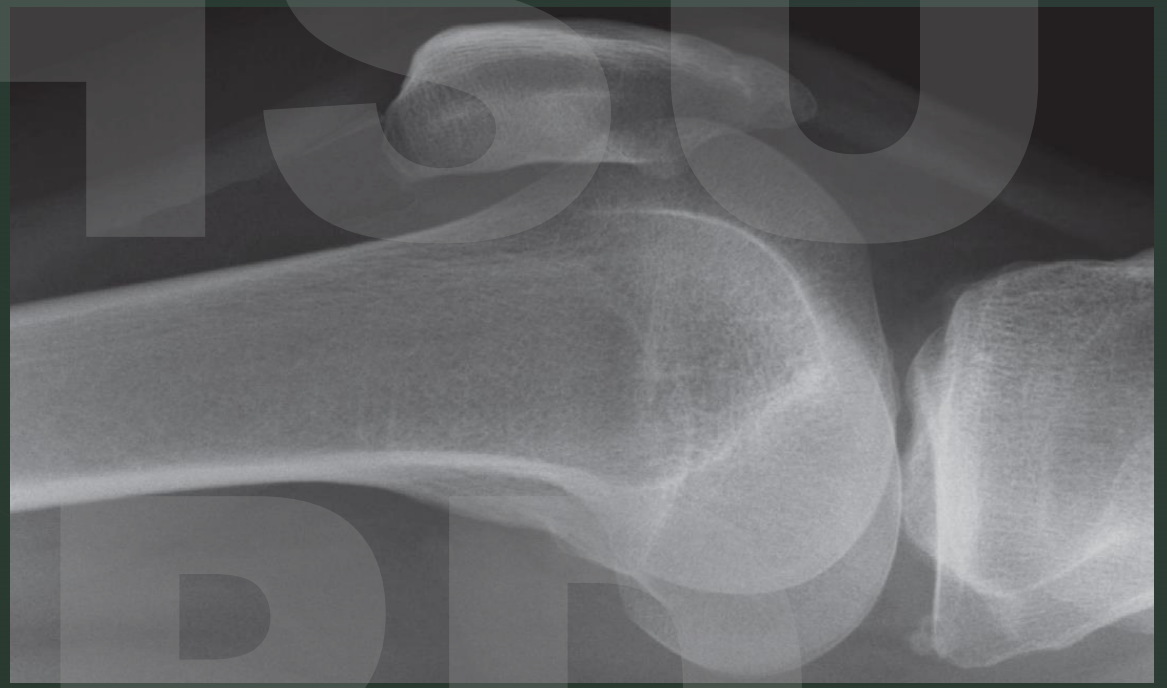
Soft Tissues

- Effusion
- Occult fracture



Soft Tissues

- Effusion
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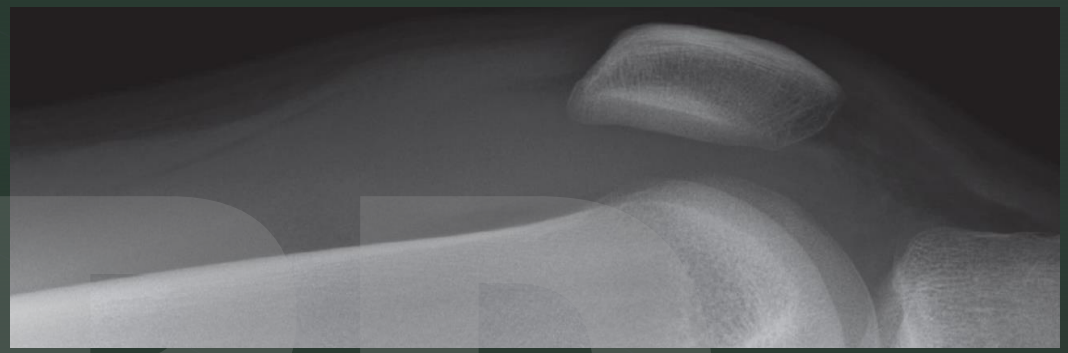


SOFT TISSUES

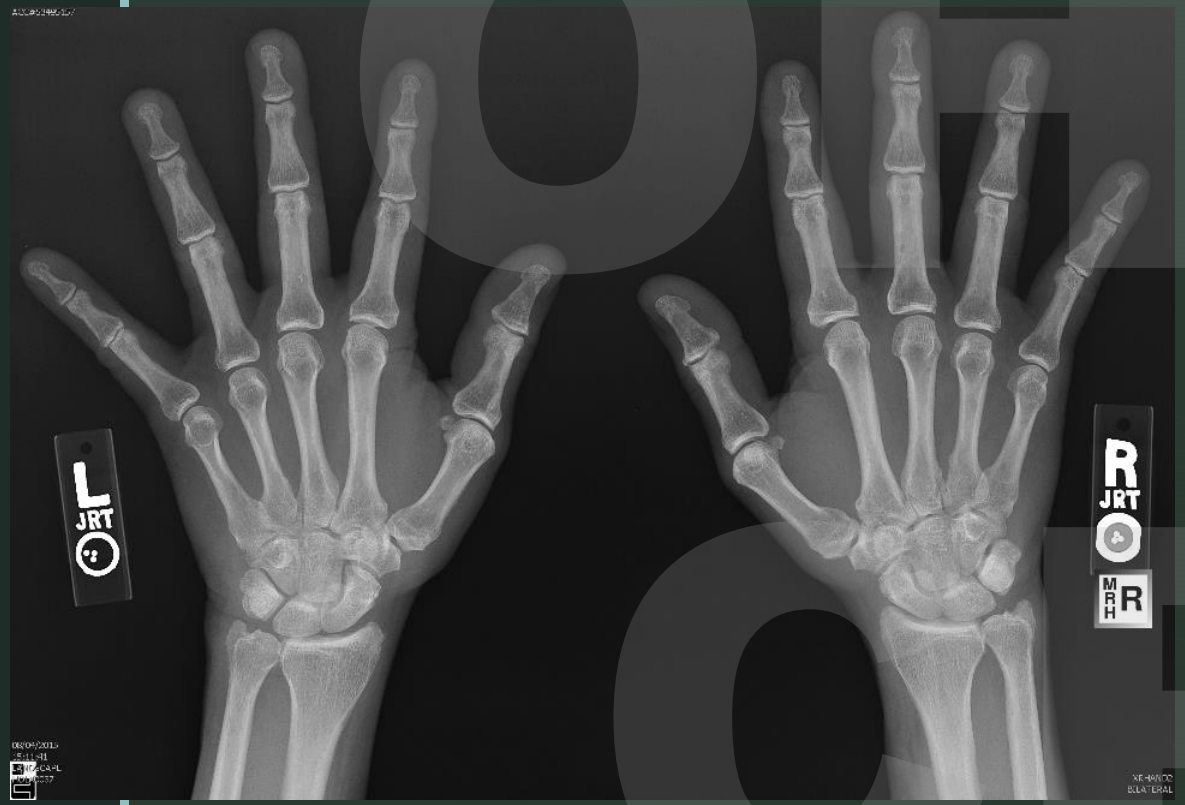
OHSU CPD

CASES

Case 1

66 year old male fell holding a glass bowl, and the bowl shattered on the ground. The patient is now having hand pain, and on physical exam has multiple cuts and scrapes on the palmar surface of his hand.

What is your first test?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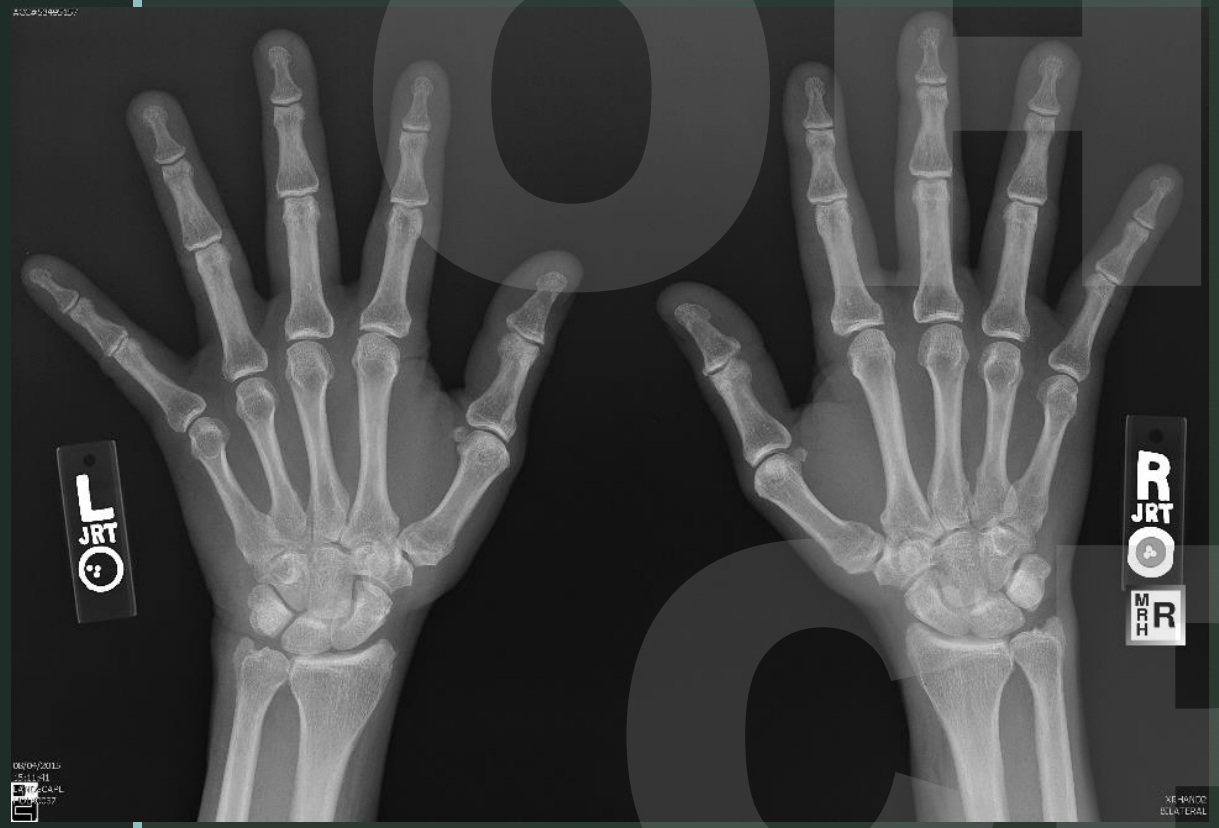
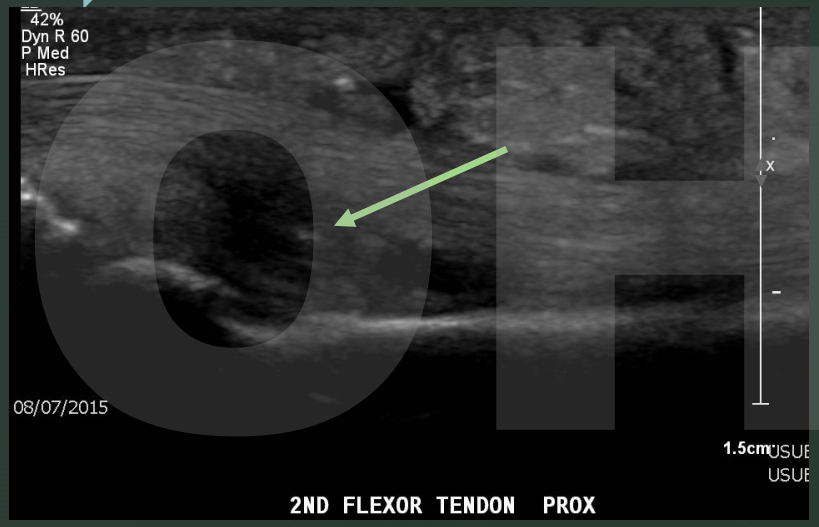
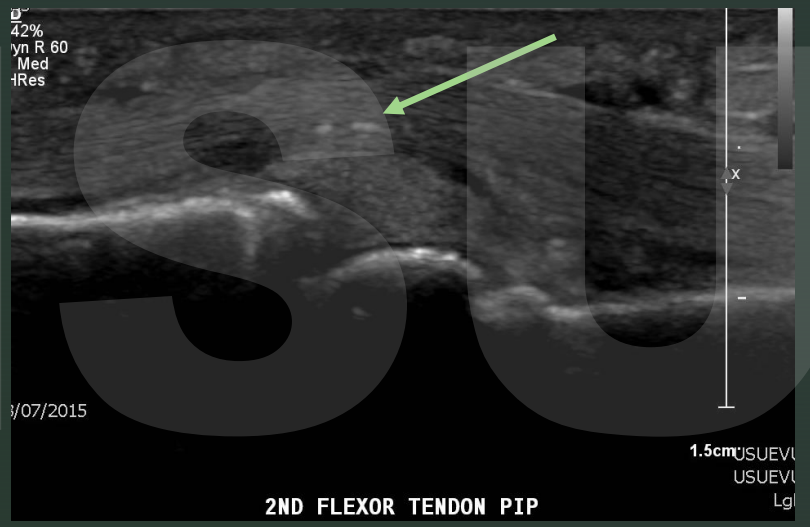
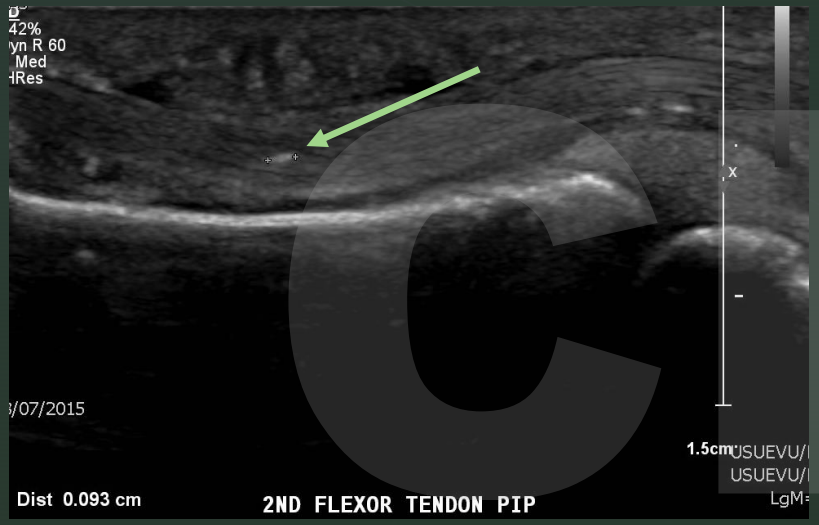


Are you satisfied with the results from this examination? If not, what would your next step be?

A. Yes, I'm satisfied
B. No, I'm not, I'll do another physical exam and get back to you
C. No, I'm not, let's order a CT
D. No, I'm not, let's order an ultrasound
E. No, I'm not, let's order an MRI







Ultrasound shows multiple echogenic foci located in the soft tissues of the finger, also lodged in the tendon

These reflect foreign bodies, shards of glass, from the patient's initial trauma

Case 2

44 year old female with knee pain. “Trauma?”

What is your first test?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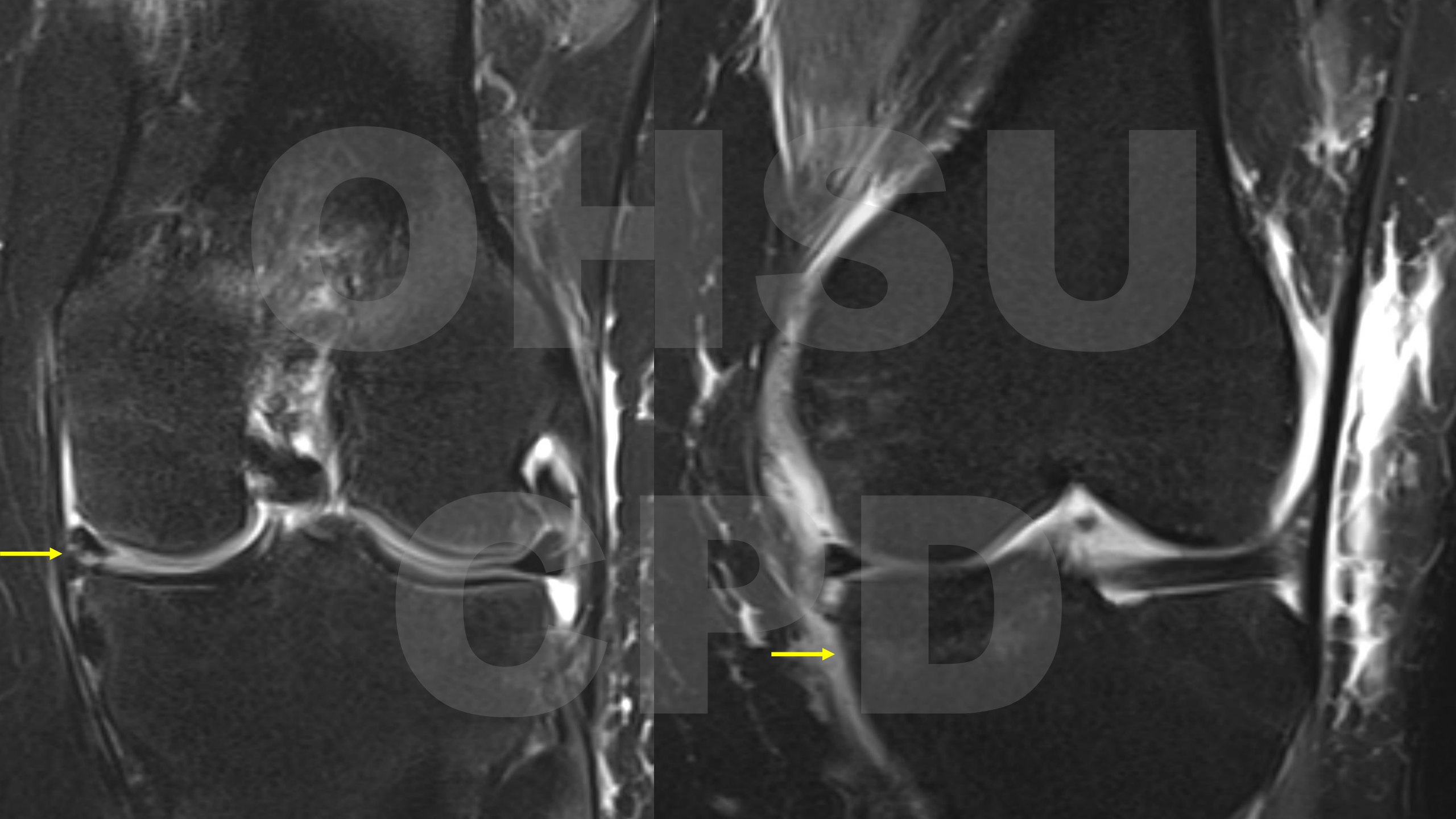
CPD


OHSU
CIRD

Case 3

60 year old female with left hip pain after fall

What is your first test?


R
JAS

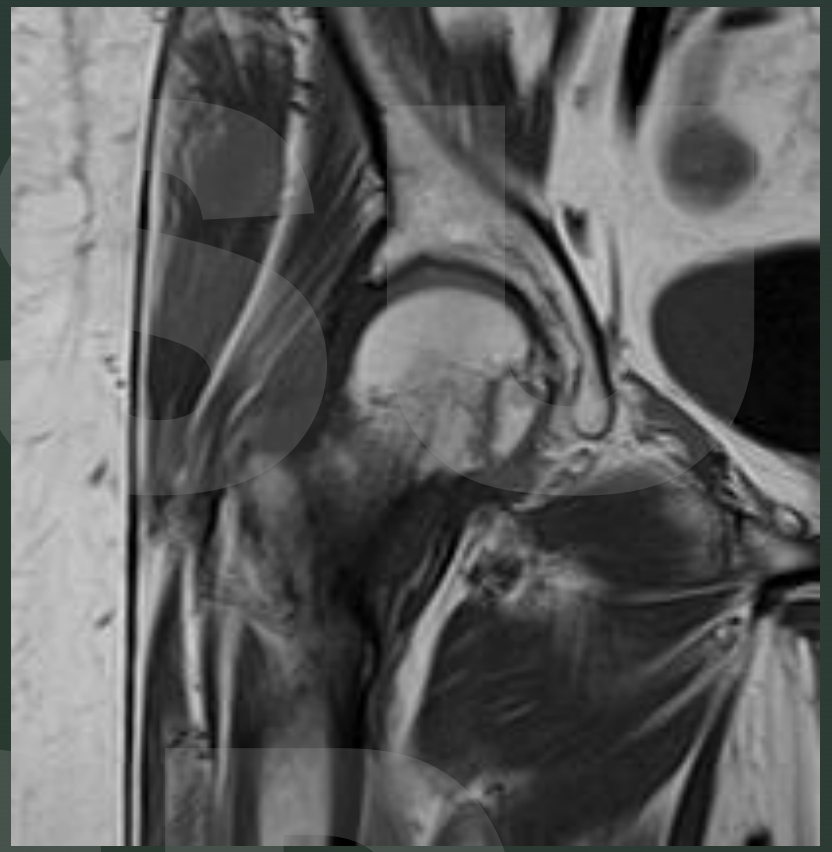
Case

85 year old female with hip pain after fall

What is your first test?

Are you satisfied with the results from this examination? If not, what would your next step be?

A. Yes, I'm satisfied
B. No, I'm not, I'll do another physical exam and get back to you
C. No, I'm not, let's order a CT
D. No, I'm not, let's order an ultrasound
E. No, I'm not, let's order an MRI



MRI shows that there is indeed a non-displaced fracture line through the medial femoral head

Objectives

- Reviewed different imaging modalities and their use in musculoskeletal imaging
  - Specifically, the role of different imaging modalities in various clinical scenarios
- Discussed the different resources available when trying to decide what to order
- Overview of basic radiograph interpretation with case examples

OHSU

Thank you!

CPD