Overview:

1. Introduction: Fast Facts
2. Review of Anatomy
3. Available Imaging Guidelines: ACR Appropriateness Criteria, Diagnostic Imaging Pathways
4. Routine Radiographic Evaluation
5. Basic MRI Protocol for the Hip
6. Basic CT Protocol for the Hip
7. Basic Ultrasound Protocol for the Hip
8. What does it Look Like? Illustrated Pathology

1. Introduction: Fast Hip Facts

- The Pathologies

- Newborns:
  - Developmental dysplasia of the hip (DDH) covers a range of hip instability, from laxity to dislocation. Estimates are 1 in 100 births present with hip subluxation, 1 in 1000 with dislocation. The left hip is more often affected, due to intrauterine positioning of the hip in adduction against the mother’s spine.

- Children: Remember that hip problems often present as referred pain in the thigh or knee:
  - Transient synovitis is an inflammatory reaction of the joint that often occurs after an upper respiratory infection.
  - Legg-Calve-Perthes is an expression of avascular necrosis of the femoral head; boys are more often affected.
  - Juvenile rheumatoid arthritis covers a subset of conditions that may be self-limiting or chronic. Peak ages of presentation are 7-12. Girls are more often affected.
- **Septic arthritis**, **septic bursitis**, or **osteomyelitis** are terms for infection in the joint, bursa, or bone.

  - **Teenagers:**
    - **Slipped femoral capital epiphysis** is a posteromedial displacement of the femoral head due to a weakening of the growth plate at the femoral head-neck junction. It is most common in adolescent boys during growth spurts at puberty.
    - **Snapping hip syndrome** is the audible “snap” of tendons gliding abnormally over bone. Most common is the iliotibial band moving over the greater trochanter. Also possible is the iliopsoas tendon moving over the iliopsoas eminence at the anterior acetabulum, and the rectus femoris tendon gliding over the femoral head.
    - **Femoroacetabular impingement** results from abutment of the femoral neck with the acetabulum. Pain is exacerbated in the athlete due to repetitive movements and the greater amount of flexion incurred during activities. Tears of the acetabular labrum are highly associated with this condition.

  - **Adults:**
    - **Osteoarthritis**: is the most common form of joint disease in humans and is a leading cause of disability among the elderly. Over 300,000 total hip replacements are performed annually in the USA.
    - **Osteoporosis**: The most devastating sequela of osteoporosis is fracture. 90% of hip fractures occur due to falls. Most often affected are elderly females due to less bone density to begin with, and longer life spans than males. Mortality rates increase significantly in the first year after a hip fracture.

- **The Imaging Choices**
  - **Radiographs** adequately demonstrate most fractures and dislocations at the hip and pelvis as well as non-traumatic disorders such as the various arthritides.
  - **Computed tomography (CT)** provides optimal visualization of complex fracture characteristics especially in characterizing fractures of the acetabulum or in localizing the position of fracture fragments.
  - **Magnetic resonance imaging (MRI)** is best for evaluating injuries to the acetabular labrum, articular cartilage, assessing femoroacetabular impingement, and in the assessment and staging of avascular necrosis of the femoral head.
  - **Musculoskeletal ultrasound (MSUS)** is primary for the detection of DDH in the neonatal hip. The origin of a snapping hip syndrome can be discerned by active movements during the examination. MSUS can determine the characteristics of an effusion or can guide an aspiration procedure.

- **The Available Guidelines**
  - **ACR Appropriateness Criteria**: Currently, eight presentations of chronic hip pain, five presentations of avascular necrosis of the hip, and nine presentations of stress fractures have been researched.
  - **Diagnostic Imaging Pathways**: Pathway diagrams for guiding clinical decision making have been established for the assessment of 1) non-traumatic hip pain, 2) suspected hip fracture, 3) avascular necrosis of the hip, and 4) suspected stress fracture.
2. Review of Anatomy

3. Available Imaging Guidelines

- **Appropriateness criteria** are evidence-based guidelines developed by expert consensus of professional groups to assist clinicians in choosing which imaging modality to order for a specific clinical condition. The *American College of Radiology (ACR)* publishes criteria for the *chronic hip pain* and for *avascular necrosis (osteonecrosis) of the hip*. *(See [www.acr.org](http://www.acr.org) for updated and complete criteria..this copy has not been approved for publishing and is used for purposes of this lecture only)*

  o See Table 5.1 for ACR Appropriateness Criteria for Chronic Hip Pain.

  o See Table 5.2 for ACR Appropriateness Criteria for Avascular Necrosis of the Hip

Also included in this chapter are appropriateness criteria for evaluation of stress fractures. **Stress fractures** are of **two** varieties: **fatigue fractures**, due to *abnormal stress on normal bone*; and **insufficiency fractures**, due to *normal stress on abnormal (demineralized) bone*. Fatigue fractures are often *associated with athletic activity* and commonly occur in the lower leg and foot. Insufficiency fractures are often *associated with osteoporosis* and commonly occur in the vertebrae, sacrum, pubic rami, and femoral neck.

  o See Table 5.3 for Appropriateness Criteria for Stress (Fatigue/Insufficiency) Fracture, Including Sacrum, Excluding Vertebrae

- **Diagnostic Imaging Pathways** are evidence-based guidelines established by the *Government of Western Australia’s Department of Health* to assist in decision-making for different clinical scenarios. Presented as decision-tree flow charts, the content is concordant with the above ACR criteria. Three pathways are given:

  o See Table 5-4 for Diagnostic Imaging Pathway for Non-Traumatic Hip Pain
  o See Table 5-5 for Diagnostic Imaging Pathway for Suspected Hip Fracture
  o See Table 5-6 for Diagnostic Imaging Pathway for Avascular Necrosis of the Hip
  o See Table 5-7 for Diagnostic Imaging Pathway for Suspected Stress Fracture
<table>
<thead>
<tr>
<th>Eight Clinical Variants</th>
<th>Usually Appropriate</th>
<th>May be Appropriate</th>
<th>Usually NOT Appropriate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1: Initial Evaluation</strong> for chronic hip pain, first test.</td>
<td>o X-ray pelvis</td>
<td></td>
<td>o MRI</td>
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<td></td>
<td>o X-ray hip</td>
<td></td>
<td>o US</td>
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<td></td>
<td>o CT</td>
<td></td>
<td>o CT</td>
</tr>
<tr>
<td></td>
<td>o Bone scan</td>
<td></td>
<td>o Arthrography</td>
</tr>
<tr>
<td><strong>2: Radiographs nondiagnostic, suspect osseous or surrounding tissue abnormality</strong>, excluding osteoid osteoma</td>
<td>o MRI</td>
<td>MRI w/contrast</td>
<td>o CT or MR arthrography</td>
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<td></td>
<td></td>
<td></td>
<td>o US</td>
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<td></td>
<td>o CT</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>o Bone scan</td>
</tr>
<tr>
<td><strong>3: Radiographs nondiagnostic, suspect osteonecrosis due to known predisposing factors</strong></td>
<td>o MRI w/ or w/o contrast</td>
<td>Bone scan</td>
<td>o US</td>
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<td>o CT</td>
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<td></td>
<td></td>
<td></td>
<td>o Arthrography</td>
</tr>
<tr>
<td><strong>4: Radiographs nondiagnostic, suspect osteoid osteoma</strong></td>
<td>o CT without contrast</td>
<td></td>
<td>o Bone Scan</td>
</tr>
<tr>
<td></td>
<td>o MRI w/ or w/o contrast</td>
<td></td>
<td>o CT or MR arthrography</td>
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<td></td>
<td>o US</td>
</tr>
<tr>
<td><strong>5: Radiographs nondiagnostic, suspect labral tear, w/ or w/o findings suggestive of femoroacetabular impingement</strong></td>
<td>o MR arthrography</td>
<td>MRI w and w/o contrast</td>
<td>o Bone Scan</td>
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<tr>
<td></td>
<td>o CT arthrography</td>
<td></td>
<td>o US</td>
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<tr>
<td><strong>6: Radiographs nondiagnostic, or mild osteoarthritis. Suspect referred pain but wish to exclude hip joint source</strong></td>
<td>o X-ray arthrography hip with anesthetic +/- corticosteroid</td>
<td>MRI w/o contrast</td>
<td>o CT or MR arthrography</td>
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<td>o Bone Scan</td>
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<td>o US</td>
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<tr>
<td><strong>7. Radiographs positive, arthritis of uncertain type. Infection not a consideration.</strong></td>
<td>MRI w/ or w/o contrast if process is atypical</td>
<td></td>
<td>o CT or MR arthrography</td>
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<td></td>
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<td></td>
<td>o Bone Scan</td>
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<td>o US</td>
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<tr>
<td><strong>8. Radiographs positive, suggestive of pigmented villonodular synovitis or osteochondromatosis.</strong></td>
<td>o MRI w/o contrast</td>
<td>CT arthrography if MRI not available or contraindicated</td>
<td>o MR arthrography</td>
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<td></td>
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<td>o CT</td>
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<td>o Bone Scan</td>
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<td>o US</td>
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<tr>
<td>Five Clinical Variants</td>
<td>Usually Appropriate</td>
<td>May be Appropriate</td>
<td>Usually NOT Appropriate</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1. <strong>Initial study</strong> when avascular necrosis (AVN) is suspected clinically.</td>
<td>• X-ray pelvis</td>
<td>• MRI may be useful to detect occult AVN in opposite hip</td>
<td>• CT</td>
</tr>
<tr>
<td></td>
<td>• X-ray hip</td>
<td></td>
<td>• Bone scan</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• MRI</td>
</tr>
<tr>
<td>2. <strong>Radiographs positive for AVN and femoral head collapse</strong>. No surgery contemplated at this time.</td>
<td>• MRI may be useful to detect occult AVN in opposite hip</td>
<td></td>
<td>• CT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Bone scan—may be useful if MRI unavailable</td>
</tr>
<tr>
<td>3. <strong>Radiographs positive for AVN and femoral head collapse</strong>. Surgery contemplated.</td>
<td>• MRI may be useful to detect occult AVN in opposite hip or if surgical planning would be affected.</td>
<td></td>
<td>• CT—may be useful in planning osteotomy by defining the extent of bone deformity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Bone scan—may be useful if MRI unavailable</td>
</tr>
<tr>
<td>4. Radiographs show mottled femoral head, <strong>suspicious for AVN</strong>. Further evaluation needed.</td>
<td>• MRI hips</td>
<td>• Bone scan with SPECT is MRI unavailable or contraindicated.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CT if MRI unavailable or contraindicated</td>
<td></td>
</tr>
<tr>
<td>5. <strong>AVN suspected</strong> clinically, but radiographs are normal. Further evaluation needed.</td>
<td>• MRI hips</td>
<td>• Bone scan with SPECT is MRI unavailable or contraindicated.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CT if MRI unavailable or contraindicated</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.3 Appropriateness Criteria for Stress (Fatigue/Insufficiency) Fracture, Including Sacrum, Excluding Vertebrae

<table>
<thead>
<tr>
<th>Nine Clinical Variants</th>
<th>Usually Appropriate</th>
<th>May be Appropriate</th>
<th>Usually NOT Appropriate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1: Suspect stress fracture.</strong> First imaging modality.</td>
<td>o X-ray area of interest</td>
<td></td>
<td>o MRI o CT o Bone scan</td>
</tr>
<tr>
<td><strong>2: Radiographs normal, suspect stress fracture</strong> in patient with “need to know diagnosis”. Not hip or sacrum.</td>
<td>o X-ray area of interest and repeat in 10-14 days. o MRI if repeated X-rays are negative, or patient unable to wait for repeated X-ray.</td>
<td></td>
<td>o CT o Bone scan</td>
</tr>
<tr>
<td><strong>3: Radiographs normal. Bone scan positive</strong> and nonspecific. Not hip or sacrum.</td>
<td>o MRI area of interest. o X-ray area of interest and repeat in 10-14 days for confirmation or question of complication.</td>
<td>o CT if MRI contraindicated.</td>
<td>o CT w/ and w/o contrast o MRI w/ and w/o contrast.</td>
</tr>
<tr>
<td><strong>4: Suspect stress fracture in otherwise normal patient, radiographs are normal.</strong></td>
<td></td>
<td></td>
<td>o If pain is persistent, re-examine the diagnosis and consider MRI, looking for soft tissue injury.</td>
</tr>
<tr>
<td><strong>5: Radiographs normal, bone scan hot.</strong> Differentiate between fracture versus metastasis in long bones.</td>
<td>o MRI area of interest arthrography</td>
<td>o MRI w/ and w/o contrast o CT</td>
<td>o CT w/ and w/o contrast o Repeat X-rays</td>
</tr>
<tr>
<td><strong>6: Radiographs normal, bone scan hot.</strong> Differentiate between fracture versus metastasis in sacrum.</td>
<td>o CT sacrum is first choice; definitive for fracture. o MRI sacrum is alternative; may show other cause for pain</td>
<td></td>
<td>o CT w/ and w/o contrast o MR w/ and w/o contrast</td>
</tr>
<tr>
<td><strong>7. Radiographs normal. Bone scan hot. Suspect insufficiency fracture in sacrum/pelvis of elderly patient.</strong></td>
<td></td>
<td>o MRI or CT pelvis for confirmation</td>
<td>o CT w/ and w/o contrast o MR w/ and w/o contrast</td>
</tr>
<tr>
<td><strong>8. Radiographs normal, suspect</strong></td>
<td>One of these 3 should</td>
<td></td>
<td>o CT w/ and w/o</td>
</tr>
</tbody>
</table>
| Insufficiency fracture (any location) in **osteoportic patient** or patient on long-term **corticosteroid therapy.** | **be done:**  
- X-ray area of interest and repeat in 10-14 days.  
- MRI area of interest if diagnosis is urgent.  
- Bone scan whole body if diagnosis is urgent, realizing **false negatives are possible in this patient population.** | **contrast**  
- MR w/ and w/o contrast |  |
<table>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>9. Radiographs and bone scan normal within preceding 48 hours. Suspect insufficiency fracture (any location) in <strong>osteoportic patient</strong> or patient on long-term <strong>corticosteroid therapy.</strong></strong></td>
<td>MRI area of interest</td>
<td>X-ray area of interest and repeat in 10-14 days. <strong>Not sensitive for sacral lesions.</strong></td>
<td></td>
</tr>
</tbody>
</table>
Table 5-4 DIAGNOSTIC IMAGING PATHWAY FOR NON-TRAUMATIC HIP PAIN

NON-TRAUMATIC HIP OR KNEE PAIN

Clinical Assessment

Initial conservative treatment is appropriate

Plein Radiography of affected joint(s)

Cause for pain found

Further investigation as indicated by severity of symptoms and fitness for potential surgery

Mild Arthritis
Conservative management

Mod-Severe Arthritis
Referral to orthopaedics, if patient fit for- and requests surgery

Cause for pain still uncertain

Whether to further investigate will depend on the level of suspicion of a serious underlying disorder

If suspected fracture
Go to Suspected Hip Fracture Pathway

If suspected bone metastases
Go to Post-Traumatic Knee Pain Pathway

If suspected infection

Septic Arthritis
Joint Aspiration and Antibiotics

Osteomyelitis
Go to Suspected Osteomyelitis Pathway

Bone Scan generally preferred
Table 5-5 DIAGNOSTIC IMAGING PATHWAY FOR SUSPECTED HIP FRACTURE

1. SUSPECTED HIP FRACTURE
   - Plain Radiograph
     - Fracture Seen
       - Treat
     - No Fracture Seen
       - Ongoing suspicion of fracture?
         - No
           - Stop
         - Yes
           - MRI
             - Bone Scan
             - Other options include CT
Table 5-6  DIAGNOSTIC IMAGING PATHWAY FOR
SUSPECTED AVASCULAR NECROSIS OF THE HIP

SUSPECTED AVASCULAR NECROSIS (AVN) OF THE HIP

Plain Radiographs

Positive for AVN

Normal or non-specific changes

Plain Radiographs have limited sensitivity for AVN and further investigation may be necessary depending on the level of clinical suspicion

Low clinical suspicion

Higher clinical suspicion

Stop

The two main imaging options for further investigation are MRI and Bone Scan. MRI has a higher sensitivity and specificity and is generally preferred where available

Bone Scan

MRI

Appropriate management depending on imaging findings
Table 5-7  DIAGNOSTIC IMAGING PATHWAY FOR SUSPECTED STRESS FRACTURE

**SUSPECTED STRESS FRACTURE**

Plain Radiographs

- **Negative**
  - There are a number of options for management and the one chosen will depend on local resources, expertise and patient preference
    - Early Imaging
    - 3-Phase Bone Scan
      - Other options that may be useful in selected clinical circumstances include
        - MRI
        - CT

- **Positive**
  - Treat
    - Delayed Imaging
    - Repeat Plain Radiography after one month
      - Appropriate management depending on imaging findings

- **The primary indication** for routine radiographs of the pelvis or hip is to identify or exclude anatomic abnormalities or disease processes. Radiographs are almost always the first imaging study performed in the diagnostic investigation.

- The basic radiologic evaluation of the pelvis is the anteroposterior (AP) projection. The AP pelvis includes, by proximity, a basic AP evaluation of the bilateral hip joints. This is advantageous for bilateral comparison purposes, or to scout for trauma, or to identify the need for a unilateral hip radiograph.

- A unilateral hip radiographic examination is ordered when the hip or proximal femur is the area of interest. The central ray is centered over the femoral neck. This provides less distortion and greater radiographic detail of the proximal femur, acetabulum, and joint space.

- Two projections make up the routine radiologic examination of the hip:
  - Anterior-Posterior (AP)
  - Lateral frog leg

- A basic evaluation of a radiograph can be condensed to the ABCs:
  - A= Alignment
  - B= Bone density
  - C= Cartilage
  - S= soft tissues

- **Trauma** of the pelvis and hip can be divided into low or high energy injuries:
  - Low-energy injuries *(avulsions, individual bone fractures)* may be adequately evaluated with the routine projections or require various optional projections. Most common are AP oblique (Judet) views of the pelvis.
  - High-energy injuries *(those that disrupt the pelvic ring and are associated with life-threatening visceral injuries)* are evaluated with high-speed CT scanning to obtain a TAP *(thorax-abdomen-pelvis)* series. The advantage of a TAP is all the serious bodily injuries of the trauma patient are assessed in one time-saving examination.

- See Table 5.8 for a summary of Routine Radiographic Projections of the Pelvis and Hip.
Symmetry is evidenced by equal size of the iliac alae and obturator foramina on either side of midline. Asymmetry can indicate improper positioning of the patient or rotation of the innomates.

The articular surfaces of the sacroiliac joints are superimposed and appear as two radiolucent lines.

The hip joints are normally articulated in a ball-and-socket configuration.

Landmarks of the acetabulum are: acetabular roof, anterior rim, posterior rim, iliopubic (or ilipectineal) line, ilioischial line, radiographic teardrop.

The hip joint is normally a ball and socket shape unless bony destruction is present due to pathology.

Cortical margins on femoral shaft are normally thick and radiodense.

Normal spatial relationships is indicated by: (a) Shenton’s hip line: an arc formed by the superior obturator foramen to the medial aspect of the femoral neck, (b) the iliofemoral line: a curve along the outer surface of the ilium that extends along the femoral neck. (c) the femoral neck angle: averages 130 degrees.
The hip is positioned in flexion, external rotation, and lateral abduction; this rotates the femur 90 degrees from the AP projection.

The lesser trochanter is now seen in profile; the greater trochanter is superimposed behind the neck.

5. Basic MRI Protocol for the Hip

- **Indications** for MRI of the pelvis or hip include assessment of:
  - osteonecrosis of the femoral head
  - marrow abnormalities
  - radiographically occult fractures
  - childhood hip disorders and their adult sequela
  - femoroacetabular impingement
  - acetabular labral tears
  - musculotendinous disorders and associated bursitises
  - athletic pubalgia
  - osteochondral abnormalities
  - sacral plexus abnormalities

- **An MRI protocol** refers to the combination of sequences performed during the MRI procedure. No absolute standard protocols exist. The combination of sequences depends on the body part and the suspected pathology. In light of the time-consuming nature of MRI, it is neither practical nor necessary to employ a high number of sequences for each orthogonal plane. Instead, a facility’s MRI protocol for the hip will include a mix of orthogonal planes and sequences, based on the anatomy and potential pathologies at the hip.

- The fundamental tenets of musculoskeletal MRI are two-fold:
  - **Define the anatomy**
  - **Detect abnormal fluid.** Abnormal fluid or edema is a sign of pathology.

- Thus basic MRI protocols for the hip will include anatomy defining sequences such as: T1, GRE (Gradient Echo) and Proton Density (PD) and fluid sensitive sequences such as Short Tau Inversion Recovery (STIR) and T2 fat saturation, although there is overlap between them.
  - In the arrangement below, the anatomy sequence is paired with the fluid sensitive sequence. A method of reading the images is to “match” these paired sequences, slice by slice, identifying the anatomy, then looking for abnormally high (bright) signal:

<table>
<thead>
<tr>
<th>Orthogonal Plane</th>
<th>Anatomy Sequence</th>
<th>Fluid –Sensitive Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial</td>
<td>T1</td>
<td>T2 with inversion recovery</td>
</tr>
<tr>
<td>Sagittal</td>
<td>T1</td>
<td>T2 with fat saturation</td>
</tr>
<tr>
<td>Coronal</td>
<td>T1</td>
<td>T2 with fat saturation</td>
</tr>
</tbody>
</table>
• Additional evaluation may also include *arthrographic sequences*, in which contrast is injected into the hip joint prior to the MRI exam. This is most frequently used to identify tears of the acetabular labrum.

• See Table 6.9 for understanding the Orthogonal Planes for MRI or CT of the Hip.
• See Table 6.10 for Basic MRI Hip Protocol.
• See Table 6.11 for Hip MR Arthrogram

<table>
<thead>
<tr>
<th>Table 6.9</th>
<th>ORTHOGONAL PLANES FOR MRI or CT EXAM OF THE PELVIS AND HIP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AXIAL PLANE</strong></td>
<td>The field of view for the axial plane extends from the iliac crests to the lesser trochanters. Reference lines are the slices that will be displayed.</td>
</tr>
<tr>
<td>![Axial Plane Images]</td>
<td></td>
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<tr>
<td><strong>SAGITTAL PLANE</strong></td>
<td>The field of view for the sagittal plane extends from the greater trochanter to the opposite greater trochanter. References lines are the slices that will be displayed.</td>
</tr>
<tr>
<td>![Sagittal Plane Images]</td>
<td></td>
</tr>
<tr>
<td><strong>CORONAL PLANE</strong></td>
<td>The field of view for the coronal plane extends from the pubic symphysis to the sacrum. Reference lines are the slices that will be displayed.</td>
</tr>
<tr>
<td>![Coronal Plane Images]</td>
<td></td>
</tr>
<tr>
<td>SEQUENCE TO DEFINE ANATOMY</td>
<td>SEQUENCES TO DETECT ABNORMAL FLUID</td>
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<td>----------------------------</td>
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</tr>
<tr>
<td>T1 Axial</td>
<td>T2 with Inversion Recovery</td>
</tr>
<tr>
<td></td>
<td>Acetabulum</td>
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<td></td>
<td>Labrum</td>
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<td></td>
<td>Pulvinar</td>
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<td>Femoral head and neck</td>
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<td>Greater and lesser trochanters</td>
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<td></td>
<td>Sacrum</td>
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<tr>
<td></td>
<td>Ilium</td>
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<td></td>
<td>Sacroiliac joints</td>
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<td></td>
<td>Pubic symphysis</td>
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<td>Alpha angle of head-to-neck is assessed on <em>axial oblique view</em>. Cam, pincer, or mixed type of femoroacetabular impingement can be evaluated.</td>
</tr>
<tr>
<td>T1 Sagittal T2 with Fat Saturation</td>
<td>Sphericity of femoral head</td>
</tr>
<tr>
<td></td>
<td>Superior aspect of acetabulum and cartilage</td>
</tr>
</tbody>
</table>
|                            | Anterior muscles:  
|                            | -Iliopsoas                        |                        |
|                            | -Sartorius                        |                        |
|                            | -Rectus femoris                   |                        |
|                            | -Vastus medialis                  |                        |
|                            | Posterior muscles:  
|                            | -Gluteals                         |                        |
|                            | -Hamstrings                       |                        |
17

T1 CORONAL T2 with Fat Saturation

- Osseous:
  - Hip joints
  - Proximal femurs
  - Sacroiliac joints
  - Ilium
- Muscles
  - Gluteals
  - Abductors
  - Adductors

Table 6.11 Hip MR Arthrogram

Axial

Sagittal

Coronal

Fluoroscopic needle guidance is used for injection of dilute gadolinium solution prior to MRI. (See Table 6.8 for sample procedure.)

- MR Arthrogram of the hip is used most frequently to identify acetabular labral tears.
- Assess:

  Contrast appears as high signal. Visualize any abnormal extension of contrast into cartilage or defects in labrum.
6. Basic CT Protocol for the Hip

- **Computed tomography (CT)** is accepted as the imaging modality of choice in most skeletal conditions when structural or spatial information of the bones and joint articulations is needed.

- The **primary indications for CT** at the hip are:
  - Severe trauma
  - Assessment of alignment and displacement of fracture fragments
  - Identify loose bodies in the joint
  - Evaluation of fractures of the acetabulum or sacrum, which can be difficult to see on conventional radiographs
  - Evaluation of bony alignment or accurate measurements of bone geometry, in cases such as congenital hip dislocations in pediatrics, or joint replacement in adults.
  - Evaluation of any condition typically seen by MRI if MRI is contraindicated. This includes the use of intra-articular contrast for a CT arthrogram, if MR arthrogram is contraindicated.

- **CT** has similar imaging principles as conventional radiography: body tissues *attenuate* xrays and are represented as shades of gray on the image. There are four basic shades of gray on radiographs and CT:
  - 1. Air = black
  - 2. Fat = gray/black
  - 3. Water (soft tissues) = gray
  - 4. Bone = white
  - Additionally: **contrast medium** is typically brightest shade of white.

- **Observations:** In each plane: Check for abnormalities in the ABCs:
  - **Alignment**: Deviations in the geography of the bones or the joint articulations signal fracture, dislocation or bone destruction.
  - **Bone density**: Similar to radiographs, cortical bone is most dense, as seen in the cortical margins of the femoral head and neck, and the portions of the ilium, ischium, and pubic bones. Assess for any erosions signifying disease or infection.
  - **Cartilage/joint space**: The sphere of the femoral head is covered with cartilage (except at the central fovea capitis) and is thickest superiorly. The acetabulum has a horseshoe shaped cartilage, devoid of cartilage in its center and inferior aspect. The labrum is attached to the acetabular rim. These structures are not visible on CT unless enhanced with arthrography. Identify any loose bodies or free fragments that may have migrated to the joint space.
  - **Soft tissues**: The joint capsule attaches at the acetabular rim and inferiorly at the intertrochanteric line anteriorly and intertrochanteric crest posteriorly. The joint capsule will be evident on CT if it is distended by joint effusion. Two clinically significant bursae are: the *iliopsoas bursa* which lies anterior to the joint and communicates with the joint capsule in 15%-20% of adults. It can become distended with any condition which causes joint effusion, and is seen in association with hip arthroplasties, arthritis, trauma, overuse, osteomyelitis, and neoplastic disease; the *trochanteric bursa* is situated between the greater trochanter and gluteus medius muscle. Inflammation of this bursa is a common condition which produces lateral hip, thigh, and referred knee pain.

- See *Table 6-12* for the **CT Protocol for the Hip**
<table>
<thead>
<tr>
<th>Reformats</th>
<th>Structures to Identify</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AXIAL</strong></td>
<td>- Femoral head in acetabular fossa</td>
</tr>
<tr>
<td></td>
<td>- Medial wall of acetabulum</td>
</tr>
<tr>
<td></td>
<td>- Anterior and posterior rims of acetabulum</td>
</tr>
<tr>
<td></td>
<td>- Sacrum</td>
</tr>
<tr>
<td></td>
<td>- Pubic rami</td>
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<tr>
<td></td>
<td>- Greater and lesser trochanters</td>
</tr>
<tr>
<td><strong>SAGITTAL REFORMAT</strong></td>
<td>- Anterior inclination of acetabular cup</td>
</tr>
<tr>
<td></td>
<td>- Acetabular roof</td>
</tr>
<tr>
<td></td>
<td>- Iliopsoas muscle anterior to hip</td>
</tr>
<tr>
<td></td>
<td>- Sacroiliac joints</td>
</tr>
<tr>
<td></td>
<td>- Pubic symphysis</td>
</tr>
<tr>
<td><strong>CORONAL REFORMAT</strong></td>
<td>- Bilateral comparison of hip joints</td>
</tr>
<tr>
<td></td>
<td>- Femoral heads, necks, shafts</td>
</tr>
<tr>
<td></td>
<td>- Greater and lesser trochanters</td>
</tr>
<tr>
<td></td>
<td>- Sacrum, Iliums, Sacroiliac joints</td>
</tr>
</tbody>
</table>
CT Arthrography

CT arthrography is performed if MR arthrography is contraindicated or unavailable. Indicated for evaluation of the joint cartilage and acetabular labrum.

Note the contrast (black on the fluoroscopic image, white on the CT images) filling the folds of the joint capsule recesses.

7. Basic Musculoskeletal Diagnostic Ultrasound Protocol for the Hip

- Musculoskeletal Diagnostic Ultrasound (MSUS) is considered a first line examination and is performed in conjunction with conventional radiography.

- Clinical symptoms to warrant MSUS examination of the hip are pain, swelling, or presence of a mass. Interpretation of US findings in traumatic hips must be correlated with the mechanism of injury and results of the radiographic examination.

- Primary indications for MSUS at the hip are to:
  - Detect soft tissue injury
  - Visualize the capsule, synovium, and bursae
  - Define ligament, muscle, or tendon tear
  - Evaluate soft tissue masses
    - Confirm the cystic nature of a mass
    - Detect intra-articular masses causing internal joint derangement
    - Evaluate peri-articular masses that are not visible arthroscopically
  - Identify loose intra-articular bodies
  - Differentiate effusion
    - Detect post-surgical complications: hematoma, abscess, seroma, tumor recurrence
  - Guide needle aspiration of the joint, periarticular area, or cystic mass (see photo)
  - Evaluate congenital or developmental abnormalities

- Points to remember:
o MSUS is real-time imaging that depends upon the expertise of the operator.

o The operator may employ physical examination techniques during the MSUS exam such as resisted contractions, passive stretching, or palpation, to reveal lesions not visible in the resting position.

o Scanning planes nomenclature: MSUS images are defined relative to the structure being examined. Sonograms are either longitudinal or transverse to the anatomy. This is achieved by aligning the long axis of the transducer either in parallel or perpendicular to a structure.

- See Table 6.13 for Musculoskeletal Ultrasound Examination of the Adult Hip
Table 6.13 Musculoskeletal Ultrasound Examination of the Adult Hip

ANTERIOR HIP JOINT: LONGITUDINAL IMAGING

Patient: Supine  
Location: Anterior hip joint area  
Transducer: Place parallel to the long axis of the femoral neck, which provides a sagittal-oblique plane image of the hip joint.  
Observe: Femoral head, neck, joint effusion, synovitis, labrum, iliopsoas tendon and bursa, femoral vessels, and the sartorius, and rectus femoris muscles. May perform flexion/extension hip movements to investigate “snapping hip” syndrome involving the iliopsoas tendon.

ANTERIOR HIP JOINT: TRANSVERSE IMAGING

Patient: Supine  
Location: Anterior hip joint area  
Transducer: Place transverse to the femoral neck, which provides an axial-oblique image of the joint.  
Observe: this is the optimal plane for evaluation of iliopsoas bursa.

LATERAL HIP JOINT: LONGITUDINAL IMAGING

Patient: Supine  
Location: Greater trochanter area  
Transducer: Place over the greater trochanter, parallel to the femoral shaft; provides a coronal plane image.
Observe: Soft tissues overlying the greater trochanter including *gluteus minimus and medius tendons*, *iliotibial tract*, and the *trochanteric bursa*.

**LATERAL HIP JOINT: TRANSVERSE IMAGING**

**Patient**: Supine  
**Location**: Greater trochanter area  
**Transducer**: Place over the greater trochanter perpendicular to the femoral shaft.  
**Observe**: Soft tissues overlying the greater trochanter including *gluteus maximus muscle, gluteus minimus and medius tendon insertions*, *iliotibial tract*, and the *trochanteric bursa*. May perform dynamic movements to assess “snapping hip” involving movement of iliotibial tract over greater trochanter.
<table>
<thead>
<tr>
<th>Pathology</th>
<th>Clinical Information</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Legg-Calve-Perthes disease</strong></td>
<td><strong>Description</strong>: An epiphyseal ischemic necrosis of the femoral head. Seen predominately in boys, average age 6. <strong>Signs and symptoms</strong>: Earliest clinical signs are related to the synovitis or inflammatory response of the joint. Pain is dull and non-specific. Often there is a painless limp. If the condition is bilateral, a waddling-type gait is seen. <strong>Etiology</strong>: The literature refers to this as an idiopathic avascular necrosis, or associates it with subtle trauma, synovitis, infection, or metabolic bone disease. <strong>Imaging</strong>: MRI is most sensitive for early diagnosis. Radiographs will appear normal for weeks until the subchondral bone of the femoral head collapses.</td>
<td><strong>Conservative</strong>: The prognosis is best for the youngest patients who are identified the earliest. This is due to a more adaptable blood supply, and less opportunity for femoral head deformity to occur. Revascularization and remodeling are usually successful with prolonged avoidance of weight-bearing, bracing, and appropriate exercise to help reshape the femoral head.</td>
</tr>
<tr>
<td><strong>Slipped Capital Femoral Epiphysis</strong></td>
<td><strong>Description</strong>: A posteromedial displacement of the proximal femoral epiphysis. It is the most common disorder of the hip in adolescence. Is bilateral in 20% of patients at initial presentation, and another 20-40% will proceed to bilateral involvement within 18 months. <strong>Signs and symptoms</strong>: Vague pain in the hip and knee, limited motion (especially IR), antalgic gait, and limb length shortening. Onset is insidious and can coincide with growth spurts at puberty. <strong>Etiology</strong>: Theorized to be related to an imbalance between growth and sex hormones, which weakens growth plates. Other etiologies are implicated, including vertical orientation of the growth plate, retroversion of the proximal femur, and activity. <strong>Imaging</strong>: Lateral frog-leg radiographs best demonstrate the amount of epiphyseal displacement.</td>
<td><strong>Conservative</strong>: Conservative treatment is generally not successful. <strong>Surgical</strong>: In situ pinning with one cannulated screw is the most common treatment. Prophylactic pinning of the uninvolved hip is controversial in the USA, but often done in Europe. Prognosis after pinning is excellent for full function.</td>
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</tbody>
</table>

Legg-Calve-Perthes disease. Bilateral frog leg position in a 7 yo boy demonstrates a normal left hip and growth plate (dotted lines) and a flattening and irregularity of the right femoral head (arrow) that is necrotic.

Slipped capital femoral epiphysis of the right hip in a 13 yo girl. The arrow points to the growth plate; the epiphysis has slipped posteromedially. The left hip is normal and dotted lines designate normal growth plate positions.

Fluoroscopic image showing placement of a screw to stabilize a slipped capital epiphysis.
**Femoral Neck Stress Fracture**

**Description:** Stress fractures (either fatigue or insufficiency types) usually occur on the compressive side (inferior aspect) of the femoral neck rather than the tension side (superior aspect).

**Signs and symptoms:** Gradually worsening pain in back, hip, or groin related to weight-bearing activities. Pain at the extremes of passive external and internal rotation is a sensitive sign for stress fractures.

**Mechanism of Injury:** Fatigue stress fractures may develop in runners and military trainees, due to increased duration, frequency, and intensity of weight-bearing activities, imposed on normal bone. Insufficiency stress fractures may develop in the osteoporotic elderly female or females with the female athlete triad (ie, disordered eating, menstrual dysfunction, premature osteoporosis) due to normal forces imposed on weakened bone.

**Imaging:**
- Initial radiographs are often negative. If clinical suspicion for fracture is high, protected weight-bearing is ordered until repeated radiographs are done in 2 weeks.
- MRI is most sensitive, and performed if an immediate diagnosis is required, or later if repeat radiographs are negative.

**Conservative:** Compression-side fractures do well with non-weightbearing on crutches, with a gradual progression to partial and then full weight bearing over 4-6 weeks depending on the clinical response.

**Surgical:** Tension-side femoral neck stress fractures are usually treated with prophylactic surgical fixation. If a compression side fracture is displaced, it also may require fixation. Typically two or more cannulated screws are inserted under fluoroscopic guidance. In older, less active patients, a hemiarthroplasty may be performed to prevent the potential complication of avascular necrosis of the femoral head.

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Stress fracture in the femoral neck of a 20 yo female runner. Coronal T1 weighted MRI shows the fracture line as low signal surrounded by intermediate signal edema (arrow).

Coronal T2 image confirms the femoral neck fracture. See the characteristic linear band of low signal surrounded by high signal of marrow edema.

AP radiograph showing placement of multi-axis screws to stabilize the femoral neck fracture.
**Osteoarthritis at the Hip**

AP radiograph of the hip showing classic signs of degenerative joint disease: A) asymmetrical joint space narrowing with superior migration of the femoral head, B) marginal osteophytes, C) sclerosis of subchondral bone on both sides of the joint, D) acetabular protrusion resulting from superomedial migration of the femoral head and an osteoporotic pelvis.

**Description:** Osteoarthritis is the most common type of arthritis, characterized by degeneration of the articular cartilage, and is present radiographically in most people over age 55.

**Signs and symptoms:** Progressive pain and loss of joint function, impaired ambulation due to loss of joint congruity as well as increased pain with weight-bearing

**Etiology:** May be primary, without a clear precursor, or secondary, related to a predisposing trauma or pathological condition.

**Imaging:** Radiographic hallmarks include:
- Joint space narrowing
- Sclerotic subchondral bone
- Osteophyte formation at joint margins

**Conservative:** Physical therapy to decrease pain, improve strength, and provide assistive devices to assist in ambulation. Non-steroidal medications help reduce inflammatory response of joint.

**Surgical:** Hemiarthroplasty replaces a degenerative femoral head. Total hip arthroplasty includes replacement of the acetabular cup. Hip resurfacing is a modification of joint replacement, offered to younger patients with good bone density. Post-operative radiograph showing a total hip arthroplasty. Both acetabular and femoral bone have been resected and replaced with prosthetic components.

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**Avascular Necrosis of the Femoral Head**

Avascular necrosis of the femoral head on coronal T1-weighted MRI. Note flattening of spherical head, a low signal serpiginous line representing collapse of necrotic bone, and diffuse edema of intermediate signal.

**Description:** an interruption of the blood supply to the femoral head results in bone tissue death.

**Signs and symptoms:** nonspecific dull pain in joint or thigh, limited joint range of motion, and a progressive painful limp.

**Etiology:** Diverse and divided into three categories: 1) conditions that result in external blood vessel compression (eg trauma) 2) conditions that occlude blood vessels by thickening vessel walls (eg radiation therapy) 3) conditions that cause a blockage due to a thromboembolic process (eg diabetes)

**Imaging:** MRI is most sensitive for early diagnosis. Radiographs will

**Conservative:** Prognosis is highly variable for adults

**Surgical:** Usually necessary in adults. May include drilling into the femoral head to hasten revascularization, grafting healthy bone into the drill holes, varus derotation osteotomy to provide a viable weight bearing surface, or, hip arthroplasty.
<table>
<thead>
<tr>
<th>signal in femoral head and neck.</th>
<th>appear normal for weeks until the subchondral bone of the femoral head collapses.</th>
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<tbody>
<tr>
<td><strong>Femoroacetabular impingement with labral tear</strong>&lt;br&gt;AP radiograph of the hip showing an osseous bump on the femoral neck (arrow) that will impinge on the acetabulum during hip flexion, causing femoroacetabular impingement syndrome.</td>
<td><strong>Description:</strong> a mechanical pathology due to abutment of the femoral neck with the acetabulum. The acetabular labrum is vulnerable to tearing due to the altered joint arthrokinematics. <strong>Signs and symptoms:</strong> snapping, clicking, limited hip range of motion and painful provocation tests which reproduce the pain at the end ranges of flexion or extension. Hip locking is associated with labral tears. <strong>Etiology:</strong> associated with predisposing factors that alter normal osseous anatomy at the hip (eg developmental dysplasias, avascular necrosis, acetabular retroversion, altered femoral head to neck junction). Cam and pincer describe two types of impingement. <strong>Imaging:</strong>&lt;br&gt;• Pelvic and hip radiographs are assessed for osseous alignment and acetabular configuration&lt;br&gt;• MR arthrography is the choice for visualizing labral tears.</td>
<td><strong>Conservative:</strong> Physical therapy to reduce pain, improve strength and flexibility, and teach modified activities, along with non-steroidal medications to reduce inflammation, may help. <strong>Surgical:</strong> the surgical goal is to restore clearance of the femur within the acetabulum. This is achieved arthroscopically via bony resection at the head-to-neck junction or acetabular rim. Labral tears may be trimmed or repaired.</td>
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