Imaging for Nonarthritic Hip Pathology

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Abstract

Diagnostic imaging is an essential aspect of the work-up for nonarthritic hip pain. This review, a comprehensive summary of orthopedic diagnostic imaging for nonarthritic hip pathology, includes the modalities of radiographs, computed tomography, and magnetic resonance imaging. The use of each modality in the work-up for nonarthritic hip pain is discussed.

In the work-up for nonarthritic hip pain, the value of diagnostic imaging is in objective findings, which can support or weaken the leading diagnoses based on subjective complaints, recalled history, and, in some cases, elusive physical examination findings. Morphologic changes alone, however, do not always indicate pathology.[1,2] At presentation and at each step in the work-up, it is imperative to evaluate the entire clinical picture. The prudent clinician uses both clinical and radiographic findings to make the diagnosis and direct treatment.

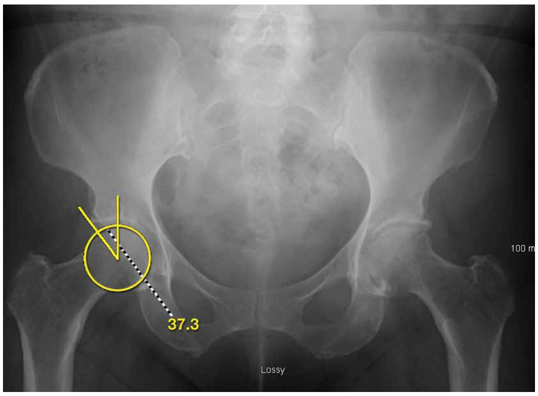

Figure 1. Anteroposterior pelvis radiograph of a 39-year-old woman shows no significant patient rotation or tilt. Measured angle is lateral center-edge angle, or angle between 2 lines from center point of femoral head. One line is straight vertical radius of circle; other is oblique line to superolateral-most aspect of acetabular sourcil. In this case, lateral center-edge angle is 37° (normal, 20°-40°).

Radiography

The first step in diagnostic imaging is radiography. Although use of plain radiographs is routine, their value cannot be understated. Standard hip radiographs—an anteroposterior (AP) radiograph of the pelvis and AP and frog-leg (cross-table lateral) radiographs of the hip—provide a wealth of information.[3-6]

Evaluated first is the radiograph itself. For example, the ideal AP radiograph of the pelvis (**Figure 1**) is centered on the lower sacrum, and the patient is not rotated. Signs of rotation on the supine AP radiograph of the pelvis include but are not limited to the asymmetric appearance of the obturator foramina, the disproportionate spacing of the ischial spines from the midsagittal plane of the pelvis, the pubic symphysis off the midsagittal plane, and the clear imbalance of iliac wings or greater trochanters from the edges of the radiograph. Pelvic rotation can affect image interpretation and be detrimental to patient care.[7-9] Further, 15° internal rotation of the hips should be confirmed to ensure that the femoral necks are to length and that the measured femoral neck–shaft angle is accurate.

AP radiographs allow for evaluation of fractures, intraosseous sclerosis, acetabular depth, inclination and version, acetabular overcoverage, joint-space narrowing, femoroacetabular congruency,

Take-Home Points

- Be sure to have a well centered AP pelvis without rotation.
- Get at least 3 plain radiographs—AP pelvis, false profile, and lateral hip view.
- Ensure that there is sufficient acetabular coverage, LCEA >20° on AP pelvis and ACEA >20° on false profile view.
- CT scans are helpful for precise hip pathomorphology but must be weighed against risk of radiation exposure.
- MRI or MRA can be helpful to diagnose intra-articular as well as extra-articular hip and pelvis abnormalities.

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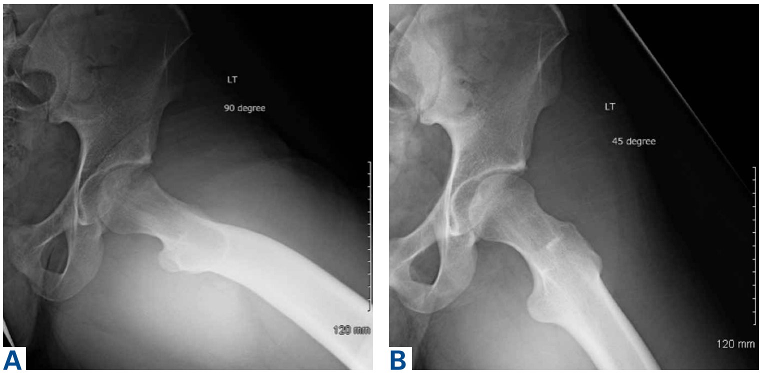

Figure 2. Dunn lateral radiographs of an 18-year-old man. (A) Traditional Dunn lateral radiograph is taken with 90° hip flexion. (B) Modified Dunn lateral radiograph is taken with 45° hip flexion. On these radiographs, the arthroscopist looks for femoral head asphericity, femoral neck version, femoral head–neck offset, and convex bony prominence of femoral head–neck junction (cam deformity).

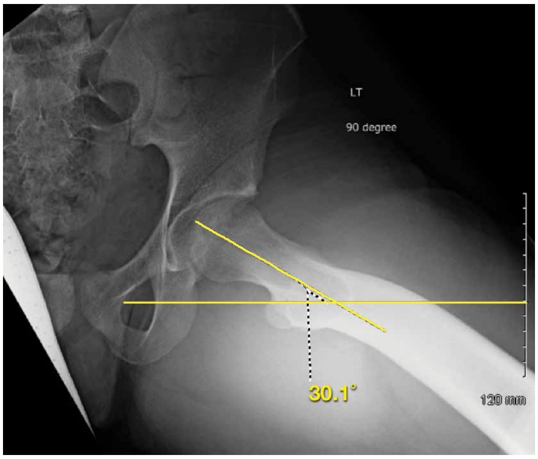

Figure 3. Femoral version. Dunn lateral radiograph of an 18-year-old man with 30° femoral anteversion. As originally described by Dunn, measured angle is formed by center line of femoral neck and line parallel to edge of film. On this radiograph, angle measurement does not take into account posterior transcondylar axis. With transcondylar axis, angle is expected to be <15°.

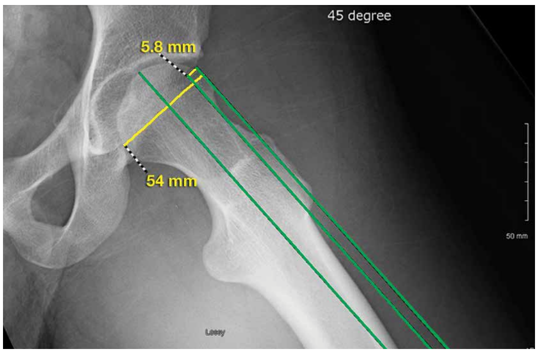

Figure 4. Femoral head–neck offset. Modified Dunn lateral radiograph (45° hip flexion) of an 18-year-old man shows measurements for femoral head–neck offset. Three parallel lines are drawn: center line of femoral neck, anterior-most cortex of femoral neck, and anterior-most cortex of femoral head. Distance between 2 anterior-most cortices (5.8 mm here) is divided by femoral head diameter (54 mm here) to obtain femoral head–neck offset (0.11). In many cases, cam deformity is present with head–neck offset ratio <0.17.

femoral head sphericity, and femoral head–neck offset.[7,8,10] Inspection for labral calcification is important, as it can indicate repetitive damage at the extremes of range of motion.

On AP pelvis radiographs, it is important to distinguish coxa profunda from acetabular protrusion. These entities are on the same pathomorphologic spectrum and are similar but distinctively different. *Coxa profunda* refers to the depth of the acetabulum relative to the ilioischial line, and *acetabular protrusion* refers to the depth (or medial position) of the femoral head relative to the ilioischial line. Each condition suggests—but is not diagnostic for—pincer-type femoroacetabular impingement (FAI).[11]

Acetabular rotation is another important entity that can be evaluated on well-centered, nontilted AP pelvic radiographs. *Acetabular rotation* refers to the opening direction of the acetabulum. It may be anterior (anteverted), neutral, or posterior (retroverted). Anteversion is present when the anterior acetabular rim does not traverse the posterior rim shadow[4]; in other words, the ring formed by the acetabulum is not twisted. When the walls overlap but do not intersect, the cup has neutral version. Retroversion is qualitatively determined by the crossover (figure-of-8) and posterior wall signs[12] and is associated with pincer-type FAI and the development of hip osteoarthritis.[12]

Dunn lateral radiographs (**Figure 2A**), taken with 90° hip flexion, were originally used to measure femoral neck anteversion.[13] Modified Dunn lateral radiographs (**Figure 2B**), taken with 45° hip flexion, have largely replaced their 90° counterparts. In addition to being used to measure femoral version (**Figure 3**), the modified radiographs can be used to detect head–neck offset and bony prominence at the head–neck junction. Head–neck offset is qualitatively determined by comparing the symmetry of the anterior and posterior femoral head–neck concavities. Dunn and modified Dunn lateral radiographs can be used to assess femoral head asphericity, which can be overlooked on standard AP or cross-table radiographs.[14] Both femoral head–neck offset (**Figure 4**) and α angle (**Figure 5**) can be measured on Dunn and modified Dunn radiographs.

False-profile radiographs (**Figure 6**), valuable in evaluating anterior acetabular coverage and femoral head–neck junction morphology,[14,15] allow characterization of both cam-type and pincer-type FAI. These weight-bearing radiographs are standing oblique radiographs of the pelvis and lateral radiographs of the proximal femur. Pincer-type FAI is indicated by increased anterior center-edge angle

Table. **Quantitative Measures on Plain Radiographs**

Measurement	Radiograph	Measuring Technique	Interpretation
Femoral neck-shaft angle (caput-collum-diaphyseal angle)	AP pelvis	Angle between long axis of femoral neck and femoral shaft.	Normal range is 120°-135°. Coxa vara is present when angle is <120°, and coxa valga is present when angle is >135°.
Acetabular angle	AP pelvis	In skeletally mature pelvis, draw horizontal line along inferior margin of acetabular tear drops. Then draw oblique line from lateral-most point of acetabular roof to acetabular tear drop. Acetabular angle is angle between these 2 lines.	Normal range is 33°-38°. Angle >47° represents acetabular dysplasia. In skeletally immature pelvis, angle is measured using triradiate cartilages, not acetabular tear drops.
Tönnis angle	AP pelvis	Draw transverse line between inferior aspect of acetabular tear drops (transverse axis of pelvis). Then draw another transverse line, parallel to first and lateral from inferomedial aspect of acetabular sourcil. Then draw oblique line from superolateral aspect to inferomedial aspect of acetabular sourcil. Tönnis angle is angle between second and third lines.	Normal range is 0°-10°. Tönnis angle measures inclination of acetabular weight-bearing surface (acetabular sourcil). Angle >15° is poor prognostic factor for development of degenerative hip disease.
Lateral center-edge angle	AP pelvis	Draw 2 lines from center point of femoral head. First is vertical line directed superiorly from center point and perpendicular to transverse axis of pelvis. Second is oblique line from center point to superolateral-most point of acetabular sourcil. LCEA is angle between these 2 lines.	LCEA measures superolateral femoral head coverage by acetabular roof. Angle <20° indicates inadequate coverage, and angle >40° indicates overcoverage, as in pincer-type femoroacetabular impingement.
Anterior center-edge angle	False-profile	Similar to LCEA, ACEA is angle between 2 lines from center point of femoral head: 1 straight vertical line and 1 line oblique to anterior-most point of acetabular sourcil.	ACEA measures anterior coverage of femoral head. Angle <20° indicates inadequate coverage and instability.
α angle	Frog-leg lateral and Dunn (90°) or modified Dunn (45°) lateral	Draw circle of best-fit around femoral head. Then draw 2 lines from center point of femoral head: 1 along long axis of femoral neck and 1 out to point where superior femoral head–neck breaks from circle of best-fit. Angle between these 2 lines is α angle.	α angle assesses for femoral head–neck offset. Angle >42° implies femoral head–neck offset deformity (cam deformity).
Femoral head–neck offset ratio	Frog-leg lateral and Dunn (90°) or modified Dunn (45°) lateral	Establish long axis of femoral neck and draw 2 lines parallel to it: 1 at anterior cortex of femoral neck and 1 at anterior aspect of femoral head. Then divide distance between these 2 lines by femoral head diameter.	Femoral head–neck offset ratio may indicate cam deformity. Ratio <0.17 likely represents cam deformity.
Femoral version	Dunn (90°) or modified Dunn (45°) lateral; cross-sectional imaging	Angle between center line of femoral neck and straight edge of film. Angle between femoral neck and shaft on these radiographs does not affect femoral version.	Femoral version is dynamic and decreases during skeletal maturation. Normal ranges are 30°-40° (at birth) and 8°-14° (adults).

Abbreviations: ACEA, anterior center-edge angle; AP, anteroposterior; LCEA, lateral center-edge angle.

(ACEA), and dysplasia is indicated by decreased ACEA (<20°). To appreciate cam-type FAI, arthroscopists look for a convex bony prominence of the femoral head–neck junction.

Quantitative measures warrant specific consideration (**Table**). Femoroacetabular morphology is quantitatively measured by α angle, Tönnis angle (acetabular inclination angle), and lateral center-edge angle (LCEA).[7,8,10] The α angle (Figure 4) detects the loss of normal anterosuperior femoral head–neck junction concavity caused by a convex osseous prominence. An α angle >50° represents a cam deformity.[16] In a cohort study of 338 patients, Nepple and colleagues[17] qualitatively associated increased α angle with severe intra-articular hip disease. Murphy and colleagues[18] found a Tönnis angle >15° to be a poor prognostic factor in untreated hip dysplasia. LCEA quantifies superolateral femoral head coverage,[19] and its normal range is 20° to 40°.[20] LCEA <20° indicates dysplasia of the femoroacetabular joint, and LCEA >40° indicates overcoverage and pincer-type FAI. As with any quantitative radiographic measurement, results should be interpreted within the presenting clinical context.

Radiographic findings, even findings based on

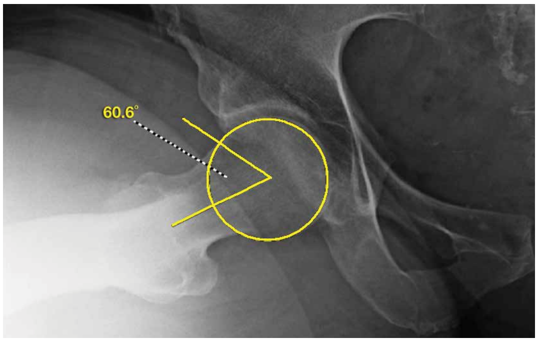

Figure 5. α angle. Dunn (90°) lateral radiograph of a 38-year-old woman allows evaluation of femoral head sphericity and measurement of α angle. Angle (61° here) is formed by long axis of femoral neck and point where femoral head–neck junction extends beyond circle of best-fit. Normal α angle is >42°.

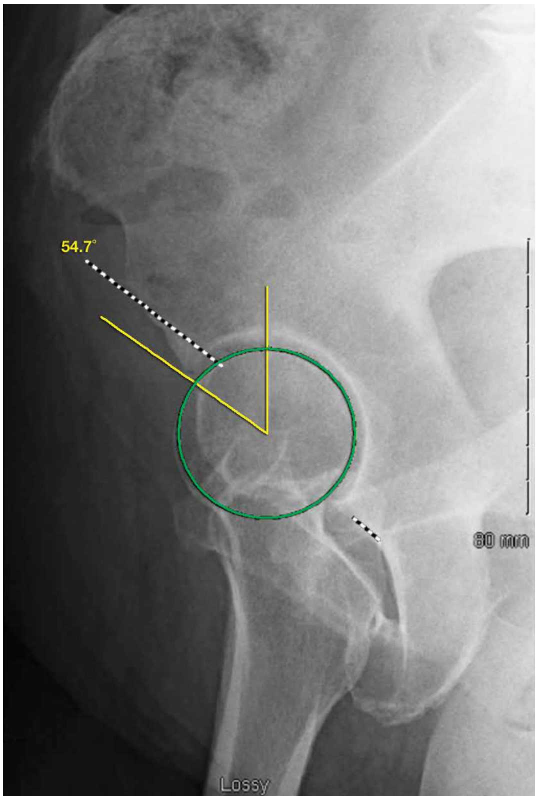

Figure 6. Weight-bearing upright false-profile radiograph of a 47-year-old woman shows anterior coverage of femoral head as well as femoral head–neck junction and femoroacetabular congruency. On radiograph, quantitative measure is anterior center-edge angle (ACEA), or angle formed by 2 lines from center point of femoral head. One line is straight vertical radius of circle; other is oblique line to anterior-most aspect of acetabular sourcil. In this case, ACEA is 55° (normal, >20°). Femoroacetabular joint is congruent.

these special radiographs, may underestimate the pathologic process. Repeat radiographs are recommended to address symptoms that persist after treatment. If technique is consistent, repeat radiographs reveal subtle changes. The other option is to proceed with cross-sectional imaging.

Computed Tomography

The benefits of computed tomography (CT) outweigh the risk of radiation exposure. CT is most useful in characterizing osseous morphology.[21] In FAI cases, CT can distinguish acetabular version abnormalities from femoral torsion (**Figures 7A-7C**), entities with very different treatment approaches.[21] CT of the entire pelvis allows accurate objective measurement of acetabular version. Software advancements provide 3-dimensional reconstructions (**Figure 8**) and afford better appreciation of symptomatic pathomorphology by patients and more sophisticated measures by surgeons. Whereas CT reveals osseous structure, magnetic resonance imaging (MRI) demonstrates acuity and response of the osseous structures to the clinical condition (eg, bone marrow edema).

Magnetic Resonance Imaging

MRI is becoming essential in the work-up for nonarthritic hip pain.[11,22] It is used for assessment of osseous, chondral, and musculotendinous soft tissues. Further, it affords appreciation of outside-the-hip-joint pathology that may mimic joint-centered pathology.

MRI techniques range from noncontrast to indirect and direct magnetic resonance arthrography (MRA).[22] Indirect MRA is performed with contrast medium administered through an intravenous line. Direct MRA has contrast administered intra-articularly and is more sensitive and specific for labral tears and ligamentous injury.[23] Excellent detection of intra-articular pathology on noncontrast studies questions the need for MRA.[24] Nevertheless, direct MRA can also be used as a therapeutic procedure when lidocaine is included in the injected gadolinium.

Labral tears, focal chondral defects, and stress or insufficiency fractures are important differentials in the work-up for nonarthritic hip pain. Over the dysplasia-to-FAI spectrum, MRI distinguishes symptomatic pathoanatomy from asymptomatic anatomical variants by revealing underlying bone edema. Capsule findings should also be considered.[21]

The most practical classification of labral tears, proposed by Blankenbaker and colleagues,[25] is based on tear type (frayed, unstable, flap), location, and extent. More than half of labral tears occur in the anterosuperior quadrant of the labrum.[25] On noncontrast MRI, these tears appear as linear T2 hyperintensity within or through an otherwise homogeneously dark labrum. Accurate findings can

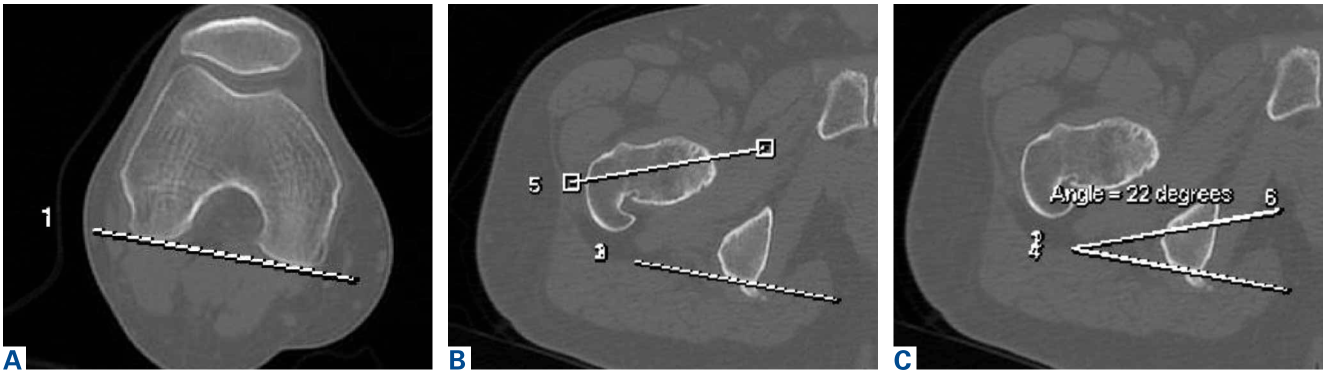

Figure 7. Femoral torsion angle is calculated from posterior margin of (A) femoral condyle and (B) long axis of femoral neck. (C) Angle here is 22° (skeletally mature normal, 8°-15°).

Figure 8. Three-dimensional reconstruction of right proximal femur illustrates cam deformity.

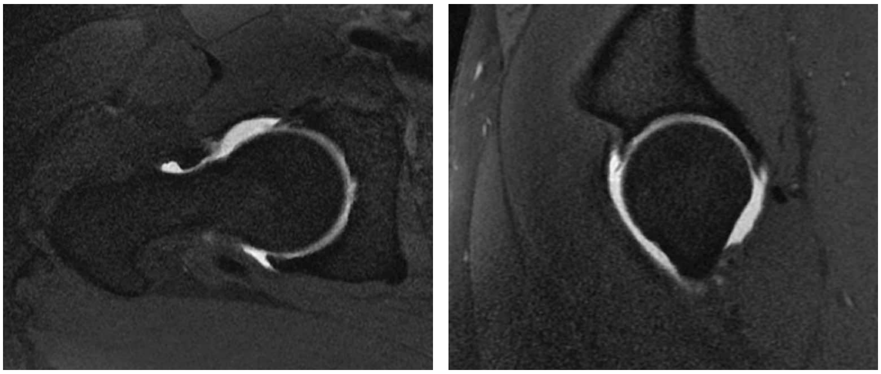

Figure 9. (A) Axial and (B) sagittal fluid-sensitive magnetic resonance arthrography shows deficient anterior labrum without underlying bone edema.

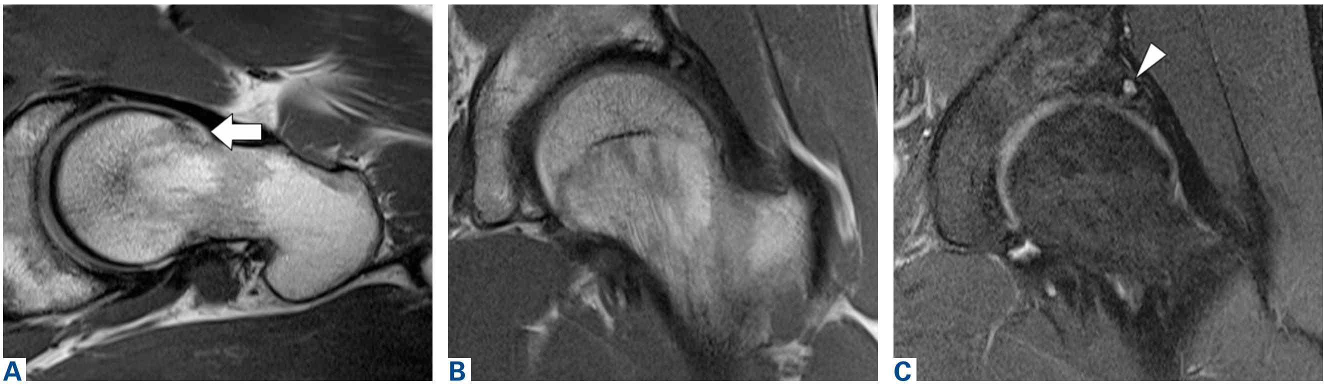

Figure 10. Combination cam–pincer deformity. (A) T2-weighted axial-oblique magnetic resonance imaging (MRI) shows convexity of anterolateral femoral head–neck junction (arrow) with decreased offset and widened femoral neck. (B) T1-weighted coronal MRI shows acetabular overcoverage. (C) Fluid-sensitive MRI shows osseous response to femoroacetabular impingement (arrowhead).

be elusive because of variant labral anatomy (**Figures 9A, 9B**).[26] Findings regarding the inside of the labrum can be signs of an overlying problem, such as FAI (**Figures 10A-10C**).

Chondral damage is identified much as labral tears are. With chondral injury, the normal intermediate signal is interrupted by a fluid-intense signal extending to the subchondral bone. A fat-saturated T2 or short-tau inversion recovery (STIR) sequence is useful in emphasizing this finding.[27]

MRI detects osseous pathology from surrounding soft-tissue edema and bone remodeling to stress and fragility fractures. In athletes, the most common fractures are pubic rami, sacral, and apophyseal avulsion fractures.[28] In all patients, attention should be given to the lower spine and the proximal femurs. Aside from MRI, nuclear medicine bone scan might also identify active osseous reaction representative of a fracture.

Conclusion

The work-up for nonarthritic hip pain substantiates differential diagnoses. A case's complexity determines the course of diagnostic imaging. At presentation and at each step in the work-up, it is imperative to evaluate the entire clinical picture. The prudent clinician uses both clinical and radiographic findings to make the diagnosis and direct treatment.

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