PROVIDER LED ENTITY

Shoulder Pain AUC
2023 Update

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Appropriateness of advanced imaging procedures* in patients with shoulder pain and the following clinical presentations:

*Including MRI, MR arthrography, CT, CT arthrography, bone scan, PET, SPECT

Abbreviation list:

AAOS	American Academy of Orthopaedic Surgeons
AC	Acromioclavicular
ACOEM	American College of Occupational & Environmental Medicine
ACR	American College of Radiology
APTA	American Physical Therapy Association
AUC	Appropriate Use Criteria
CE	Contrast-enhanced
CT	Computed tomography
CTA	Computed tomographic arthrography
GH	Glenohumeral
LR	Likelihood Ratio
MAVRIC	Multiacquisition variable-resonance imaging combination
MRA	Magnetic resonance arthrography
MRI	Magnetic resonance imaging
OA	Osteoarthritis
PET	Positron emission tomography
PLE	Provider Led Entity
SLAP	Superior labrum anterior-to-posterior
SPECT	Single-photon emission computed tomography
US, U/S	Ultrasound

Appropriate Use Criteria: How to Use this Document

The CDI Quality Institute follows the recommendation framework defined by the Appraisal of Guidelines for Research & Evaluation (AGREE II), AMSTAR 2 (A Measurement Tool to Assess Systematic Reviews) and a modified version of the QUADAS-2 (Quality Assessment of Diagnostic Accuracy Studies) to evaluate the strength of recommendations concerning advanced imaging. Considerations used to determine a recommendation are listed below.

Primary recommendation (green): A strong recommendation for initial imaging for this presentation; there is confidence that the desirable effects of imaging outweigh its undesirable effects.

Alternative recommendation (yellow): A conditional recommendation for imaging; the desirable effects of imaging likely outweigh its undesirable effects, although some uncertainty may exist. The individual patient's circumstances, preferences, and values should be considered on a case-by-case basis. This may include: contraindication to the primary recommendation, specific clinical circumstances that require use of the alternative recommendation, or the primary recommendation has results that are inconclusive or incongruent with the patient's clinical diagnosis. Case-by-case indications to consider have been noted in brackets when appropriate.

Recommendation against imaging (red): The undesirable effects of imaging outweigh any desirable effects. Additionally, the recommendation may be impractical or not feasible in the targeted population and/or practice setting(s).

Shoulder pain AUC summary:

- In most instances, **MRI without IV contrast** is the advanced imaging procedure of choice for shoulder pain. It is indicated in the acute setting for suspected full-thickness rotator cuff tears, traumatic dislocations, and occult fractures not identified on initial radiographs.
    - MRI is otherwise generally indicated for patients whose pain and dysfunction persists after four to six weeks of conservative therapy. MRI is useful to detect and direct treatment decisions for rotator cuff tears, labral tears, bicep tendon tears, chondral loss of the glenohumeral joint, and bursitis.
    - The use of MRI with IV contrast is limited in the shoulder, however, may be useful in the evaluation of adhesive capsulitis.
- **MR arthrography** may increase the sensitivity of MRI for partial-thickness rotator cuff tears and labral tears. It is also useful in patients with a history of previous surgery and in patients with indeterminate or nondiagnostic findings on previous MRI.
- **CT arthrography** is generally reserved for patients unable to undergo MRI or for patients who have had prior shoulder arthroplasty surgery.
- **CT without IV contrast** is recommended for characterizing bony Bankart lesions and Hill-Sachs deformities for surgical planning, and to assess glenoid version and posterior glenoid wear in osteoarthritis patients undergoing evaluation for shoulder arthroplasty. It can also be useful to detect occult fractures that are suspected following radiographs.
- **Conventional radiographs** are commonly used for the initial evaluation of a suspected fracture or dislocation, osteoarthritis, or calcific tendinitis.
- **Ultrasound**, while not defined as an advanced imaging modality, can be useful to assess suspected complete biceps tendon tears, full-thickness rotator cuff tears and high-grade partial-thickness rotator cuff tears. Its use should be limited to trained and experienced experts.

PICO 1: Shoulder pain with either of the following rotator cuff scenarios:

- **Suspected full-thickness rotator cuff tear in patients who are candidates for early surgical repair**
- **Suspected rotator cuff tear and failure of conservative therapy***

- **Green – MRI shoulder without IV contrast**
- **Yellow – MR arthrography shoulder**
  [Previous noncontrast MRI findings are indeterminate]
- **Yellow – CT arthrography shoulder**
  [MRI not available or contraindicated; or prior shoulder arthroplasty/significant metal artifact]
- **Yellow – CT shoulder without IV contrast**
  [Further evaluation or surgical planning of bone abnormality]
- **Red – MRI shoulder without and with IV contrast; MRI shoulder with IV contrast**
- **Red – CT shoulder without and with IV contrast; CT shoulder with IV contrast**
- **Red – PET; bone scan; SPECT**

*Failure of conservative therapy can be defined as moderate to severe persistent symptoms following conservative care for 4-6 weeks or increasing pain during a trial of conservative care. Those with uncontrolled pain, significant limitation of function, inability to perform activities of daily living, or physical inability to participate in noninvasive care for an appropriate period of time also fall into this category (PLE expert panel consensus opinion).

Level of Evidence:

- High level evidence that MRI, MR arthrography, and ultrasound (US) are accurate in the diagnosis of full-thickness rotator cuff tears
- Moderate level evidence that MRI and MR arthrography are accurate for the diagnosis of partial-thickness rotator cuff tears

Notes concerning use of contrast:
MRI without IV contrast is the advanced imaging procedure of choice for visualization of soft tissue structures of the shoulder, including ligaments, tendons, joint capsules, and joint cartilage structures (*CO Department of Labor* 2014; PLE expert panel consensus opinion). The addition of intra-articular contrast (arthrography) can improve the detection and definition of rotator cuff tears (*CO Department of Labor* 2014; Liu et al 2020; *AAOS* 2019; PLE expert panel consensus opinion). The use of MRI with IV contrast is limited in the shoulder, however, may be useful in the evaluation of adhesive capsulitis (Erber et al 2022; Pessis et al 2020; Ahn et al 2015).

Notes concerning applicability and/or patient preferences: none.

Guideline and PLE expert panel consensus opinion summary:
Overview:
Conventional radiographs are the preferred initial study following acute shoulder injuries to rule out fractures, avulsions, and dislocation (Amini et al [*ACR*] 2018). They may also be useful to evaluate for osteoarthritis or calcific tendonitis in patients with rotator cuff syndrome (Bussieres et al 2008). Advanced imaging is indicated in patients with suspected full-thickness rotator cuff tears who are candidates for early surgical repair. This includes suspected tears following trauma, a palpable defect at

the greater tuberosity following trauma, and/or a new onset of significant weakness on elevation or rotation (i.e., drop arm) (PLE expert panel consensus opinion). While not considered to be an advanced imaging modality, ultrasound can also be useful in the evaluation of rotator cuff tears when utilized by an experienced operator (Bussieres et al 2008; *CO Department of Labor* 2014; Hopman et al 2013; PLE expert panel consensus opinion).

Patients with rotator cuff syndrome and suspected rotator cuff tears commonly respond to a 4-to-6-week course of conservative care and may be able to avoid surgery (Hegmann et al [*ACOEM*] 2016; Hopman et al 2013; *CO Department of Labor* 2014; PLE expert panel consensus opinion). As such, advanced imaging is not typically indicated in the first 4-6 weeks for patients presenting with suspected rotator cuff syndrome in the absence of the "red flags" noted above (Hopman et al 2013, Grade C; Hegmann et al [*ACOEM*] 2016; PLE expert panel consensus opinion).

MRI shoulder:
Multiple high-quality guidelines note that MRI (without IV contrast) is useful to provide more definitive visualization of soft tissue structures and is generally accepted as the gold standard to evaluate for a rotator cuff tear (Nacey et al [*ACR*] 2022; Bussieres et al 2008; Hopman et al 2013; *CO Department of Labor* 2014; Amini et al [*ACR*] 2018; *AAOS* 2019; strength of recommendation: strong; Hegmann et al [*ACOEM*] 2016). MRI has been found to be a moderate to strong test for ruling in a full thickness tear over no tear (*AAOS* 2019). Patients with suspected full thickness rotator cuff tear following trauma, a palpable defect at the greater tuberosity following trauma or new significant weakness on elevation or rotation should have early use of MRI (*CO Department of Labor* 2014; PLE expert panel consensus opinion). MRI should also be considered when shoulder pain is refractory to conservative care, such as an appropriate shoulder rehabilitation program, for 4 to 6 weeks (Hopman et al 2013; *CO Department of Labor* 2014; *British Orthopaedic Association*, 2014; PLE expert panel consensus opinion). A positive MRI has been found to produce a small, but sometimes important increase in probability of a partial tear (*AAOS* 2019). In addition to evaluating the rotator cuff itself, MRI can also detect extra-articular abnormalities that may predispose to shoulder impingement (Nacey et al [*ACR*] 2022).

MR arthrography shoulder:
MR arthrography can improve the diagnostic accuracy of a full-thickness rotator cuff tear when initial MRI is inconclusive (Bussieres et al 2008; Hopman et al 2013; *CO Department of Labor* 2014; *AAOS* 2019; strength of recommendation: strong). A positive MR arthrography test for full-thickness tears has been found to produce a large increase in probability that a patient truly has a full tear instead of a partial tear or no tear (*AAOS* 2019). MR arthrography also provides greater sensitivity and specificity compared to conventional MRI in evaluating partial thickness articular surface tears (Nacey et al [*ACR*] 2022). It may also be marginally more sensitive and specific than MRI for assessing glenohumeral lesions (*CO Department of Labor* 2014). However, the advantages of MR arthrography over conventional MRI must be weighed against the invasive nature of the arthrogram procedure (Nacey et al [*ACR*] 2022).

CT arthrography shoulder:
CT arthrography can be useful to evaluate a suspected rotator cuff tear in patients with significant metal artifact, in patients following total shoulder arthroplasty, or in patients with contraindication to MRI (Amini et al [*ACR*] 2018; Hegmann et al [*ACOEM*] 2016; PLE expert panel consensus opinion). CT arthrography shows good diagnostic performance for depicting rotator cuff tendon tears and can detect very subtle articular surface cuffs defects (Nacey et al [*ACR*] 2022). However, because of lack of contrast extension from the glenohumeral joint space, it is generally less effective at demonstrating bursal surface or intrasubstance tears, which are typically well seen with MRI or ultrasound (Nacey et al [*ACR*]

2022).

CT shoulder:
Routine CT is generally not recommended for the initial evaluation of shoulder pain (Hegmann et al [*ACOEM*] 2016: not recommended, insufficient evidence). CT shoulder without IV contrast is of limited utility for evaluating a rotator cuff tear but can sometimes demonstrate fatty infiltration of rotator cuff muscles with a corresponding tear (Nacey et al [*ACR*] 2022). For instances where evaluation and surgical planning of bone abnormality is necessary, a noncontrast CT is generally recommended (Hegmann et al [*ACOEM*] 2016; *CO Department of Labor* 2014; PLE expert panel consensus opinion). There is insufficient evidence to support the use of CT shoulder with IV contrast in evaluating chronic shoulder pain with suspected rotator cuff disorder (Nacey et al [*ACR*] 2022).

Ultrasound:
Some practitioners may use ultrasound as an initial imaging modality when rotator cuff pathology is suggested by the clinical examination (Nacey et al [*ACR*] 2022). Ultrasound is accurate for full-thickness rotator cuff tears, particularly among patients with severe pain or who cannot undergo MRI (Bussieres et al 2008; *CO Department of Labor* 2014; *AAOS* 2019; strength of recommendation: strong; Hegmann et al [*ACOEM*] 2016; PLE expert panel consensus opinion). It may also be useful as an initial imaging study when rotator cuff disease/impingement is suggested by the clinical examination (Nacey et al [*ACR*] 2022). Ultrasound has a high accuracy for rotator cuff disease, with studies showing a sensitivity of 85%-95% and specificity of 72%-92%; this is similar to noncontrast MRI and slightly lower than MR arthrography (Nacey et al [*ACR*] 2022). The accuracy of ultrasound for rotator cuff tears is highly operator-dependent, and the performance of ultrasound may vary significantly depending on local expertise (Bussieres et al 2008; *CO Department of Labor* 2014; Hopman et al 2013).

Clinical/imaging notes:

- 3.0T MRI has been reported to have overall increased accuracy for rotator cuff tears compared to 1.5T, 1.0T or lower field strength MRI systems (Smith et al 2012a *CO Department of Labor* 2014). Lower-field strength imaging may be indicated, however, in patients with severe claustrophobia or if a patient cannot fit in the high-field strength scanner (*CO Department of Labor* 2014).
- Ultrasound can be used as an option for evaluation of rotator cuff tears in patients who have previous had a total shoulder arthroplasty (PLE expert panel consensus opinion). MRI (or MR arthrography) may be used in such patients if systems utilize advanced metal suppression techniques (e.g., MAVRIC or WARP) (PLE expert panel consensus opinion).

Evidence update (2012–present):
High Level of Evidence:
Roy et al (2015), in a systematic review, found an equivalent performance of US, MRI, and MR arthrography for the diagnosis of full- or partial-thickness rotator cuff tears (Sn: 0.90 to 0.91; Sp: 0.86 to 0.90) (high level of evidence). In studies with a low risk of bias, MR arthrography had the best likelihood ratio profile (LR+ 16.6, LR- 0.2) followed by MRI (LR+ 8.3, LR-0.1) and ultrasound (LR+ 7.6, LR- 0.3) for the diagnostic accuracy of full-thickness tears. The authors found no difference in diagnostic accuracy or likelihood ratios for full-thickness tear at $\leq$ 1.5T or 3.0T for either MRI or MR arthrography.

Moderate Level of Evidence:
Liu et al (2020), in a network meta-analysis, examined which of three common imaging modalities (MRI, MR arthrography [MRA], ultrasound [US]) is optimal for diagnosing rotator cuff tears. Data were

extracted from 144 diagnostic studies (14,212 shoulders). A network meta-analysis was performed using an arm-based model to pool absolute sensitivity and specificity, relative sensitivity and specificity, diagnostic odds ratio, and superiority index for ranking the probability of these techniques (**note* "superiority index" measures the superiority of a diagnostic test compared to others by simultaneously optimizing test assessment measures [e.g., sensitivity, specificity, likelihood ratio, predictive value]*). Results found that, for the detection of full-thickness (FT) tears, partial-thickness (PT) tears, or any tear, MRA had the highest sensitivity, specificity, and superiority index. For the detection of any tear, MRI had better performance than US (sensitivity: 0.84 vs 0.81, specificity: 0.86 vs 0.82, and superiority index: 0.98 vs 0.22, respectively). With regard to FT tears, MRI had a higher sensitivity and superiority index than US (0.91 vs 0.87 and 0.67 vs 0.28, respectively) and a similar specificity (0.88 vs 0.88, respectively). The results for PT tears were similar to the detection of FT tears.

VanBeek et al (2014), in a study of 84 consecutive patients undergoing arthroscopic surgery for rotator cuff disease, showed that the overall accuracy of noncontrast MRI in detecting glenohumeral articular cartilage lesions is good. However, detection of cartilage lesions is reader dependent. Furthermore, accurate characterization of a lesion by MRI, including location, depth, and size, is difficult, probably secondary to the relatively thin glenohumeral articular cartilage. Orthopedic surgeons must exercise caution when relying on noncontrast MRI for the detection and characterization of cartilage lesions.

Lenza et al (2013), in a systematic review, concluded that "MRI, MR arthrography and ultrasound (US) have good diagnostic accuracy and any of these tests could equally be used for detection of full-thickness tears in people with shoulder pain for whom surgery is being considered". "MRI and US may have poor sensitivity for detecting partial-thickness rotator cuff tears and the sensitivity of US may be much lower than MRI".

Smith et al (2012b), in a meta-analysis of 2751 shoulders in 2710 patients, reported that MRI had a sensitivity of 0.91 and specificity of 0.97 for full-thickness tears, and a sensitivity of 0.80 and specificity of 0.95 for partial-thickness tears (high level of evidence). Results indicated superior overall diagnostic accuracy for 3.0T imaging compared to 1.5T or $\leq$ 1.0T MRI systems for both full-thickness and partial-thickness tears (LR+ 30 [6.6-139] at 3.0T; 8.6 [2.4-31.2] at 1.5T).

Low Level of Evidence:
Sill et al (2022), in a retrospective study, investigated the effect of calcific tendinosis on the diagnosis of rotator cuff tears (RCTs) on MRI and MR arthrography. Two musculoskeletal radiologists independently reviewed 48 MRI and 7 MRA examinations, with surgery or arthroscopy performed in the following 90 days. Reader 1 and reader 2 sensitivity/specificity values for RCTs on MRI were 95%/50% and 89%/30%, and the values on MRA were 100%/67% and 100%/100%, respectively. Overall agreement was present in 87% (48 of 55; $\kappa = 0.55$ [95% CI, 0.26–0.85]). The authors conclude that MRI has decreased specificity in diagnosing RCTs when calcific tendinosis is present, while MR arthrography performed better in this population and could be considered.

Khil et al (2021), in a retrospective study, evaluated the diagnostic performance and reliability of MR arthrography (MRA) in diagnosing subscapularis (SSC) tendon tears in 272 patients with arthroscopic confirmations. A total of 548 shoulder MRAs were evaluated by two musculoskeletal radiologists, and SSC tendon pathologies were classified into three groups: intact tendon (n = 149), partial-thickness tear (n = 92), or full-thickness tear (n = 31). For full-thickness tears, mean values of sensitivity, specificity, and accuracy of reviewer one/reviewer two were 71.0%/87.1%, 97.3%/98.3%, and 94.4%/95.5%, respectively. For partial-thickness tears, mean values of sensitivity, specificity, and accuracy were

72.8%/73.4%, 78.3%/81.2%, and 76.5%/78.5%, respectively. Intra- and inter-observer reliabilities for both reviewers were good to very good ($k = 0.85/0.93$, $p < 0.001$; $k = 0.74–0.89$, $p < 0.001$). The authors conclude that MRA showed high diagnostic performance for SSC tendon tears, especially full-thickness tears, with good inter- and intra-observer reliabilities.

Malavolta et al (2019), in a systematic review and meta-analysis, sought to determine the diagnostic accuracy of MRI in the detection of subscapularis tendon tears. A total of 14 articles (n = 1858 shoulders with 613 subscapularis tears) were included. For overall subscapularis tears, sensitivity of MRI was 0.68 (95% CI 0.64–0.72) and specificity was 0.90 (95% CI 0.89–0.92). Sensitivity of MRI was 0.93 (95% CI 0.83–0.98) for full-thickness tears and 0.74 (95% CI 0.66–0.82) for partial tears. Specificity of MRI was 0.97 (95% CI 0.94–0.98) for full-thickness tears and 0.88 (95% CI 0.85–0.91) for partial tears. Among studies with MRI field of strength ≥ 1.5 T, sensitivity was 0.80 (95% CI 0.76–0.84) and specificity 0.84 (95% CI 0.81–0.87). The authors conclude that MRI is an accurate method for diagnosing subscapularis tendon tears; however, its accuracy is lower than that of overall rotator cuff tears, due to its lower sensitivity.

Cortes et al (2019) conducted a prospective study to determine the value of MRI when used before a trial of conservative therapy in patients with atraumatic shoulder pain. A total of 51 prospective, consecutive patients were included; all were suspected to have cuff tendinopathy based on clinical findings. Every patient underwent MRI and was offered an initial trial of conservative management. Patients had an average follow-up of 28 months after imaging to determine whether surgery was performed. Of the cohort, 46 (90%) patients did not go on to surgical intervention, with 5 (10%) doing so an average 68 days after imaging. The authors conclude that the use of MRI before a trial of conservative management in patients with atraumatic shoulder pain, minimal to no strength deficits on physical examination, and suspected cuff tendinopathy other than full-thickness tears provides negative value in the management of patients, at both the individual and population level.

Lee et al (2018) conducted a retrospective study of 120 consecutive patients undergoing 3T MR arthrography to evaluate for subscapularis (SSC) tendon tear, using arthroscopic findings as reference standard. Two musculoskeletal radiologists, blinded to results, evaluated T1-weighted spectral presaturation with inversion-recovery sequences (T1 SPIR) and T2-weighted turbo spin-echo sequences (T2 TSE) images in separate sessions, examining normal/articular-surface partial-thickness tear (PTTa)/full-thickness tear (FTT). Significant differences were found between T1 SPIR and T2 TSE among 74 SSC tendon tears: sensitivity 95.9−94.6% vs. 71.6−75.7% and accuracy 90.8−91.7% vs. 79.2−83.3% for detecting tear; 55.3% vs. 31.6−34.2% and 85.8% vs. 78.3−79.2%, respectively, for FTT; and 91.7−97.2% vs. 58.3−61.1% and 89% vs. 78−79.3%, respectively, for PTTa. The authors conclude that T1 SPIR is more sensitive and accurate compared to T2 TSE in detecting SSC tendon tear on 3T MR arthrography.

PICO 2: Suspected rotator cuff re-tear (following previous rotator cuff repair):

- Green – **MRI shoulder without IV contrast**
- Green – **MR arthrography shoulder**
- Yellow – **CT arthrography shoulder**
  [MRI not available or contraindicated; or prior shoulder arthroplasty/significant metal artifact]
- Yellow – **CT shoulder without IV contrast**
  [Further evaluation or surgical planning of bone abnormality]
- Red – **MRI shoulder without and with IV contrast; MRI shoulder with IV contrast**
- Red – **CT shoulder without and with IV contrast; CT shoulder with IV contrast**
- Red – **PET; bone scan; SPECT**

Level of Evidence: low

Notes concerning use of contrast:
MRI without IV contrast is the advanced imaging procedure of choice for visualization of soft tissue structures of the shoulder, including ligaments, tendons, joint capsules, and joint cartilage structures (*CO Department of Labor* 2014; PLE expert panel consensus opinion). The addition of intra-articular contrast (arthrography) can improve the detection and definition of rotator cuff tears particularly in patients with a history of prior rotator cuff repair (*CO Department of Labor* 2014; Liu et al 2020; expert panel consensus opinion). The use of MRI with IV contrast is limited in the shoulder, however, may be useful in the evaluation of adhesive capsulitis (Erber et al 2022; Pessis et al 2020; Ahn et al 2015).

Notes concerning applicability and/or patient preferences: none.

Guideline and PLE expert panel consensus opinion summary:
Overview:
Areas of rotator cuff attenuation and/or perforation may persist in patients with prior rotator cuff repair, and advanced imaging can be useful to evaluate for moderate or large full-thickness defects and tendon retraction (PLE expert panel consensus opinion). Multiple high-quality guidelines note that MRI (without IV contrast) is widely used to provide more definitive visualization of soft tissue structures and is generally accepted as the gold standard to evaluate for a rotator cuff tear (Nacey et al [*ACR*] 2022; Bussieres et al 2008; Hopman et al 2013; *CO Department of Labor* 2014; *AAOS* 2019; strength of recommendation: strong). MR arthrography is also useful for evaluation of the postoperative rotator cuff and can improve diagnostic accuracy over conventional MRI (Nacey et al [*ACR*] 2022). CT arthrography can be useful to evaluate a suspected rotator cuff tear in patients with significant metal artifact, in patients following total shoulder arthroplasty, or in patients with contraindication to MRI (Nacey et al [*ACR*] 2022; Hegmann et al [*ACOEM*] 2016; PLE expert panel consensus opinion). Routine CT is not recommended for the evaluation of shoulder pain (Hegmann et al [*ACOEM*] 2016: not recommended, insufficient evidence), and there is insufficient evidence to support CT for evaluating a history of prior rotator cuff repair when rotator cuff disorder is suspected (Nacey et al [*ACR*] 2022). However, for instances where evaluation and surgical planning of bone abnormality is necessary, a noncontrast CT is generally recommended (Hegmann et al [*ACOEM*] 2016; *CO Department of Labor* 2014; PLE expert panel consensus opinion). An advantage of ultrasound evaluation in the postoperative shoulder is absence of metal-induced artifact when examining the rotator cuff and adjacent soft tissues (Nacey et al [*ACR*] 2022).

Clinical/imaging notes:

- MR imaging systems following shoulder arthroplasty should utilize advanced metal suppression techniques (e.g., MAVRIC or WARP) (PLE expert panel consensus opinion).
- The accuracy of ultrasound for rotator cuff tears is highly operator-dependent, and the performance of ultrasound may vary significantly depending on local expertise (Bussieres et al 2008; *CO Department of Labor* 2014; Hopman et al 2013).

Evidence update (2012–present):

Moderate Level of Evidence

Gyftopoulos et al (2022), in a systematic review and meta-analysis, evaluated MRI (noncontrast MRI and MR arthrography) and ultrasound (US) for diagnosing retear of a repaired rotator cuff tendon. Inclusion criteria were those studies that assessed diagnostic accuracy using either of the two modalities as the index test, with surgical findings as the reference standard. A total of 8 studies were included with 304 total patients (MRI = 221, US = 83). For all retears, mean sensitivity and specificity for MRI were 81.4% (95% CI, 73.3–87.5%) and 82.6% (95% CI, 76.3–87.5%) vs. 83.7% (95% CI, 67.4–92.7%) and 90.7% (95% CI, 73.6–97.1%) for US. For full-thickness retears, mean sensitivity and specificity for MRI were 85.9% (95% CI, 80.2–90.2%) and 89.1% (95% CI, 84.6–92.4%) vs. 89.7% (95% CI, 75.6–96.1%) and 91.0% (95% CI, 75.5–97.1%) for US. There was no significant difference in terms of sensitivity or specificity for either comparison (p = .28–.76). The authors conclude that either MRI or US can be considered as a first-line imaging option to assess suspected rotator cuff retear after previous repair.

PICO 3: Shoulder pain with any of the following scenarios:

- **Suspected labral tear following acute trauma**
- **Suspected labral tear and failure of conservative therapy***
- **Instability (e.g., from dislocation event(s)) and nondiagnostic radiographs**

- **Green – MRI shoulder without IV contrast**
- **Green – MR arthrography shoulder**
- **Yellow – CT arthrography shoulder**
  [MRI not available or contraindicated; or prior shoulder arthroplasty/significant metal artifact]
- **Yellow – CT shoulder without IV contrast**
  [Further evaluation or surgical planning of bone abnormality]
- **Red – MRI shoulder without and with IV contrast; MRI shoulder with IV contrast**
- **Red – CT shoulder without and with IV contrast; CT shoulder with IV contrast**
- **Red – PET; bone scan; SPECT**

*Failure of conservative therapy can be defined as moderate to severe persistent symptoms following conservative care for 4-6 weeks or increasing pain during a trial of conservative care. Those with uncontrolled pain, significant limitation of function, inability to perform activities of daily living, or physical inability to participate in noninvasive care for an appropriate period of time also fall into this category (PLE expert panel consensus opinion).

Level of Evidence: MRI, MR arthrography: high

Notes concerning use of contrast:
MRI without IV contrast is the advanced imaging procedure of choice for visualization of soft tissue structures of the shoulder, including ligaments, tendons, joint capsules, and joint cartilage structures (*CO Department of Labor* 2014; PLE expert panel consensus opinion). The addition of intra-articular contrast (arthrography) can enhance definition of selected pathologies, particularly labral tears (*CO Department of Labor* 2014). The use of MRI with IV contrast is limited in the shoulder, however, may be useful in the evaluation of adhesive capsulitis (Erber et al 2022; Pessis et al 2020; Ahn et al 2015).

Notes concerning applicability and/or patient preferences: none.

Guideline and PLE expert panel consensus opinion summary:
Overview:
Conventional radiographs are preferred for initial imaging following acute shoulder injuries to rule out fractures, avulsions, and dislocation (Amini et al [*ACR*] 2018). Advanced imaging is indicated in patients with shoulder pain whenever an acute labral tear is suspected, symptoms persist following an appropriate trial (4-6 weeks) of conservative therapy, or dislocation or instability is suspected and radiographs are nondiagnostic (Amini et al [*ACR*] 2018; Hegmann et al [*ACOEM*] 2016; Bussieres et al 2008; *CO Department of Labor* 2014; PLE expert panel consensus opinion).

MRI shoulder:
In patients with traumatic shoulder pain and suspected labral tear, instability, and/or Bankart or Hill-Sachs lesion, MRI (preferably 3T) is an advanced imaging modality of choice (Nacey et al [*ACR*] 2022; Amini et al [*ACR*] 2018). In the acute setting, MRI shows labral, Bankart, ligamentous, and tendinous

injuries that result from dislocations and can lead to instability (Bussieres et al 2008). In the acute setting, it is also useful in identifying joint effusions which, if present, indicate the presence of injuries to intra-articular structures (Amini et al [*ACR*] 2018; PLE expert panel consensus opinion). MRI is also useful to evaluate for labral detachment and capsular stress injury or laxity after conservative therapy (*CO Department of Labor* 2014). In the setting of acute shoulder dislocation when post-traumatic joint effusion is present, MRI without IV contrast may be preferred to MR arthrography, as it can provide sufficient visualization of soft tissue structures (Amini et al [*ACR*] 2018).

MR arthrography shoulder:
In patients with traumatic shoulder pain and suspected labral tear, instability, and/or Bankart or Hill-Sachs lesion, MR arthrography can also be useful as a preferred advanced imaging modality (Amini et al [*ACR*] 2018). It is more accurate than MRI in diagnosing and excluding acute labral tears, and more accurate than CT arthrography in the assessment of labroligamentous injuries (Amini et al [*ACR*] 2018). Multiple meta-analyses have found MR arthrography to have a higher sensitivity (80%-87% vs. 63%-76%) and specificity (91%-92% vs. 87%) compared to conventional MRI for the detection of SLAP tears (Nacey et al [*ACR*] 2022). However, this increased accuracy should be balanced against the need for an invasive arthrogram procedure (Nacey et al [*ACR*] 2022). Its use is also recommended for diagnosing labral tears, shoulder dislocations, or recurrent instability in patients with subacute or chronic shoulder pain (Amini et al [*ACR*] 2018; Hegmann et al [*ACOEM*] 2016; Bussieres et al 2008).

CT arthrography shoulder:
CT arthrography has been shown to be an accurate modality in assessing shoulder instability because of its depiction of osseous, cartilaginous, and labroligamentous injuries (Nacey et al [*ACR*] 2022). While CT arthrography and MR arthrography have comparable diagnostic accuracy in evaluation of SLAP tears, Bankart lesions, and Hill-Sachs fractures, CT arthrography exposes the patient to ionizing radiation (Amini et al [*ACR*] 2018). It can be useful to evaluate labral detachment, shoulder instability/dislocation, or capsular stress injury or laxity in patients with significant metal artifact, in patients who have previously undergone total shoulder arthroplasty, or in those with contraindication to MRI (Amini et al [*ACR*] 2018; Hegmann et al [*ACOEM*] 2016; *CO Department of Labor* 2014; PLE expert panel consensus opinion). Labral evaluation in the postoperative setting may be better with CT arthrography than MRI in patients with metallic suture anchors and to evaluate for healing after SLAP repair (Nacey et al [*ACR*] 2022).

CT shoulder:
Routine CT is not recommended for the evaluation of shoulder pain (Hegmann et al [*ACOEM*] 2016: not recommended, insufficient evidence), and is not effective for direct evaluation of the labrum (Nacey et al [*ACR*] 2022). However, CT without contrast can be useful to assess bony glenoid deficiency and Hills-Sachs deformities prior to surgery (Nacey et al [*ACR*] 2022; Amini et al [*ACR*] 2018; Hegmann et al [*ACOEM*] 2016; PLE expert panel consensus opinion). Noncontrast CT can be used to assess bone loss in those with recurrent dislocation or chronic instability (Amini et al [*ACR*] 2018).

<u>Clinical/imaging notes:</u>

- Anterior shoulder instability is the most common form of shoulder instability and is usually due to traumatic injury such as a collision or fall on an outstretched arm with the shoulder abducted and externally rotated (Provenchar et al 2021).
- Anterior shoulder instability can also present without dislocation of the glenohumeral joint; repetitive microtrauma can cause glenohumeral subluxation beyond the physiologic limits but with remaining glenohumeral contact (Provenchar et al 2021).

- 3T MRI and modern 1.5T MRI systems with optimized technique may have comparable accuracies to MR arthrography (Arirachakaran et al 2017; PLE expert panel consensus opinion). If a patient is to undergo low field strength imaging because of claustrophobia or bariatric issues, MR arthrography should be considered instead of MRI for improved diagnostic accuracy in the detection of labral tears (PLE expert panel consensus opinion).

Evidence update (2012-present):

Moderate Level of Evidence:

Vopat et al (2021), in a systematic review, examined the reliability and accuracy of different imaging modalities in assessing Hill-Sachs lesions within the setting of anterior shoulder instability. Forty studies (2,560 shoulders) met inclusion criteria. For diagnosing the presence of Hill-Sachs lesions, computed tomography (CT) arthrography had the highest reported accuracy (median, 91%; range, 66%-100%). For the same assessment, CT arthrography also had the greatest reported sensitivity (median, 94%; range, 50%-100%). For the quantification of Hill-Sachs lesion parameters, reported intraobserver reliabilities were highest for three-dimensional (3D) CT (intraclass correlation coefficient [ICC] range, 0.916-0.999), followed by 2-dimensional CT (ICC range, 0.858-0.861) and MRI (ICC range, 0.28-0.97). For the same quantification parameters, interobserver reliabilities were also reported for 3D CT (ICC range, 0.772-0.996), 2-dimensional CT (ICC range, 0.721-0.879), and MRI (k range, 0.444-0.700). Intraobserver reliabilities for determining glenoid tracking were only reported for 3D CT (k range, 0.730-1.00; ICC range, 0.803-0.901) and MRI (ICC range, 0.770-0.790). The authors conclude that the current literature supports a variety of different imaging modalities that provide clinically acceptable accuracy in diagnosing and quantifying Hill-Sachs lesions.

Foti et al (2020), in a prospective study, compared the diagnostic accuracy of dual-energy CT arthrography (DE-CTA) and MR arthrography (MRA) of the shoulder in depicting glenoid labral tears. 47 consecutive patients underwent both DE-CTA and MRA the same day. Two radiologists, blinded to clinical data, evaluated the presence of labral tears on standard CTA and DE-CTA images. A third radiologist evaluated the MRA images. Diagnostic accuracy values were calculated with surgery as reference standard; surgery revealed the presence of labral tear in 38/47 patients (80.9%). Sensitivity and specificity values were 84.2% and 77.8% for MRA, and average values were 84.2% and 83.4% for CTA, and 90.8% and 88.9% for DE-CTA. Inter-observer agreements were near perfect for CTA (k = 0.84) and substantial for DE-CTA (k = 0.76). Intra-observer agreements were near perfect for both CTA (k = 0.88) and DE-CTA (k = 0.82). The authors conclude that a nonsignificant increase in diagnostic accuracy in diagnosing labral tears was obtained by using CTA in comparison with MRA. DE-CTA allowed a further but not significant increase in diagnostic accuracy, when compared to both MRA and CTA.

Smith et al (2012b), in a meta-analysis, reported that overall MR arthrography appears marginally superior to MRI for the detection of glenohumeral labral lesions (MR arthrography sensitivity 88%, specificity 93% vs. MRI sensitivity 76%, specificity 87%).

PICO 4: Suspected biceps tendon tear, or suspected biceps tendinopathy with symptoms that persist following conservative therapy*:

- **Green – MRI shoulder without IV contrast**
- **Green – MR arthrography shoulder**
- **Yellow – CT arthrography shoulder**
  [MRI not available or contraindicated; or prior shoulder arthroplasty/significant metal artifact]
- **Yellow – CT shoulder without IV contrast**
  [Further evaluation or surgical planning of bone abnormality]
- **Red – MRI shoulder without and with IV contrast; MRI shoulder with IV contrast**
- **Red – CT shoulder without and with IV contrast; CT shoulder with IV contrast**
- **Red – PET; bone scan; SPECT**

*Failure of conservative therapy can be defined as moderate to severe persistent symptoms following conservative care for 4-6 weeks or increasing pain during a trial of conservative care. Those with uncontrolled pain, significant limitation of function, inability to perform activities of daily living, or physical inability to participate in noninvasive care for an appropriate period of time also fall into this category (PLE expert panel consensus opinion).

Level of Evidence: low

Notes concerning use of contrast:
MRI without IV contrast is the advanced imaging procedure of choice for visualization of soft tissue structures of the shoulder, including ligaments, tendons, joint capsules, and joint cartilage structures (*CO Department of Labor* 2014; PLE expert panel consensus opinion). The addition of intra-articular contrast (arthrography) can enhance definition of selected pathologies, particularly labral tears (*CO Department of Labor* 2014). The use of MRI with IV contrast is limited in the shoulder, however, may be useful in the evaluation of adhesive capsulitis (Erber et al 2022; Pessis et al 2020; Ahn et al 2015).

Notes concerning applicability and/or patient preferences: none

Guideline and PLE expert panel consensus opinion summary:
Overview:
Advanced imaging is recommended for patients with suspected full-thickness biceps tendon tear, or in patients whose symptoms persist after 4-6 weeks of conservative therapy (*CO Department of Labor* 2014; Hegmann et al [*ACOEM*] 2016). When initial radiographs are normal or inconclusive, MRI without contrast or MR arthrography are generally recommended for suspected atraumatic biceps tendinitis, bursitis, or tear (Nacey et al [*ACR*] 2022; PLE expert panel consensus opinion). MRI and ultrasound are also accurate for the diagnosis of full-thickness biceps tendon tears (Amini et al [*ACR*] 2018; PLE expert panel consensus opinion). If there is a coexisting rotator cuff tear, MRI has a greater specificity for biceps tendon abnormality (Nacey et al [*ACR*] 2022). MR arthrography may improve the accuracy of MRI in detection of long head of the bicep tears, specifically for evaluation of biceps pulley lesions and rotator cuff interval widening, which can be associated with instability (Nacey et al [*ACR*] 2022; PLE expert panel consensus opinion). It is also moderately accurate for assessing biceps tendon subluxation (Nacey et al [*ACR*] 2022). Reports on the accuracy of CT arthrography for biceps tendinopathy are variable, and diagnosis is primarily based off the change in tendon caliber (Nacey et al [*ACR*] 2022). There is limited evidence for the use of CT to specifically evaluate the biceps tendon (Nacey et al [*ACR*]

2022; Hegmann et al [*ACOEM*] 2016: not recommended, insufficient evidence). However, for instances where evaluation and surgical planning of bone abnormality is necessary, a noncontrast CT is generally recommended (Hegmann et al [*ACOEM*] 2016; PLE expert panel consensus opinion).

Clinical/imaging notes:

- Patients with bicipital tendon disorders may present with aching, burning and/or stabbing pain in the anterior medial aspect of the shoulder. They may also report snapping with a subluxing tendon (*Colorado Department of Labor*, 2014).
- Immediate sharp pain in the biceps region along with tenderness, bruising and a "Popeye" deformity may indicate an acute full-thickness tear of the long head of the biceps following trauma (*Colorado Department of Labor*, 2014).
- Biceps tears and tendinopathy are often associated with anterior supraspinatus abnormalities, superior subscapularis pathology, and subacromial bursitis. These entities may be difficult to distinguish on physical exam (PLE expert panel consensus opinion).
- Ultrasound is accurate in the evaluation of full-thickness biceps tendon tears and is useful to perform directed therapeutic injections into the biceps tendon sheath (Amini et al [*ACR*] 2018; PLE expert panel consensus opinion). Apart from the biceps anchor, the intra-articular and extra-articular portions of the biceps tendon are well seen on routine ultrasound imaging (Nacey et al [*ACR*] 2022).
- CT arthrography and MR arthrography have comparable diagnostic accuracies in the detection of biceps tendon pathology; however, CT exposes the patient to ionizing radiation (De Maeseneer et al 2012).

Evidence update (2012–present):

Low Level of Evidence:

Razmjou et al (2016), in a retrospective study evaluating the accuracy of MRI for biceps tendon abnormalities in 183 patients with rotator cuff disorders, showed the following sensitivities and specificities: 0.54 and 0.98 for full tears, 0.27 and 0.86 for partial tears, and 1.0 and 0.83 for subluxation/dislocation.

Tadros et al (2015) found that both MRI and MR arthrography had good diagnostic accuracy with no significant difference for tears and had good specificity but low sensitivity for tendinosis. For tears, MRI versus MR arthrography showed 75–83% and 64–73% sensitivity; 73–75% and 82–91% specificity; 66–69% and 41– 62% PPV; 82–87% and 92–94% NPV; and 74–78% and 79– 88% accuracy, respectively. For tendinosis, MRI versus MR arthrography showed 18–36% and 15–38% sensitivity; 69–79% and 83–91% specificity; 22–28% and 18–50% PPV; 74–76% and 80–86% NPV; and 61–64% and 70–81% accuracy, respectively.

PICO 5: Suspected adhesive capsulitis:

- Green – **MRI shoulder without IV contrast**
- Yellow – **MRI shoulder without and with IV contrast** or **MRI shoulder with IV contrast**
- Yellow – **MR arthrography shoulder**
  [Previous noncontrast MRI findings are indeterminate]
- Yellow – **CT arthrography shoulder**
  [MRI not available or contraindicated; or prior shoulder arthroplasty/significant metal artifact]
- Red – **CT shoulder; Bone scan; PET; SPECT**

Level of Evidence: low

Notes concerning use of contrast:
MRI without IV contrast is the advanced imaging procedure of choice for visualization of soft tissue structures of the shoulder, including ligaments, tendons, joint capsules, and joint cartilage structures (*CO Department of Labor* 2014; PLE expert panel consensus opinion). The use of MRI with IV contrast may be useful in the evaluation of adhesive capsulitis (Erber et al 2022; Pessis et al 2020; Ahn et al 2015). The addition of intra-articular contrast (arthrography) can enhance definition of selected pathologies (*CO Department of Labor* 2014).

Notes concerning applicability and/or patient preferences: none.

Guideline and PLE expert panel consensus opinion summary:
Overview:
For patients with suspected adhesive capsulitis, radiographs, including a transaxillary view, are useful at the time of initial evaluation to exclude the presence of calcific tendinitis, osteoarthritis, and chronic posterior dislocation, each of which can result in pain and limitations of mobility (Kelley et al [*APTA*] 2013; Bussieres et al 2008; PLE expert panel consensus opinion). MRI is generally the preferred advanced imaging modality of choice (Nacey et al [*ACR*] 2022; Kelley et al [*APTA*] 2013; Bussieres et al 2008). Contrast-enhanced MRI can increase the conspicuity of axillary recess capsular thickening and rotator interval thickening (Nacey et al [*ACR*] 2022). While thickening of the capsule/synovium in the axillary recess may be useful for diagnosis on coronal oblique T2-weighted MR arthrography images (Bussieres et al 2008), fluid within the rotator interval or along the axillary recess due to the injection itself can serve as a limitation (Nacey et al [*ACR*] 2022). Routine CT is not recommended for the evaluation of shoulder pain, and there is insufficient evidence for its specific use in patients with suspected adhesive capsulitis (Nacey et al [*ACR*] 2022; Hegmann et al [*ACOEM*] 2016: not recommended, insufficient evidence).

Clinical/imaging notes:

- Adhesive capsulitis is characterized by gradual and insidious onset of pain and restriction of glenohumeral joint mobility in multiple planes, particularly with external rotation (Kelley et al [*APTA*] 2013).
- Adhesive capsulitis may follow trauma, myocardial infarction, neck or cardiac surgery, radiation therapy, or prolonged immobilization (Kelley et al [*APTA*] 2013). Other risk factors for adhesive capsulitis can include diabetes and thyroid disease (Kelley et al [*APTA*] 2013; Hopman et al 2013).

- Thickening of the axillary capsule with T2 hyperintensity are useful criteria for the diagnosis of adhesive capsulitis; STIR, fat-suppressed PD and fat-suppressed T2-weighted sequences are more sensitive than non-fat-suppressed sequences for hyperintensity (PLE expert panel consensus opinion).
- Patients with adhesive capsulitis show effacement of fat within the anterior rotator cuff interval, secondary to capsular and ligamentous thickening (PLE expert panel consensus opinion).
- Rotator interval enhancement may increase the specificity of adhesive capsulitis on MRI with IV contrast (Ahn et al 2015).
- Patients with adhesive capsulitis may also show a disproportionate amount of fluid within the biceps tendon sheath and subcoracoid recess relative to fluid in the joint space (PLE expert panel consensus opinion).
- Although there are several ultrasound findings that can be seen in patients with adhesive capsulitis, ultrasound is not typically performed specifically for this indication (Nacey et al [*ACR*] 2022).

Evidence update (2012–present):

Low Level of Evidence:

Erber et al (2022) retrospectively investigated the influence of IV contrast administration on sensitivity and specificity of MRI in diagnosing adhesive capsulitis of the shoulder (ACS). A total of 60 subjects with at least 4 of 5 clinical signs of ACS and 120 patients with other shoulder diseases who underwent contrast-enhanced MRI were included. First, non-enhanced images and second, contrast-enhanced images for all patients were independently evaluated by three radiologists. Using non-enhanced MRI, readers achieved a mean sensitivity of 63.9% and a mean specificity of 86.4%. With addition of CE sequences, the mean sensitivity (85.5%) and the sensitivity for each reader increased significantly ($p = .046$, $p < .01$, $p < .001$, $p = .045$) while the improvement in mean specificity was not significant. The authors conclude that addition of CE sequences can significantly increase the sensitivity of MRI in the diagnosis of ACS.

Pessis et al (2020) retrospectively compared reliability and performance of MRI measures enhanced with IV gadolinium contrast versus non-enhanced MRI measures for the diagnosis of adhesive capsulitis (AC) among 42 patients. AC was confirmed by arthrography and MRI findings were correlated with clinical stage, etiology, and pain. Results found sensitivity (97.6%) and specificity (97.6%) of axillary-recess capsule signal enhancement for AC diagnosis were significantly superior ($p = 0.02$) to hyperintense signals on T2-weighted fat-suppressed images (sensitivity 90.5%, specificity 92.7%). Authors found 100% specificity of enhancement of the coracohumeral ligament signal for AC diagnosis. The early stage of adhesive capsulitis was positively correlated with joint capsule enhancement in the rotator interval. The authors conclude that IV contrast injection with MRI can be helpful for AC diagnosis in difficult cases.

Ahn et al (2015) reported that capsular thickening and altered signal of the axillary recess of the capsule on both non-CE and CE MRI had similar diagnostic performance with high sensitivity, moderate specificity, and excellent interobserver agreement. Contrast-enhanced MRI may improve assessment of the rotator interval and lend further confidence in the radiologic diagnosis of AC. With respect to the axillary joint capsule thickness, a cutoff value of 5.0 mm provided the highest sensitivity and specificity. Interobserver reliability was excellent for rotator cuff thickness (low level of evidence).

PICO 6: Osteoarthritis of the shoulder on conventional radiography with any of the following:

- **New-onset severe pain**
- **Significant change in symptoms (e.g., locking, clicking, loss of range of motion)**
- **Pain that is disproportionate to findings on radiography**
- **Pre-surgical planning is necessary:**

- **Green – MRI shoulder without IV contrast**
- **Green – MR arthrography shoulder**
- **Green – CT shoulder without IV contrast**
- **Yellow – CT arthrography shoulder**
  [MRI not available or contraindicated; or prior shoulder arthroplasty/significant metal artifact]
- **Red – MRI shoulder without and with IV contrast; MRI shoulder with IV contrast**
- **Red – CT shoulder without and with IV contrast; CT shoulder with IV contrast**
- **Red – PET; bone scan; SPECT**

Level of Evidence: low

Notes concerning use of contrast:
When planning for shoulder arthroplasty, MRI without IV contrast or CT without IV contrast can be helpful to evaluate glenoid morphology, version, and extent and location of glenoid bone loss (Small et al [*ACR*] 2018; PLE expert panel consensus opinion). MR arthrography and CT arthrography can be used to evaluate the integrity of the rotator cuff particularly in patients with a history of previous surgery. The addition of IV contrast is not generally indicated in this clinical scenario (PLE expert panel consensus opinion).

Notes concerning applicability and/or patient preferences: none.

Guideline and PLE expert panel consensus opinion summary:
Overview:
In the absence of reliable evidence, it is recommended that patients with glenohumeral osteoarthritis undergoing arthroplasty first be imaged with axillary and true AP (Grashey view) radiographs, with advanced imaging performed at the discretion of the clinician (*AAOS* 2020, strength of recommendation: consensus). If initial radiographs are conducted, the presence of glenohumeral osteoarthritis may not require further imaging unless additional pathology is suspected (e.g., rotator cuff tear), atypical features are present, or surgery is a consideration (Nacey et al [*ACR*] 2022; *NICE* 2022). When advanced imaging is necessary, CT without IV contrast can be helpful to evaluate osseous morphology when surgery is a consideration, as it demonstrates high interrater reliability for glenoid version, glenoid bone loss, and humeral head subluxation (Nacey et al [*ACR*] 2022; PLE expert panel consensus opinion). MRI, MR arthrography, or CT arthrography can be used to evaluate the integrity of the rotator cuff (PLE expert panel consensus opinion; *AAOS* 2020). While MRI can be used to detect the degree of glenohumeral chondral loss, this diagnosis is generally easily made with radiographs (Nacey et al [*ACR*] 2022). Glenoid version measured by MRI is usually similar to that measured by CT (Nacey et al [*ACR*]

2022). Glenoid retroversion can also be assessed on MRI if additional T1 axial images are obtained with the field of view increased to include the medial border of the scapula (PLE expert panel consensus opinion). MR arthrography may be useful in characterizing the degree of chondral loss, presence of full thickness rotator cuff tear, and characterization of glenoid morphology (Nacey et al [*ACR*] 2022). CT arthrography can be helpful for preoperative planning in patients with severe glenohumeral arthritis, particularly those with contraindication to MRI, as it provides excellent imaging of osseous detail (Nacey et al [*ACR*] 2022; PLE expert panel consensus opinion).

Clinical/imaging notes:

- Glenohumeral osteoarthritis is typically well visualized on conventional radiographs, without the need for special views (Nacey et al [*ACR*] 2022).
- Pre-operative evaluation of patients undergoing shoulder arthroplasty helps to define osseous anatomy, pathology, and potential component positioning (*AAOS* 2020).
- Quantifying glenoid version and the presence or severity of subchondral cystic change is useful for surgical planning in anticipation of shoulder arthroplasty (PLE expert panel consensus opinion).
- Three-dimensional (3D) CT imaging has been shown to improve accuracy of the desired implant position, however, there is inadequate data on long term clinical outcomes (*AAOS* 2020).
- Ultrasound is not typically performed for indications of osteoarthritis (Nacey et al [*ACR*] 2022).

Evidence update (2008–present):

Moderate Level of Evidence

Omoumi et al (2015), in a prospective study comparing CT arthrography and MR arthrography in 56 consecutive patients with arthroscopic correlation, showed that the diagnostic performance in detecting glenohumeral cartilage lesions was moderate with both techniques, although statistically significantly better with CT arthrography (moderate level of evidence).

Low Level of Evidence

Raymond et al (2013) compared glenoid version on axillary radiographs (AXR) and MRI in 33 consecutive patients with a diagnosis of end-stage osteoarthritis. They found that the mean retroversion measured on AXR was significantly greater than that measured on MRI, with the mean difference of glenoid version of 7.36° ($P < .001$), and the interobserver and intraobserver reliabilities were greater for MRI than for radiography. Glenoid retroversion was greater on radiography in 73% of cases. The authors conclude that axillary radiographs should be interpreted with caution when assessing the pattern and extent of posterior glenoid wear in osteoarthritis. The authors suggest that radiographs should not be used for preoperative templating but may be useful for basic diagnostic purposes. MRI represents a precise and accurate technique for evaluating glenoid wear without exposure to ionizing radiation, in addition to its established role in the assessment of the rotator cuff (low level of evidence).

Hoenecke et al (2010) compared the assessment of glenoid version on two-dimensional (2D) CT versus three-dimensional (3D) CT in 33 consecutive osteoarthritis patients undergoing evaluation for osteoarthritis. When the high-resolution 3D-CT reconstructions were analyzed, the location of maximum wear in arthritic glenoids was most commonly posteroinferior (36% in the posterior direction at 9 o'clock and 21% in the posterior inferior position at 8 o'clock). This maximum wear was detected accurately in only 48% of cases in the clinical 2D axial CT slices. The average absolute error in the version measured on the 2D-CT slice passing through the tip of the coracoid was 5.1 (range, 0-16; $P < .001$) (low level of evidence).

PICO 7: Further evaluation/surgical planning of suspected or known acute* fracture following radiographs:

- **Green – CT shoulder without IV contrast**
- **Green – MRI shoulder without IV contrast**
- **Red – MRI shoulder without and with IV contrast; MRI shoulder with IV contrast**
- **Red – CT shoulder without and with IV contrast; CT shoulder with IV contrast**
- **Red – MR arthrography shoulder**
- **Red – CT arthrography shoulder**
- **Red – PET; bone scan; SPECT**

*A fracture occurring within the past 4 weeks is considered acute (PLE expert panel consensus opinion).

Level of Evidence: Moderate

Notes concerning use of contrast:
The addition of contrast is usually not necessary in the assessment of fractures (Amini et al [*ACR*] 2018; PLE expert panel consensus opinion).

Notes concerning applicability and/or patient preferences: Consulting and reporting requirements are not required for orders for applicable imaging services made by ordering professionals under the following circumstances (*42 C.F.R. § 414.94. 2015*):

- Emergency services when provided to individuals with emergency medical conditions.
- For an inpatient and for which payment is made under Medicare Part A.

Guideline and PLE expert panel consensus opinion summary:
Overview:
In patients with traumatic shoulder pain, conventional radiographs are initially recommended and can identify most fractures (Amini et al [*ACR*] 2018; Hegmann et al [*ACOEM*] 2016; *CO Department of Labor* 2014; Bussieres et al 2008). Advanced imaging modalities may be helpful to further evaluate a fracture detected on previous radiographs, such as for pre-operative planning (CO Department of Labor 2014; Bussieres et al 2008). If fracture remains a possibility after normal radiographs, CT is generally recommended as the modality of choice (Hegmann et al [*ACOEM*] 2016: recommended, insufficient evidence (I); Bussieres et al 2008), particularly if the radiographs show fracture of the humeral head/neck or scapula (*CO Department of Labor* 2014; Amini et al [*ACR*] 2018). CT is also useful for characterizing fractures if more information is needed, such as fracture complexity, displacement, or angulation (Bussieres et al 2008; Amini et al [*ACR*] 2018). MRI is effective for shoulder pathology evaluation, including assessment of bony morphology and bone loss in patients with traumatic shoulder injuries, however, it is used less often in the acute setting (Amini et al [*ACR*] 2018; Bussieres et al 2008). In the evaluation of suspected fracture, MRI may be most useful when there is suspicion of associated soft-tissue pathology (Amini et al [*ACR*] 2018).

Evidence update (2017-present):
There were no recent articles that significantly affected the recommendations or conclusions found in the guidelines referenced above.

PICO 8: Suspicion for septic arthritis, osteomyelitis, or periarticular abscess, and non-diagnostic radiographs:

- **Green** – **MRI shoulder without and with IV contrast**
- **Green** – **MRI shoulder without IV contrast**
- **Yellow** – **CT shoulder with IV contrast**
- **Yellow** – **CT shoulder without IV contrast**
- **Yellow** – **Bone scan** and/or **WBC scan** (with or without **sulfur colloid marrow scan** and/or **SPECT** or **SPECT/CT**)
  [patient unable to undergo MRI; or findings on previous MRI are non-diagnostic]
- **Yellow** – **FDG-PET** or **FDG-PET/CT**
  [patient unable to undergo MRI; or findings on previous MRI are non-diagnostic]
- **Red** – **CT without and with IV contrast**, **MR arthrography**, **CT arthrography**

Level of Evidence: MRI without contrast, MRI without and with contrast: moderate; CT without contrast, bone scan, WBC scintigraphy, FDG-PET/CT, CT with contrast: low; MRI with contrast, MR arthrography, CT without and with contrast, CT arthrography: insufficient

Notes concerning use of contrast:
The use of contrast-enhanced MRI or CT may further increase diagnostic sensitivity for abscess, fistula, vascular complication, and/or inflammation (Pierce et al [ACR] 2022).

Notes concerning applicability and/or patient preferences:
Nuclear medicine studies fused with CT are not yet widely available, and therefore may have applicability or generalizability issues in the community outpatient setting (PLE expert panel consensus opinion).

Guideline and PLE expert panel consensus opinion summary:
Conventional Radiography
Radiographs are the initial evaluation of choice for musculoskeletal infections, including osteomyelitis and septic arthritis (Pierce et al [*ACR*] 2022; Bussieres et al 2008). While not specific, radiographs can be used to provide an overview of the anatomic area and look for bony abnormalities (deformity, destruction), fractures, and other causes of pain (Pierce et al [*ACR*] 2022).

MRI
MRI is the advanced imaging modality of choice for suspected infection and has high sensitivity and specificity in diagnosing osteomyelitis (Pierce et al [*ACR*] 2022; Bussieres et al 2008). Particularly, MRI has high sensitivity to fluid and inflammation (Pierce et al [*ACR*] 2022). Contrast-enhanced MRI is preferred to help evaluate the soft tissues, and can further increase the diagnostic sensitivity for abscess, fistula, and vascular complications (Pierce et al [*ACR*] 2022). Its use can also improve detection of inflammation of joints, bursa, tendons, and muscles (Pierce et al [*ACR*] 2022). Compared with CT, however, soft tissue gas is not well-visualized on MRI (Pierce et al [*ACR*] 2022).

Bone scan and/or WBC scan (with or without sulfur colloid scan and/or SPECT or SPECT/CT)
There are several limitations regarding the value of radionuclide imaging in musculoskeletal infection, and well-designed prospective multicenter investigations are virtually nonexistent (Palestro et al

[*SNMMI*] 2021). Depending on availability, bone scintigraphy may be an acceptable alternative for imaging of uncomplicated osteomyelitis (Palestro et al [*SNMMI*] 2021). While 3-phase bone scan, WBC scan, or sulfur colloid scan can be ordered to increase the accuracy of diagnosing osteomyelitis, they have relatively poor spatial resolution and low specificity (Pierce et al [*ACR*] 2022; Hegmann et al [*ACOEM*] 2016; *CO Department of Labor* 2014). In instances of uncomplicated peripheral bone osteomyelitis, WBC bone scan (alone or in combination with bone scanning) should be reserved for which PET or bone scan are not available or are non-diagnostic (Palestro et al [*SNMMI*] 2021). For the diagnosis of complicated peripheral bone osteomyelitis, WBC scan with bone marrow scintigraphy is an appropriate nuclear medicine modality, while WBC scan with or without bone scanning can also be used (Palestro et al [*SNMMI*] 2021). In certain circumstances, such as when MRI is contraindicated or not available, radionuclide imaging may be of use for the diagnosis of septic arthritis and soft tissue infection (Pierce et al [*ACR*] 2022; Hegmann et al [*ACOEM*] 2016). Because of its high sensitivity, bone scintigraphy is a useful rule-out test for septic arthritis (Palestro et al [*SNMMI*] 2021). WBC scan, either alone or in combination with bone scintigraphy or marrow scan, may be helpful for ruling-out septic arthritis when PET or bone scintigraphy is inconclusive, and osteomyelitis is a diagnostic consideration (Palestro et al [*SNMMI*] 2021). Sulfur colloid scan may be considered if prior 3-phase and WBC scans are non-diagnostic, and if a 3-phase bone scan is positive, also obtaining both a WBC scan and sulfur colloid scan may further increase specificity (Pierce et al [*ACR*] 2022). The addition of SPECT/CT is recommended in positive WBC studies for more accurate localization and to help differentiate soft tissue infection from osteomyelitis (Pierce et al [*ACR*] 2022). However, this modality may have applicability or generalizability issues in the community outpatient setting (PLE expert panel consensus opinion).

CT

CT with or without IV contrast demonstrates the features of acute osteomyelitis in more detail than radiographs but is less sensitive than MRI or nuclear medicine studies for detecting early intramedullary changes (Pierce et al [*ACR*] 2022). CT, however, is the most sensitive modality for detection of soft tissue gas, is useful to evaluate soft tissue compartments, and can help to differentiate cellulitis, myositis, tenosynovitis, abscess, and septic arthritis (Pierce et al [*ACR*] 2022). Contrast-enhanced CT improves the assessment for abscess, tissue necrosis, vascular complications, and extent of infection (Pierce et al [*ACR*] 2022). There is no additional benefit in performing a CT without and with IV contrast (Pierce et al [*ACR*] 2022).

FDG-PET/CT

^{18}F-FDG and PET/CT are the nuclear medicine imaging tests of choice for diagnosing uncomplicated peripheral bone osteomyelitis, with high sensitivity and specificity (Palestro et al [*SNMMI*] 2021; Pierce et al [*ACR*] 2022). For the diagnosis of complicated peripheral bone osteomyelitis, ^{18}F-FDG PET and PET/CT is also an appropriate nuclear medicine modality (Palestro et al [*SNMMI*] 2021). Because of its high sensitivity, ^{18}F-FDG PET and PET/CT can be useful as a rule-out test for septic arthritis (Palestro et al [*SNMMI*] 2021).

<u>Clinical/imaging notes:</u>

- Predisposing factors for osteomyelitis generally include diabetes mellitus, sickle cell disease, intravenous drug abuse, alcoholism, immunosuppression, open fractures, recent orthopedic surgery, and joint prostheses (Palestro et al [*SNMMI*] 2021).
- Signs of symptoms of osteomyelitis are typically nonspecific, and the diagnosis cannot be made by laboratory testing alone (Palestro et al [*SNMMI*] 2021).

- The term complicated osteomyelitis is used to describe those situations in which infection develops in bone that has been previously violated by processes such as tumors, fractures, and orthopedic hardware (Palestro et al [*SNMMI*] 2021).
- Septic arthritis is the invasion of a joint and synovial fluid by an infectious agent and is up to seven times more common among those with rheumatoid arthritis or a prosthetic joint (Palestro et al [*SNMMI*] 2021).
- Septic arthritis commonly presents as single-joint pain, combined with erythema, soft-tissue swelling, diminished range of motion, and often accompanied by fever, general weakness, and headaches (Palestro et al [*SNMMI*] 2021).
- The reference standard for diagnostic septic arthritis is a positive result from joint aspirate samples, but a negative culture result does not exclude the diagnosis (Palestro et al [*SNMMI*] 2021).
- Ultrasound is a useful methodology for detecting fluid, such as joint effusion, abscess and infected tendon sheaths but is of limited benefit compared to MRI or CT in detection of osteomyelitis because of its inability to penetrate the cortex of the bone (Pierce et al [*ACR*] 2022).

Evidence update (2017-present):
There were no recent articles that significantly affected the recommendations or conclusions found in the guidelines referenced above.

PICO 9: Shoulder pain persisting after failure of conservative therapy*, and radiographs are non-diagnostic or noncontributory:

- **Green – MRI shoulder without IV contrast**
- **Yellow – MR arthrography shoulder**
  [Previous noncontrast MRI findings are indeterminate]
- **Yellow – CT arthrography shoulder**
  [MRI not available or contraindicated; or prior shoulder arthroplasty/significant metal artifact]
- **Yellow – CT shoulder without IV contrast**
  [Further evaluation or surgical planning of bone abnormality]
- **Red – MRI shoulder without and with IV contrast; MRI shoulder with IV contrast**
- **Red – CT shoulder without and with IV contrast; CT shoulder with IV contrast**
- **Red – PET; bone scan; SPECT**

*Failure of conservative therapy can be defined as moderate to severe persistent symptoms following conservative care for 4-6 weeks or increasing pain during a trial of conservative care. Those with uncontrolled pain, significant limitation of function, inability to perform activities of daily living, or physical inability to participate in noninvasive care for an appropriate period of time also fall into this category (PLE expert panel consensus opinion).

Level of Evidence (for additional detail, see topic-specific AUC recommendation):

- Low-to-moderate

Notes concerning use of contrast:
MRI without IV contrast is the advanced imaging procedure of choice for visualization of soft tissue structures of the shoulder, including ligaments, tendons, joint capsules, and joint cartilage structures (*CO Department of Labor* 2014; PLE expert panel consensus opinion). The addition of intra-articular contrast (arthrography) can enhance definition of selected pathologies (*CO Department of Labor* 2014). The use of MRI with IV contrast is limited in the shoulder, however, may be useful in the evaluation of adhesive capsulitis (Erber et al 2022; Pessis et al 2020; Ahn et al 2015).

Notes concerning applicability and/or patient preferences: none.

Guideline and PLE expert panel consensus opinion summary:
Overview:
Conventional radiography should generally be the initial imaging study in patients with shoulder pain, and can evaluate for unexpected fracture or bony lesion, inflammatory arthropathy, osteonecrosis, or calcium hydroxyapatite deposition (Ha et al [ACR] 2022; Nacey et al [*ACR*] 2022; Amini et al [*ACR*] 2018; Bussieres et al 2008). After physical examination and radiographs, advanced imaging, particularly MRI, is indicated in those patients whose pain persists after four or more weeks of conservative care (Bussieres et al 2008; Hegmann et al [*ACOEM*] 2016; PLE expert panel consensus opinion). MRI provides the best imaging details for evaluation of shoulder pathology, including marrow, and joint disease (Amini et al [*ACR*] 2018; Bussieres et al 2008). MRI can also detect extra-articular abnormalities that may predispose to impingement, such as acromioclavicular degenerative change or a subacromial spur (Nacey et al [*ACR*] 2022). Following normal or suspicious radiographs, MRI is also the most sensitive and specific imaging modality for the diagnosis of osteonecrosis, with a sensitivity and specificity nearing 100% (Ha et al [*ACR*] 2022). CT arthrography, MR arthrography, or ultrasound can also be useful in certain circumstances for nonlocalized shoulder pain when initial radiographs are negative (Amini et al [*ACR*]

2018). Routine CT is typically not recommended for the evaluation shoulder pain, as CT is considered inferior to MRI for diagnosing essentially all soft-tissue shoulder injuries (Amini et al [*ACR*] 2018). (Hegmann et al [*ACOEM*] 2016: not recommended, insufficient evidence (I). However, noncontrast CT can be used to evaluate bony abnormalities, suspected occult fracture, or other osseous involvement (Nacey et al [*ACR*] 2022; PLE expert panel consensus opinion). CT is less sensitive for detecting early osteonecrosis but is superior to MRI in showing the location and extent of articular collapse and, therefore, plays a critical role in surgical planning (Ha et al [*ACR*] 2022). Bone scanning is not recommended for routine use in shoulder joint evaluations, as MRI is more specific and more sensitive (Hegmann et al [*ACOEM*] 2016: not recommended, insufficient evidence), while bone scan has relatively poor resolution and specificity (Amini et al [*ACR*] 2018; PLE expert panel consensus opinion).

Clinical/imaging notes:

- Accurate interpretation of radiographs can often obviate additional imaging or be complementary to subsequent imaging studies (Nacey et al [*ACR*] 2022).
- Ultrasound allows excellent evaluation of the bursae situated about the shoulder (Nacey et al [*ACR*] 2022).

Evidence update (2017-present):
There were no recent articles that significantly affected the recommendations or conclusions found in the guidelines referenced above.

General Exclusions:

- Cases meeting the definition of a suspected or confirmed emergency medical condition, including high energy trauma
- Shoulder pain secondary to cancer-related concern
- Painful total joint arthroplasty
- Pediatric patients
- Pregnant patients

AUC Revision History:

Revision Date	New Clinical Scenario	Approval Body
05/16/2017	Initial Document Development	CDI Quality Institute's Multidisciplinary Committee
05/22/2018	N/A	CDI Quality Institute's Multidisciplinary Committee
07/09/2019	N/A	CDI Quality Institute's Multidisciplinary Committee
07/28/2020	Shoulder Fracture	CDI Quality Institute's Multidisciplinary Committee
09/14/2021	N/A	CDI Quality Institute Multidisciplinary Committee
03/14/2023	Osteomyelitis	RAYUS Quality Institute Multidisciplinary Committee

Information on our evidence development process, including our conflicts of interest policy is available on our website at **https://www.rayusradiology.com/ple**

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Appropriateness of Advanced Imaging in Patients with Shoulder Pain: Bibliography

03/14/2023

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