

**American College of Radiology  
ACR Appropriateness Criteria®  
Chronic Shoulder Pain**

**Variant 1: Chronic shoulder pain. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography shoulder	Usually Appropriate	⊕
US shoulder	May Be Appropriate	○
Image-guided anesthetic +/- corticosteroid injection shoulder or surrounding structures	Usually Not Appropriate	Varies
MR arthrography shoulder	Usually Not Appropriate	○
MRI shoulder without and with IV contrast	Usually Not Appropriate	○
MRI shoulder without IV contrast	Usually Not Appropriate	○
Bone scan shoulder	Usually Not Appropriate	⊕⊕⊕
CT shoulder with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT shoulder without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT shoulder without IV contrast	Usually Not Appropriate	⊕⊕⊕
CT arthrography shoulder	Usually Not Appropriate	⊕⊕⊕⊕
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	⊕⊕⊕⊕

**Variant 2: Chronic shoulder pain. Suspect rotator cuff disorders or subacromial subdeltoid bursitis (no prior surgery). Initial radiographs normal or inconclusive. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
US shoulder	Usually Appropriate	○
MR arthrography shoulder	Usually Appropriate	○
MRI shoulder without IV contrast	Usually Appropriate	○
Image-guided anesthetic +/- corticosteroid injection shoulder or surrounding structures	May Be Appropriate	Varies
CT arthrography shoulder	May Be Appropriate	⊕⊕⊕⊕
Radiography shoulder additional views	Usually Not Appropriate	⊕
MRI shoulder without and with IV contrast	Usually Not Appropriate	○
Bone scan shoulder	Usually Not Appropriate	⊕⊕⊕
CT shoulder with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT shoulder without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT shoulder without IV contrast	Usually Not Appropriate	⊕⊕⊕
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	⊕⊕⊕⊕

**Variant 3:****Chronic shoulder pain. Radiographs demonstrate calcific tendinopathy or calcific bursitis. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
Image-guided anesthetic +/- corticosteroid injection shoulder or surrounding structures	Usually Appropriate	Varies
US shoulder	May Be Appropriate	○
MR arthrography shoulder	May Be Appropriate	○
MRI shoulder without IV contrast	May Be Appropriate	○
Radiography shoulder additional views	Usually Not Appropriate	⊕
MRI shoulder without and with IV contrast	Usually Not Appropriate	○
Bone scan shoulder	Usually Not Appropriate	⊕⊕⊕
CT shoulder with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT shoulder without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT shoulder without IV contrast	Usually Not Appropriate	⊕⊕⊕
CT arthrography shoulder	Usually Not Appropriate	⊕⊕⊕⊕
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	⊕⊕⊕⊕

**Variant 4:****Chronic shoulder pain. Suspect labral pathology or shoulder instability. Initial radiographs normal or inconclusive. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MR arthrography shoulder	Usually Appropriate	○
MRI shoulder without IV contrast	Usually Appropriate	○
CT shoulder without IV contrast	May Be Appropriate	⊕⊕⊕
CT arthrography shoulder	May Be Appropriate	⊕⊕⊕⊕
US shoulder	Usually Not Appropriate	○
Radiography shoulder additional views	Usually Not Appropriate	⊕
Image-guided anesthetic +/- corticosteroid injection shoulder or surrounding structures	Usually Not Appropriate	Varies
MRI shoulder without and with IV contrast	Usually Not Appropriate	○
Bone scan shoulder	Usually Not Appropriate	⊕⊕⊕
CT shoulder with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT shoulder without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	⊕⊕⊕⊕

**Variant 5: Chronic shoulder pain. Suspect adhesive capsulitis. Initial radiographs normal or inconclusive. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
Image-guided anesthetic +/- corticosteroid injection shoulder or surrounding structures	Usually Appropriate	Varies
MRI shoulder without IV contrast	Usually Appropriate	○
US shoulder	May Be Appropriate (Disagreement)	○
MR arthrography shoulder	May Be Appropriate	○
Radiography shoulder additional views	Usually Not Appropriate	⊕
MRI shoulder without and with IV contrast	Usually Not Appropriate	○
Bone scan shoulder	Usually Not Appropriate	⊕⊕⊕
CT shoulder with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT shoulder without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT shoulder without IV contrast	Usually Not Appropriate	⊕⊕⊕
CT arthrography shoulder	Usually Not Appropriate	⊕⊕⊕⊕
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	⊕⊕⊕⊕

**Variant 6: Chronic shoulder pain. Suspect biceps tendon abnormality. Initial radiographs normal or inconclusive. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
US shoulder	Usually Appropriate	○
Image-guided anesthetic +/- corticosteroid injection shoulder or surrounding structures	Usually Appropriate	Varies
MR arthrography shoulder	Usually Appropriate	○
MRI shoulder without IV contrast	Usually Appropriate	○
CT arthrography shoulder	May Be Appropriate	⊕⊕⊕⊕
Radiography shoulder additional views	Usually Not Appropriate	⊕
MRI shoulder without and with IV contrast	Usually Not Appropriate	○
Bone scan shoulder	Usually Not Appropriate	⊕⊕⊕
CT shoulder with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT shoulder without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT shoulder without IV contrast	Usually Not Appropriate	⊕⊕⊕
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	⊕⊕⊕⊕

**Variant 7: Chronic shoulder pain. Initial radiographs demonstrate osteoarthritis. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI shoulder without IV contrast	Usually Appropriate	○
Image-guided anesthetic +/- corticosteroid injection shoulder or surrounding structures	May Be Appropriate	Varies
MR arthrography shoulder	May Be Appropriate	○
CT shoulder without IV contrast	May Be Appropriate	☼☼☼
CT arthrography shoulder	May Be Appropriate	☼☼☼☼
US shoulder	Usually Not Appropriate	○
Radiography shoulder additional views	Usually Not Appropriate	☼
MRI shoulder without and with IV contrast	Usually Not Appropriate	○
Bone scan shoulder	Usually Not Appropriate	☼☼☼
CT shoulder with IV contrast	Usually Not Appropriate	☼☼☼
CT shoulder without and with IV contrast	Usually Not Appropriate	☼☼☼
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☼☼☼☼

**Variant 8: Chronic shoulder pain. History of prior rotator cuff repair. Suspect rotator cuff disorders or subacromial subdeltoid bursitis. Initial radiographs normal or inconclusive. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
US shoulder	Usually Appropriate	○
MR arthrography shoulder	Usually Appropriate	○
MRI shoulder without IV contrast	Usually Appropriate	○
CT arthrography shoulder	Usually Appropriate	☼☼☼☼
Image-guided anesthetic +/- corticosteroid injection shoulder or surrounding structures	May Be Appropriate	Varies
Radiography shoulder additional views	Usually Not Appropriate	☼
MRI shoulder without and with IV contrast	Usually Not Appropriate	○
Bone scan shoulder	Usually Not Appropriate	☼☼☼
CT shoulder with IV contrast	Usually Not Appropriate	☼☼☼
CT shoulder without and with IV contrast	Usually Not Appropriate	☼☼☼
CT shoulder without IV contrast	Usually Not Appropriate	☼☼☼
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☼☼☼☼

## CHRONIC SHOULDER PAIN

Expert Panel on Musculoskeletal Imaging: Nicholas Nacey, MD<sup>a</sup>; Michael G. Fox, MD, MBA<sup>b</sup>; Donna G. Blankenbaker, MD<sup>c</sup>; Doris Chen, MD<sup>d</sup>; Matthew A. Frick, MD<sup>e</sup>; Shari T. Jawetz, MD<sup>f</sup>; Ross E. Mathiasen, MD<sup>g</sup>; Noah M. Raizman, MD<sup>h</sup>; Kavita H. Rajkotia, MD<sup>i</sup>; Nicholas Said, MD, MBA<sup>j</sup>; J. Derek Stensby, MD<sup>k</sup>; Naveen Subhas, MD, MPH<sup>l</sup>; Devaki Shilpa Surasi, MD<sup>m</sup>; Eric A. Walker, MD, MHA<sup>n</sup>; Eric Y. Chang, MD.<sup>o</sup>

### Summary of Literature Review

#### **Introduction/Background**

Chronic shoulder pain lasting >6 months is a common presenting complaint, particularly in patients ≥40 years of age [1]. Along with a thorough history and physical examination, imaging plays a critical role in determining the source of chronic shoulder pain. Common pain generators in the shoulder include the rotator cuff tendons, biceps tendon, labrum, glenohumeral articular cartilage, acromioclavicular joint, bones, suprascapular and axillary nerves, and the joint capsule/synovium. Imaging can help to guide appropriate therapy, which can range from conservative measures such as physical therapy and corticosteroid injections to more invasive procedures such as arthroscopy or surgery. This document focuses on the imaging approach to patients with suspected chronic mechanical shoulder pain. See the separate ACR Appropriateness Criteria<sup>®</sup> topics on “[Chronic Extremity Joint Pain-Suspected Inflammatory Arthritis](#)” [2], “[Imaging After Shoulder Arthroplasty](#)” [3], “[Primary Bone Tumors](#)” [4], “[Soft-Tissue Masses](#)” [5], and “[Shoulder Pain-Traumatic](#)” [6] if further guidance is needed for potential alternative causes of shoulder pain.

#### **Special Imaging Considerations**

Several studies have looked for ways to shorten typical shoulder conventional MRI or MR arthrogram protocols while maintaining diagnostic accuracy. Isotropic 3-D imaging has been increasingly used as a substitute for conventional multiplanar 2-D MRI, with a similar sensitivity and specificity for rotator cuff tear and labral abnormalities at a lower scan time [7,8]. Faster scans can also be performed using 2-D fast spin echo sequences with parallel imaging, which produce similar findings as seen on conventional MRI [9].

#### **Initial Imaging Definition**

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient’s care).

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<sup>a</sup>Panel Vice-chair, University of Virginia Health System, Charlottesville, Virginia. <sup>b</sup>Panel Chair, Mayo Clinic Arizona, Phoenix, Arizona. <sup>c</sup>University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin. <sup>d</sup>Stanford University, Stanford, California, Primary care physician. <sup>e</sup>Mayo Clinic, Rochester, Minnesota. <sup>f</sup>Hospital for Special Surgery, New York, New York. <sup>g</sup>University of Nebraska Medical Center, Omaha, Nebraska; American College of Emergency Physicians. <sup>h</sup>The Centers for Advanced Orthopaedics, George Washington University, Washington, District of Columbia; American Academy of Orthopaedic Surgeons. <sup>i</sup>University of Michigan Health System, Ann Arbor, Michigan; Committee on Emergency Radiology-GSER. <sup>j</sup>Duke University Medical Center, Durham, North Carolina. <sup>k</sup>University of Missouri Health Care, Columbia, Missouri. <sup>l</sup>Cleveland Clinic, Cleveland, Ohio. <sup>m</sup>The University of Texas MD Anderson Cancer Center, Houston, Texas; Commission on Nuclear Medicine and Molecular Imaging. <sup>n</sup>Penn State Milton S. Hershey Medical Center, Hershey, Pennsylvania and Uniformed Services University of the Health Sciences, Bethesda, Maryland. <sup>o</sup>Specialty Chair, VA San Diego Healthcare System, San Diego, California.

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## **Discussion of Procedures by Variant**

### **Variant 1: Chronic shoulder pain. Initial imaging.**

#### **Bone Scan Shoulder**

There is insufficient evidence to support the use of bone scan shoulder in the initial evaluation of chronic shoulder pain.

#### **CT Arthrography Shoulder**

There is insufficient evidence to support the use of CT arthrography shoulder in the initial evaluation of chronic shoulder pain.

#### **CT Shoulder With IV Contrast**

There is insufficient evidence to support the use of CT shoulder with intravenous (IV) contrast in the initial evaluation of chronic shoulder pain.

#### **CT Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of CT shoulder without and with IV contrast in the initial evaluation of chronic shoulder pain.

#### **CT Shoulder Without IV Contrast**

There is insufficient evidence to support the use of CT shoulder without IV contrast in the initial evaluation of chronic shoulder pain.

#### **FDG-PET/CT Skull Base to Mid-Thigh**

There is insufficient evidence to support the use of fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT skull base to mid-thigh in the initial evaluation of chronic shoulder pain.

#### **Image-Guided Anesthetic +/- Corticosteroid Injection Shoulder or Surrounding Structures**

There is insufficient evidence to support the use of image-guided anesthetic +/- corticosteroid injection of the shoulder in the initial evaluation of chronic shoulder pain.

#### **MR Arthrography Shoulder**

There is insufficient evidence to support the use of MR arthrography shoulder in the initial evaluation of chronic shoulder pain.

#### **MRI Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of MRI shoulder without and with IV contrast in the initial evaluation of chronic shoulder pain.

#### **MRI Shoulder Without IV Contrast**

There is insufficient evidence to support the use of MRI shoulder without IV contrast in the initial evaluation of chronic shoulder pain.

#### **Radiography Shoulder**

Most literature suggests that radiographs should be the initial imaging study in patients with shoulder pain [1,10]. Standard radiographic examination consists of a combination of different projections typically including anteroposterior (AP) internal rotation, AP external rotation, Grashey (oblique AP in the plane of the glenohumeral joint), scapular “Y,” and axillary views [10]. Radiographs can evaluate for unexpected fracture, unsuspected aggressive bony lesion, osteoarthritis, inflammatory arthropathy, osteonecrosis, or calcium hydroxyapatite deposition. Accurate interpretation of radiographs can often obviate additional imaging or be complementary to subsequent imaging studies. A high-riding humeral head on radiographs is highly associated with chronic rotator cuff tear [11], particularly if seen in combination with sclerosis of the inferior acromion, greater tuberosity cysts, a lateral acromial spur, and cortical irregularity or sclerosis of the greater tuberosity [12-14].

#### **US Shoulder**

The literature suggests that radiographic evaluation should generally be the first imaging study ordered in patients with shoulder pain [1,10-14]. Some practitioners may use ultrasound (US) as an initial imaging study when rotator cuff disease/impingement is suggested by the clinical examination.

**Variant 2: Chronic shoulder pain. Suspect rotator cuff disorders or subacromial subdeltoid bursitis (no prior surgery). Initial radiographs normal or inconclusive. Next imaging study.**

#### **Bone Scan Shoulder**

There is insufficient evidence to support the use of bone scan shoulder in the evaluation of chronic shoulder pain when rotator cuff disorder or subacromial subdeltoid bursitis is suspected.

#### **CT Arthrography Shoulder**

CT arthrography has shown good diagnostic performance for depicting rotator cuff tendon tears with a reported respective sensitivity and specificity of 99% and 100% for the supraspinatus tendon, 97.4% and 99.5% for the infraspinatus tendon, and 64.7% and 98.2% for the subscapularis tendon [15]. CT arthrography provides a comparable alternative to MR arthrography in the evaluation of rotator cuff tendon tears [16,17]. CT arthrography is able to detect very subtle articular surface cuff defects, but, because of lack of contrast extension from the glenohumeral joint space, it is less effective at demonstrating bursal surface or intrasubstance tears, which are typically well seen with MRI or US [18].

#### **CT Shoulder With IV Contrast**

There is insufficient evidence to support the use of CT shoulder with IV contrast in the evaluation of chronic shoulder pain when rotator cuff disorder or subacromial subdeltoid bursitis is suspected.

#### **CT Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of CT shoulder without and with IV contrast in the evaluation of chronic shoulder pain when rotator cuff disorder or subacromial subdeltoid bursitis is suspected.

#### **CT Shoulder Without IV Contrast**

CT shoulder without IV contrast is of limited utility when evaluating for rotator cuff tear or subacromial subdeltoid bursitis. Noncontrast CT can sometimes demonstrate fatty infiltration of rotator cuff muscles with a corresponding rotator cuff tear, although the overall sensitivity of this finding is low [19]. CT may demonstrate a high-riding humeral head or remodeling of the acromial undersurface in patients with large rotator cuff tears. However, this finding is generally seen on initial radiographs, and CT does not allow for characterization of the underlying tear because CT lacks the soft-tissue contrast resolution necessary to adequately evaluate the rotator cuff tear itself. CT may be able to directly demonstrate some large rotator cuff tears as well as fatty infiltration of the rotator cuff musculature; however, it was found to have a sensitivity of 20% for full thickness rotator cuff tears in one small study [19]. Large amounts of fluid in the subacromial subdeltoid bursa can sometimes be visualized with CT.

#### **FDG-PET/CT Skull Base to Mid-Thigh**

There is insufficient evidence to support the use of FDG-PET/CT skull base to mid-thigh in the evaluation of chronic shoulder pain when rotator cuff disorder or subacromial subdeltoid bursitis is suspected.

#### **Image-Guided Anesthetic +/- Corticosteroid Injection Shoulder or Surrounding Structures**

Corticosteroid injection is sometimes used before advanced imaging is obtained but may serve as a better diagnostic tool in patients with subacromial subdeltoid bursitis as opposed to those patients with suspected rotator cuff tear. US image-guided injection with local anesthetic and corticosteroid into the subacromial-subdeltoid bursa has been shown to result in improvement in pain and range of motion in patients with rotator cuff symptoms [20,21]. Subacromial bursal injections are used by some as a diagnostic tool to evaluate for rotator cuff pathology [22], although the diagnostic utility of this approach is unclear in the literature. Glenohumeral joint injection has been found to not have significant diagnostic utility for patients with suspected rotator cuff tear [23].

#### **MR Arthrography Shoulder**

MR arthrography provides greater sensitivity and specificity compared to conventional MRI in evaluating partial thickness articular surface tears [24-26]. Partial bursal and purely intrasubstance tears should have similar rates of detection on conventional MRI and MR arthrography because the diagnosis is dependent on the same fluid-sensitive sequences [27]. Extension of intra-articular gadolinium into the subacromial subdeltoid bursa can sometimes differentiate a high-grade partial tear from a full thickness tear [28]. However, the advantages of MR arthrography over conventional MRI for detecting rotator cuff tear must be weighed against the invasive nature of the arthrogram procedure [29]. Arthrograms with saline have been shown in some studies to have similar accuracy for rotator cuff tear as those performed with dilute gadolinium [30,31]. Some authors suggest that adding an abduction external rotation imaging position to an MR arthrogram improves the accuracy in diagnosing partial articular surface tears [32,33], although this positioning is often omitted because of patient discomfort.

### **MRI Shoulder Without and With IV Contrast**

IV injection of gadolinium can be used to enhance the highly vascular synovium producing an indirect arthrogram effect [34]. Indirect MR arthrography has been shown to have a slightly higher specificity for diagnosing articular-surface partial thickness tears of the supraspinatus and infraspinatus tendons, as well as a greater specificity for diagnosing subscapularis tendon tears [35], relative to noncontrast MRI, and has shown high accuracy relative to arthroscopy [36]. Although the accuracy of indirect MR arthrography has been described in the literature, it is not commonly used in clinical practice.

### **MRI Shoulder Without IV Contrast**

MRI of the shoulder is a highly accurate tool in the assessment of the rotator cuff. MRI findings of tendinopathy consist of intermediate increased signal and tendon thickening [28]. Rotator cuff tears, particularly full thickness tears, can be reliably identified using conventional MRI with high sensitivity and specificity [37-39]. Sensitivity and specificity for detecting partial thickness bursal surface tears is similar for conventional MRI and MR arthrography [27]. Although MR arthrography may have a slightly higher sensitivity and specificity than conventional MRI for diagnosing rotator cuff tears, particularly partial thickness articular surface tears, this difference in accuracy must be weighed against the need for an invasive arthrogram procedure [29]. Tendon retraction, muscle atrophy, and fatty infiltration are associated important findings that are well seen on MRI and predict reparability of rotator cuff tear [40]. Axial images can be helpful in determining rotator cuff tear shape [41], which can aid in the selection of a particular surgical technique. In addition to evaluating the rotator cuff itself, MRI can detect extra-articular abnormalities that may predispose to shoulder impingement such as acromioclavicular degenerative change or a subacromial spur. Fluid accumulation within the subacromial subdeltoid bursa is visualized on MRI and is often a nonspecific finding seen with a rotator cuff tear or an underlying inflammatory disorder [42].

### **Radiography Shoulder Additional Views**

The rotator cuff tendons cannot be directly assessed radiographically, regardless of the view. Secondary findings of rotator cuff tear such as a high-riding humeral head or changes at the greater tuberosity can be seen on standard radiographic views. There have been several reports assessing special views for the evaluation of potential impingement from the anterior acromion. Outlet views can be used to determine acromial shape and have been shown to be more accurate than a single-slice MRI [43]. The Rockwood and cassette tilt views are angled frontal projections that can be used to detect anterior acromial osteophytes [44]. The subacromial subdeltoid bursa is a soft-tissue potential space and is not directly visualized on radiographs. There is a peribursal fat plane between the rotator cuff tendons and the deltoid muscle; however, obliteration of the peribursal fat stripe is not a specific indicator of shoulder pathology and may be seen in normal subjects [42].

### **US Shoulder**

US has been found to have a high accuracy in assessing rotator cuff disease [38,45], including the subscapularis tendon [46]. Meta-analyses have found a sensitivity of US ranging from 85% to 95% and a specificity ranging from 72% to 92%, which is similar to noncontrast MRI and slightly lower than MR arthrography [24,47]. Fatty infiltration within the rotator cuff muscles can be adequately demonstrated with US [48]. US may; however, be less accurate than MRI in measuring tear size and the degree of retraction in larger tears [49]. US allows excellent evaluation of the bursae situated about the shoulder, particularly the subacromial subdeltoid bursa [50]. Color flow imaging can demonstrate hyperemia in cases of bursitis with a significant inflammatory component [51].

**Variant 3: Chronic shoulder pain. Radiographs demonstrate calcific tendinopathy or calcific bursitis. Next imaging study.**

### **Bone Scan Shoulder**

There is insufficient evidence to support the use of bone scan shoulder in the evaluation of chronic shoulder pain when radiographs demonstrate calcific tendinosis or calcific bursitis. Cases with intraosseous extension of calcium hydroxyapatite can potentially demonstrate increased radionuclide uptake due to bony inflammatory change, which can potentially be confused with a neoplastic process and result in diagnostic confusion.

### **CT Arthrography Shoulder**

There is insufficient evidence to support the use of CT arthrography shoulder in the evaluation of chronic shoulder pain when radiographs demonstrate calcific tendinopathy or calcific bursitis. Hyperdense intratendinous calcium may resemble intratendinous contrast from a partial thickness articular-sided rotator cuff tear, which could potentially result in diagnostic confusion. The role of CT arthrography is limited to cases in which there is concern



for a concomitant rotator cuff tear and, even in this situation, may be lacking in utility in cases of partial thickness interstitial or bursal surface tear [18].

### **CT Shoulder With IV Contrast**

There is insufficient evidence to support the use of CT shoulder with IV contrast in the evaluation of chronic shoulder pain when radiographs demonstrate calcific tendinopathy or calcific bursitis.

### **CT Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of CT shoulder without and with contrast in the evaluation of chronic shoulder pain when radiographs demonstrate calcific tendinopathy or calcific bursitis.

### **CT Shoulder Without IV Contrast**

Calcific hydroxyapatite deposition in the rotator cuff tendons is easily visualized by CT; however, the diagnosis of calcium hydroxyapatite is typically able to be made on radiographs alone. CT can be helpful in evaluating osseous involvement [52] and is the most accurate modality in evaluating the consistency of the deposit, which may be helpful when planning intervention [53] but is not routinely obtained.

### **FDG-PET/CT Skull Base to Mid-Thigh**

There is insufficient evidence to support the use of FDG-PET/CT skull base to mid-thigh in the evaluation of chronic shoulder pain when radiographs demonstrate calcific tendinopathy or calcific bursitis. Areas of calcium hydroxyapatite deposition in tendon, bursa, or bone can result in increased FDG uptake, which can potentially be confused with a neoplastic process and result in diagnostic confusion.

### **Image-Guided Anesthetic +/- Corticosteroid Injection Shoulder or Surrounding Structures**

If calcium hydroxyapatite is seen on radiographs, calcium hydroxyapatite lavage with imaging guidance can be performed both for both therapeutic and diagnostic purposes. US or, less commonly, fluoroscopy can be used for guidance. US-guided calcium lavage has been shown to be a highly effective percutaneous treatment in patients with suspected calcific tendinitis [54-62]. Outcomes are similar whether the procedure is performed with the 1 or 2 needle technique [63]. Injection of corticosteroid into the subacromial subdeltoid bursa as part of the barbotage procedure has been shown to have significant impact on pain and function 3 months after the procedure [64,65]. The degree of calcium removal does not necessarily correlate with pain improvement from the procedure [66]. Lavage may be less effective at providing pain relief for patients with intraosseous migration of calcium hydroxyapatite [67]. Given the high efficacy of calcium hydroxyapatite lavage in the rotator cuff, if patient symptoms do not resolve following calcium hydroxyapatite lavage, then other diagnostic entities for shoulder pain should be considered and further imaging evaluation can be performed subsequently.

### **MR Arthrography Shoulder**

Calcium hydroxyapatite may be difficult to visualize on MRI given the lack of contrast between hypointense calcium and an adjacent normal tendon. However, MR arthrography can be used to identify a concomitant rotator cuff tear. In the setting of calcific tendonitis, 93% of rotator cuff tears are partial thickness [68]. Given the improved ability of MR arthrography to detect partial thickness articular-surface tears of the rotator cuff compared to conventional shoulder MRI [24-26], there may be an advantage to performing MR arthrography in patients with calcific tendinopathy [69].

### **MRI Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of MRI shoulder without and with IV contrast in the evaluation of chronic shoulder pain when radiographs demonstrate calcific tendinopathy or calcific bursitis.

### **MRI Shoulder Without IV Contrast**

The signal void of calcium hydroxyapatite deposition can be difficult to distinguish from the hypointense signal in normal rotator cuff tendon, thus making identification of calcific tendonitis by MRI alone difficult in some cases. However, MRI can be used in calcific tendonitis cases to evaluate the extent of adjacent soft-tissue and bone abnormalities as well as exclude other causes of shoulder pain. Patients with calcific tendonitis on radiographs have up to a 56% incidence of concomitant rotator cuff tear seen on MRI [68]. Intraosseous migration of calcium hydroxyapatite can produce extensive marrow edema, which can be confused with a neoplastic process [52,70].

### **Radiography Shoulder Additional Views**

Calcium hydroxyapatite deposition in tendon or bursa is typically well seen on conventional radiographic projections, without a need for specialized additional views.

## **US Shoulder**

US is reported to be 98% sensitive and 94% specific for calcium hydroxyapatite in the rotator cuff tendons [71], although identification may be challenging if the area of calcium deposition is small. At times US may have difficulty distinguishing calcific deposits from heterotopic ossification because both can result in dense shadowing at US. US can be used if there is concern for concomitant rotator cuff tendon tear and may be a better modality than MRI in this situation given the difficulty of distinguishing calcium from normal tendon at MRI.

**Variant 4: Chronic shoulder pain. Suspect labral pathology or shoulder instability. Initial radiographs normal or inconclusive. Next imaging study.**

### **Bone Scan Shoulder**

There is insufficient evidence to support the use of bone scan shoulder in the evaluation of chronic shoulder pain when labral pathology or shoulder instability is suspected.

### **CT Arthrography Shoulder**

CT arthrograms have been shown to be an accurate modality in the assessment of shoulder instability because of its depiction of osseous, cartilaginous, and labroligamentous injuries [18,72]. Labral evaluation in the postoperative setting may be better with CT arthrography than MRI in patients with metallic suture anchors [73] and has been used to evaluate for healing after superior labrum anterior-to-posterior (SLAP) repair [74]. Dual-energy CT arthrography has a similar diagnostic performance as MR arthrography [75]. Although CT arthrography aids in the evaluation of underlying soft tissues, the injected contrast may limit evaluation of the underlying osseous structures, and cortical fragments in the injected contrast solution often have a similar attenuation to cortical bone [76]. Other limitations include the need for an invasive arthrography procedure and poor assessment of bone marrow edema [72].

### **CT Shoulder With IV Contrast**

There is insufficient evidence to support the use of CT shoulder with IV contrast in the evaluation of chronic shoulder pain when labral pathology or shoulder instability is suspected.

### **CT Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of CT shoulder without and with IV contrast in the evaluation of chronic shoulder pain when labral pathology or shoulder instability is suspected.

### **CT Shoulder Without IV Contrast**

CT is helpful for assessing bony glenoid deficiency as well as the size of a Hill-Sachs deformity when surgery is a consideration but is not effective at evaluating the labrum. CT is often preferable to MRI when evaluating for small fracture fragments of the glenoid rim and assessing bone stock in patients with recurrent dislocation [77-79]. Three-dimensional reconstructions can be used to quantify osseous defect width and glenoid surface area [80,81]. CT can also be used to measure the size of a Hill-Sachs defect [82,83], which has become more important with the development of the glenoid track concept for determining instability [84,85]. In the postoperative setting, CT can be used to evaluate integration of bone graft from a coracoid transfer with the underlying glenoid [86,87].

### **FDG-PET/CT Skull Base to Mid-Thigh**

There is insufficient evidence to support the use of FDG-PET/CT skull base to mid-thigh in the evaluation of chronic shoulder pain when labral pathology or shoulder instability is suspected.

### **Image-Guided Anesthetic +/- Corticosteroid Injection Shoulder or Surrounding Structures**

Patients with labral tears have been found to have no significant decrease in pain with glenohumeral injection relative to other patients, and, in fact, patients with labral tears may have less pain relief than those with an intact labrum [23]. Thus, corticosteroid injection does not have a significant diagnostic benefit in distinguishing patients with labral tears from other pathology.

### **MR Arthrography Shoulder**

Multiple meta-analyses have found MR arthrography to have a higher sensitivity (80%–87% versus 63%–76%) and specificity (91%–92% versus 87%) compared to conventional MRI for the detection of SLAP tears [88,89]. A 2018 meta-analysis found arthrography to be slightly more sensitive for anterior labral lesions (87% compared to 83%) [90]. Provocative positioning maneuvers, including abduction external rotation, can result in improved detection of nondisplaced anteroinferior labral tears [91,92], although this positioning may be uncomfortable for many patients. MR arthrography is highly accurate for detection of injury to the inferior glenohumeral ligament, which can be associated with shoulder instability [93]. Arthrograms with saline have been shown in some studies to have similar

accuracy for a labral tear as those performed with dilute gadolinium [30,31]. Although diagnosing recurrent labral tears after prior labral repair is challenging, MR arthrography is particularly helpful in this scenario in which discrete fluid or gadolinium signal within or underlying the labrum, absent labrum, and paralabral cyst are all highly suggestive of recurrent tear [94], with a greater sensitivity than seen with conventional MRI [73].

#### **MRI Shoulder Without and With IV Contrast**

IV injection of gadolinium can be used to enhance the highly vascular synovium producing an indirect arthrogram effect [34]. Indirect arthrography has been found to have a sensitivity of 74% and a specificity of 67% for SLAP tear, which is lower than for direct MR arthrography [89]. Although the accuracy of indirect MR arthrography has been described in the literature, it is not commonly used in clinical practice.

#### **MRI Shoulder Without IV Contrast**

Conventional MRI with 3T imaging is highly accurate for the detection of a labral tear, with a sensitivity of 83% and a specificity of 99% to 100% for a labral tear [90]. MR arthrography adds additional benefit to conventional shoulder MRI because it may identify some labral tears that are not seen with conventional MRI [95]. The increased accuracy with MR arthrography should be balanced against the need for an invasive arthrogram procedure. Although evaluation of glenoid bony integrity is typically better with CT imaging, some practitioners have used ultrashort or zero echo time sequences [96-98], 3-D sequences [99], or conventional MRI sequences [100] to measure glenoid bone loss with a high concordance to CT images.

#### **Radiography Shoulder Additional Views**

There are several options for additional radiographic views in patients with suspected instability [1]. The West Point and Garth views can demonstrate the anterior inferior glenoid at a better advantage in patients with a suspected Bankart fracture. A Stryker notch view can sometimes demonstrate a Hill-Sachs lesion that is difficult to see on conventional projections. Although these additional projections are used by some practitioners, they do not usually alleviate the need for advanced imaging.

#### **US Shoulder**

The posterior labrum can be reliably visualized with US, with posterior labral tears potentially visualized particularly if the joint is distended [101]. However, US is of limited benefit in assessing the anterior labroligamentous complex, superior labrum, articular surface, and subchondral bone.

**Variant 5: Chronic shoulder pain. Suspect adhesive capsulitis. Initial radiographs normal or inconclusive. Next imaging study.**

#### **Bone Scan Shoulder**

There is insufficient evidence to support the use of bone scan shoulder in the evaluation of chronic shoulder pain when adhesive capsulitis is suspected.

#### **CT Arthrography Shoulder**

There is insufficient evidence to support the use of CT arthrography shoulder in the evaluation of chronic shoulder pain when adhesive capsulitis is suspected.

#### **CT Shoulder With IV Contrast**

There is insufficient evidence to support the use of CT shoulder with IV contrast in the evaluation of chronic shoulder pain when adhesive capsulitis is suspected.

#### **CT Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of CT shoulder without and with IV contrast in the evaluation of chronic shoulder pain when adhesive capsulitis is suspected.

#### **CT Shoulder Without IV Contrast**

There is insufficient evidence to support the use of CT shoulder without IV contrast in the evaluation of chronic shoulder pain when adhesive capsulitis is suspected.

#### **FDG-PET/CT Skull Base to Mid-Thigh**

Increased PET uptake in the rotator interval and inferior joint capsule is moderately associated with adhesive capsulitis [102-104]. However, this is generally an incidental finding on PET examinations performed for other reasons, and PET/CT is not typically performed specifically for this indication.

### **Image-Guided Anesthetic +/- Corticosteroid Injection Shoulder or Surrounding Structures**

Image-guided injection of the glenohumeral joint for adhesive capsulitis can be performed with either fluoroscopy or US guidance. Image-guided corticosteroid injection has been shown to have a significant reduction in pain and an improvement in the range of motion for patients with adhesive capsulitis [105,106]. Use of US guidance for glenohumeral corticosteroid injection may be more accurate and produce a greater improvement in pain and functional scores relative to blind injection [107]. Patients with adhesive capsulitis have been found to be the only group with a statistically better outcome after glenohumeral joint injection than other patients; thus a positive response to a glenohumeral injection can be suggestive of the presence of adhesive capsulitis in the appropriate clinical context [23]. Fluoroscopic injection can also demonstrate diagnostic findings suggestive of adhesive capsulitis including joint space capacity <10 mL, diminished axillary recess, and irregularity of the capsular margin [108].

### **MR Arthrography Shoulder**

Mengiardi et al [109] reported that thickening of the coracohumeral ligament (specificity 95%, sensitivity 59%), thickening of the joint capsule (specificity 86%, sensitivity 64%), and obliteration of the subcoracoid triangle (specificity 100%, sensitivity 32%) are characteristic MR arthrography findings in adhesive capsulitis. However, fluid within the rotator interval or along the axillary recess due to the arthrogram injection itself can serve as a limitation to detecting findings of adhesive capsulitis on MRI arthrography.

### **MRI Shoulder Without and With IV Contrast**

Contrast-enhanced MRI can increase the conspicuity of axillary recess capsular thickening [110] and rotator interval soft-tissue thickening [111], although there are conflicting data on the relationship of this capsular enhancement with patient symptoms [112].

### **MRI Shoulder Without IV Contrast**

Zhao et al [113] showed that coracohumeral ligament thickening, anterior capsule thickening, and obliteration of the subcoracoid fat are the most characteristic findings of adhesive capsulitis on conventional MRI. Chi et al [114] found a sensitivity of 77% and a specificity of 53% for adhesive capsulitis with only coracohumeral ligament thickening on noncontrast MRI, with a lower sensitivity (23%) but a higher specificity (87%) in patients who had all 3 findings of adhesive capsulitis, including coracohumeral ligament thickening, rotator interval infiltration, and axillary recess thickening.

### **Radiography Shoulder Additional Views**

There is insufficient evidence to support the use of additional radiographic views in the evaluation of chronic shoulder pain when adhesive capsulitis is suspected.

### **US Shoulder**

US in the setting of potential adhesive capsulitis is often used to exclude rotator cuff tear. Although there are several US findings that can be seen in patients with adhesive capsulitis, US is not typically performed specifically for this indication. Thickening of the coracohumeral ligament, increased rotator interval soft tissue, and decreased external rotation on dynamic US are all highly sensitive and specific findings for adhesive capsulitis [115]. Thickening of the axillary recess capsule can be accurately measured with US and is associated with adhesive capsulitis [116]. Hyperemia with Doppler imaging, particularly with microflow imaging, can also be seen in the subcoracoid fat triangle in patients with adhesive capsulitis [117]. One study found that findings of adhesive capsulitis on US were correlated with clinical assessment, whereas findings on MRI were not [108].

**Variant 6: Chronic shoulder pain. Suspect biceps tendon abnormality. Initial radiographs normal or inconclusive. Next imaging study.**

### **Bone Scan Shoulder**

There is insufficient evidence to support the use of bone scan shoulder in the evaluation of chronic shoulder pain when biceps tendon abnormality is suspected.

### **CT Arthrography Shoulder**

Reports on the accuracy of CT arthrography for biceps tendinopathy are variable. Teixeira et al [118] reported a sensitivity of 74% to 79% and a specificity of 93% to 95% for tendinopathy as well as 100% sensitivity and 93% specificity for complete biceps ruptures. However, Rol et al [119] reported a correlation of only 45% to 65% with subsequent arthroscopy in a study consisting mostly of patients who underwent CT arthrography. CT arthrography diagnosis of biceps tendinopathy is primarily based off the change in tendon caliber.

### **CT Shoulder With IV Contrast**

There is insufficient evidence to support the use of CT shoulder with IV contrast in the evaluation of chronic shoulder pain when biceps tendon abnormality is suspected.

### **CT Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of CT shoulder without and with IV contrast in the evaluation of chronic shoulder pain when biceps tendon abnormality is suspected.

### **CT Shoulder Without IV Contrast**

There is limited literature regarding the use of noncontrast CT to specifically evaluate the biceps tendon. In a small study, pooled sensitivity and specificity for proximal biceps lesions including degeneration, tendon subluxation, and tendon tear using CT were shown to be 31% and 95%, respectively [120].

### **FDG-PET/CT Skull Base to Mid-Thigh**

There is insufficient evidence to support the use of FDG-PET/CT skull base to mid-thigh in the evaluation of chronic shoulder pain when biceps tendon abnormality is suspected.

### **Image-Guided Anesthetic +/- Corticosteroid Injection Shoulder or Surrounding Structures**

Image-guided injection of the biceps tendon sheath using US guidance may be useful in patients with biceps pain for both diagnostic and therapeutic purposes [22]. Although either fluoroscopy or US can be used as imaging guidance for biceps tendon injection, US guidance is more accurate [121]. US is more accurate in injection location placement compared with blind injections with a lower risk of intratendinous injection [122,123]. Many patients with sonographically normal biceps tendons may obtain pain relief with US-guided injection, suggesting that injection response may diagnostically identify patients with biceps pathology that is not seen by US [124].

### **MR Arthrography Shoulder**

MR arthrography may improve the accuracy of MRI in the detection of long head of the bicep tears, although results are mixed. Zanetti et al [125] found MR arthrography to be sensitive and moderately specific in the diagnosis of long head of the biceps tendon disorders with a sensitivity of 92% and a specificity of 56%. However, Looock et al [126] found a lower sensitivity and specificity for MR arthrography detection of biceps abnormalities, with only a 49% sensitivity for tendinopathy. Accuracy for middle-aged patients may be lower [127]. MR arthrography is moderately accurate at assessing for biceps tendon subluxation, with a sensitivity of 61% to 87% and a specificity of 83% to 92% [128].

### **MRI Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of MRI shoulder without and with IV contrast in the evaluation of chronic shoulder pain when biceps tendon abnormality is suspected.

### **MRI Shoulder Without IV Contrast**

Standard noncontrast MRI is limited in detecting bicep abnormalities, including tendinopathy or tearing of the long head of the biceps. Studies have shown MRI to both under- and overdiagnose intra-articular biceps pathology [129-131], with sensitivities and specificities of 28% and 84% (partial tear) and 56% and 98% (complete), respectively [130]. Using diagnostic criteria of having 2 or more signs of biceps tendinopathy (contour irregularity, diameter change, or abnormal signal) has a sensitivity of 78% and a specificity of 94% [132]. It has been reported that normal appearing tendons on MRI frequently have histopathologic findings of tendinopathy [133,134]. Biceps tendon subluxation can be diagnosed by displacement of the biceps tendon over the lesser tuberosity [135] and is highly associated with tearing of the subscapularis tendon [136]. MRI has a greater specificity for biceps tendon abnormality if there is a coexisting rotator cuff tear [129,137].

### **Radiography Shoulder Additional Views**

There is insufficient evidence to support the use of additional radiographic views in the evaluation of chronic shoulder pain when a biceps tendon abnormality is suspected.

### **US Shoulder**

Apart from the biceps anchor, the intra-articular and extra-articular portions of the biceps tendon are well seen on routine US imaging. Tendinopathy, tears and rupture, tenosynovitis, subluxation, and frank dislocation are readily assessed [138,139]. Provocative maneuvers may be helpful while observing in real time to assess the degree of subluxation.

**Variant 7: Chronic shoulder pain. Initial radiographs demonstrate osteoarthritis. Next imaging study.**

The presence of glenohumeral osteoarthritis on initial radiographs does not typically require additional imaging unless additional pathology is suspected, such as a rotator cuff tear or surgery is a consideration.

**Bone Scan Shoulder**

There is insufficient evidence to support the use of bone scan shoulder in the evaluation of chronic shoulder pain when initial radiographs demonstrate osteoarthritis.

**CT Arthrography Shoulder**

CT arthrography can be helpful in the preoperative planning of total shoulder arthroplasty in patients with severe glenohumeral arthritis. CT arthrography provides excellent imaging of osseous detail allowing for characterization of glenoid morphology, version, and bone loss. Unlike nonarthrogram CT, CT arthrography allows for adequate characterization of a rotator cuff tear [16,17], which may alter the chosen arthroplasty type. Arthrogram contrast also outlines the articular cartilage surface, demonstrating areas of cartilage loss, which cannot be directly visualized with conventional CT.

**CT Shoulder With IV Contrast**

There is insufficient evidence to support the use of CT shoulder with IV contrast in the evaluation of chronic shoulder pain when initial radiographs demonstrate osteoarthritis.

**CT Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of CT shoulder without and with IV contrast in the evaluation of chronic shoulder pain when initial radiographs demonstrate osteoarthritis.

**CT Shoulder Without IV Contrast**

CT can be helpful in evaluating osseous morphology in cases in which arthroplasty surgery is under consideration for treatment of severe glenohumeral arthritis. CT images are commonly obtained to classify the morphology of the glenoid according to the Walch classification system [140]. CT measurements of glenoid version, glenoid bone loss, and humeral head subluxation demonstrate high interrater reliability [141]. CT can potentially demonstrate rotator cuff muscle fatty infiltration, which is often associated with rotator cuff tears; however, overall sensitivity for full thickness rotator cuff tears is only 20% for noncontrast CT [19].

**FDG-PET/CT Skull Base to Mid-Thigh**

There is insufficient evidence to support the use of FDG-PET/CT skull base to mid-thigh in the evaluation of chronic shoulder pain when initial radiographs demonstrate osteoarthritis.

**Image-Guided Anesthetic +/- Corticosteroid Injection Shoulder or Surrounding Structures**

Intra-articular corticosteroid injection using either fluoroscopy or US guidance is often used in the conservative management of glenohumeral arthritis [122] and may be performed in some situations before advanced imaging is obtained. The diagnostic utility of glenohumeral corticosteroid injection for confirming osteoarthritis as a source of pain is limited, because patients with osteoarthritis have a similar degree of pain improvement (74% rate of clinically relevant improvement at 1 month) as patients with other underlying causes of shoulder pain [23].

**MR Arthrography Shoulder**

The role of MR arthrography relative to conventional shoulder MRI in the setting of osteoarthritis has not been specifically studied. However, MR arthrography may have use in characterizing the degree of chondral loss, the presence of a full thickness rotator cuff tear, and characterizing glenoid morphology.

**MRI Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of MRI shoulder without and with IV contrast in the evaluation of chronic shoulder pain when initial radiographs demonstrate osteoarthritis.

**MRI Shoulder Without IV Contrast**

MRI can be used to detect the degree of glenohumeral chondral loss, although the diagnosis of arthritis is generally easily made with conventional radiographs [142]. MRI can demonstrate the presence of a partial or full thickness rotator cuff tear, which is frequently associated with osteoarthritis. Although CT is most frequently used for evaluating glenoid morphology, glenoid version measured by MRI is generally similar to that measured with CT [143]; however, MRI may be less accurate than CT at identifying the Walch classification of glenoid morphology [144].

### **Radiography Shoulder Additional Views**

Glenohumeral osteoarthritis is typically well visualized on conventional radiographic views, without the need for special views. A standard axillary view can demonstrate posterior subluxation of the humeral head and abnormal glenoid morphology in patients with severe osteoarthritis [145-147]. A measurement of the critical shoulder angle can be drawn on routine AP radiographs by measuring the angle between a line along the glenoid surface and a line from the inferior glenoid to the lateral acromial margin; patients with a higher measurement may be at high risk of having a full thickness rotator cuff tear [148].

### **US Shoulder**

Although secondary signs of osteoarthritis such as osteophytes, joint effusion, and intra-articular bodies can be seen with US [142], it is not typically performed for this indication.

**Variant 8: Chronic shoulder pain. History of prior rotator cuff repair. Suspect rotator cuff disorders or subacromial subdeltoid bursitis. Initial radiographs normal or inconclusive. Next imaging study.**

### **Bone Scan Shoulder**

There is insufficient evidence to support the use of bone scan shoulder in the evaluation of chronic shoulder pain with a history of prior rotator cuff repair when rotator cuff disorder or subacromial subdeltoid bursitis is suspected.

### **CT Arthrography Shoulder**

As in the native shoulder, CT arthrography can be used to evaluate for rotator cuff tear after surgery. In patients with metal in the shoulder, CT arthrography can be beneficial in detecting supraspinatus tears that may be obscured by metal artifact [73]. Gadolinium contrast can potentially be drawn up into a mixture with iodinated contrast at the time of the arthrogram procedure, thus allowing for a shift from MRI to CT if artifact on MRI precludes evaluation.

### **CT Shoulder With IV Contrast**

There is insufficient evidence to support the use of CT shoulder with IV contrast in the evaluation of chronic shoulder pain with a history of prior rotator cuff repair when rotator cuff disorder or subacromial subdeltoid bursitis is suspected.

### **CT Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of CT shoulder without and with IV contrast in the evaluation of chronic shoulder pain with a history of prior rotator cuff repair when rotator cuff disorder or subacromial subdeltoid bursitis is suspected.

### **CT Shoulder Without IV Contrast**

There is insufficient evidence to support the use of CT shoulder without IV contrast in the evaluation of chronic shoulder pain with a history of prior rotator cuff repair when rotator cuff disorder or subacromial subdeltoid bursitis is suspected.

### **FDG-PET/CT Skull Base to Mid-Thigh**

There is insufficient evidence to support the use of FDG-PET/CT skull base to mid-thigh in the evaluation of chronic shoulder pain with a history of prior rotator cuff repair when a rotator cuff disorder or subacromial subdeltoid bursitis is suspected.

### **Image-Guided Anesthetic +/- Corticosteroid Injection Shoulder or Surrounding Structures**

Image-guided corticosteroid injection may be useful for therapeutic purposes in patients with recurrent pain after rotator cuff repair. US-guided injection of corticosteroid into the glenohumeral joint has been found to improve pain and range of motion in patients with prior rotator cuff repair, without increasing the risk of recurrent rotator cuff tear [149]. There is insufficient evidence to support the use of image guided injection for diagnostic purposes in evaluation for recurrent cuff tear, but it may be of use for diagnosis in patients with suspected subacromial subdeltoid bursitis.

### **MR Arthrography Shoulder**

MR arthrography is useful in the evaluation of the postoperative rotator cuff. MR arthrography can improve diagnostic accuracy over conventional MRI in patients who have had prior rotator cuff repair due to joint distention and improved signal-to-noise ratio [150]. Of note, contrast within the subacromial subdeltoid bursa on routine and MR arthrogram examinations is a nonspecific finding that can potentially be seen in a nonwatertight rotator cuff repair [151]. T2 hyperintensity of the repaired rotator cuff tendon is a common postoperative finding, particularly in the first 2 years after surgery, and does not reflect adequacy of tendon healing or clinical outcome [152].

### **MRI Shoulder Without and With IV Contrast**

There is insufficient evidence to support the use of MRI shoulder without and with IV contrast in the evaluation of chronic shoulder pain with a history of prior rotator cuff repair when a rotator cuff disorder or subacromial subdeltoid bursitis is suspected.

### **MRI Shoulder Without IV Contrast**

MRI is useful in the evaluation of the postoperative rotator cuff. The shift from metallic to bioabsorbable suture anchors tends to result in fewer cases with metal artifact implications [153]. For patients with metallic suture anchors, there are a variety of commercially available metal artifact reduction sequences, which can limit artifact. MRI can demonstrate complications with suture anchors such as osteolysis or migration [154], even if the suture anchors are nonmetallic. MRI can also demonstrate potential improvements in muscle atrophy and fatty infiltration after rotator cuff repair [155,156].

### **Radiography Shoulder Additional Views**

There is insufficient evidence to support the use of additional radiographic views in the evaluation of chronic shoulder pain with a history of prior rotator cuff repair when rotator cuff disorder or subacromial subdeltoid bursitis is suspected.

### **US Shoulder**

An advantage of US evaluation of the postoperative shoulder is the absence of metal-induced artifact when examining the rotator cuff and adjacent soft tissues. Patients who have undergone rotator cuff repair may show discrete defects on US imaging that may persist for years with some potential for delayed healing [157]. Despite these limitations, US still provides an excellent method to assess repair integrity, with a high sensitivity (80.8%) and specificity (100%) for recurrent rotator cuff tear [158]. The ability to perform provocative maneuvers can further demonstrate abnormalities that other forms of imaging would be incapable identifying.

### **Summary of Recommendations**

- **Variation 1:** Radiography is usually appropriate for the initial imaging of chronic shoulder pain.
- **Variation 2:** US or MR arthrography or MRI without IV contrast is usually appropriate as the next imaging study in the evaluation of chronic shoulder pain when radiographs are normal or inconclusive and rotator cuff disorders or subacromial subdeltoid bursitis (no prior surgery) is suspected. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variation 3:** Image-guided anesthetic +/- corticosteroid injection is usually appropriate as the next imaging study in the evaluation of chronic shoulder pain when radiographs demonstrate calcific tendinopathy or calcific bursitis.
- **Variation 4:** MR arthrography or MRI without IV contrast is usually appropriate as the next imaging study in the evaluation of chronic shoulder pain when radiographs are normal or inconclusive and labral pathology or shoulder instability is suspected. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variation 5:** Image-guided anesthetic +/- corticosteroid injection or MRI without IV contrast is usually appropriate as the next imaging study in the evaluation of chronic shoulder pain when radiographs are normal or inconclusive and adhesive capsulitis is suspected. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care). Although the panel did not agree on recommending US because there is insufficient medical literature to conclude whether these patients would benefit from the procedure, its use may be appropriate.
- **Variation 6:** US or Image-guided anesthetic +/- corticosteroid injection or MR arthrography or MRI without IV contrast is usually appropriate as the next imaging study in the evaluation of chronic shoulder pain when radiographs are normal or inconclusive and biceps tendon abnormality is suspected. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variation 7:** MRI without IV contrast is usually appropriate as the next imaging study in the evaluation of chronic shoulder pain when radiographs demonstrate osteoarthritis.



- **Variation 8:** US or MR arthrography or MRI without IV contrast or CT arthrography is usually appropriate as the next imaging study in the evaluation of chronic shoulder pain with a history of prior rotator cuff repair when radiographs are normal or inconclusive and rotator cuff disorders or subacromial subdeltoid bursitis is suspected. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care).

### Supporting Documents

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to [www.acr.org/ac](http://www.acr.org/ac).

### Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel’s recommendation. “May be appropriate” is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

### Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document [159].

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
○	0 mSv	0 mSv
⊕	<0.1 mSv	<0.03 mSv
⊕⊕	0.1-1 mSv	0.03-0.3 mSv
⊕⊕⊕	1-10 mSv	0.3-3 mSv
⊕⊕⊕⊕	10-30 mSv	3-10 mSv
⊕⊕⊕⊕⊕	30-100 mSv	10-30 mSv

\*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as “Varies.”

## References

1. Tuite MJ, Small KM. Imaging Evaluation of Nonacute Shoulder Pain. *AJR Am J Roentgenol* 2017;209:525-33.
2. Jacobson JA, Roberts CC, Bencardino JT, et al. ACR Appropriateness Criteria® Chronic Extremity Joint Pain-Suspected Inflammatory Arthritis. *J Am Coll Radiol* 2017;14:S81-S89.
3. American College of Radiology. ACR Appropriateness Criteria®: Imaging After Shoulder Arthroplasty. Available at: <https://acsearch.acr.org/docs/3097049/Narrative/>. Accessed September 30, 2022.
4. Bestic JM, Wessell DE, Beaman FD, et al. ACR Appropriateness Criteria® Primary Bone Tumors. *J Am Coll Radiol* 2020;17:S226-S38.
5. Kransdorf MJ, Murphey MD, Wessell DE, et al. ACR Appropriateness Criteria® Soft-Tissue Masses. *J Am Coll Radiol* 2018;15:S189-S97.
6. Amini B, Beckmann NM, Beaman FD, et al. ACR Appropriateness Criteria® Shoulder Pain-Traumatic. *J Am Coll Radiol* 2018;15:S171-S88.
7. Horiuchi S, Nozaki T, Tasaki A, et al. Comparison Between Isotropic 3-Dimensional Fat-Suppressed T2-Weighted Fast Spin Echo (FSE) and Conventional 2-Dimensional Fat-Suppressed Proton-Weighted FSE Shoulder Magnetic Resonance Imaging at 3-T in Patients With Shoulder Pain. *J Comput Assist Tomogr* 2018;42:559-65.
8. Lee SH, Yun SJ, Jin W, Park SY, Park JS, Ryu KN. Comparison between 3D isotropic and 2D conventional MR arthrography for diagnosing rotator cuff tear and labral lesions: A meta-analysis. *J Magn Reson Imaging* 2018;48:1034-45.
9. Subhas N, Benedick A, Obuchowski NA, et al. Comparison of a Fast 5-Minute Shoulder MRI Protocol With a Standard Shoulder MRI Protocol: A Multiinstitutional Multireader Study. *AJR Am J Roentgenol* 2017;208:W146-W54.
10. Goud A, Segal D, Hedayati P, Pan JJ, Weissman BN. Radiographic evaluation of the shoulder. *Eur J Radiol* 2008;68:2-15.
11. Park SH, Choi CH, Yoon HK, Ha JW, Lee C, Chung K. What can the radiological parameters of superior migration of the humeral head tell us about the reparability of massive rotator cuff tears? *PLoS One* 2020;15:e0231843.
12. Ghandour TM, Elghazaly SA, Ghandour AM. Greater Tuberosity Sclerosis: A Radiographic Sign Of Rotator Cuff Tear? *Acta Orthop Belg* 2017;83:416-20.
13. Hussain A, Muzzammil M, Butt F, Valsamis EM, Dwyer AJ. Effectiveness Of Plain Shoulder Radiograph In Detecting Degenerate Rotator Cuff Tears. *J Ayub Med Coll Abbottabad* 2018;30:8-11.
14. van der Reijden JJ, Nienhuis SL, Somford MP, et al. The value of radiographic markers in the diagnostic work-up of rotator cuff tears, an arthroscopic correlated study. *Skeletal Radiol* 2020;49:55-64.
15. Charoussat C, Bellaiche L, Duranthon LD, Grimberg J. Accuracy of CT arthrography in the assessment of tears of the rotator cuff. *J Bone Joint Surg Br* 2005;87:824-8.
16. Oh JH, Kim JY, Choi JA, Kim WS. Effectiveness of multidetector computed tomography arthrography for the diagnosis of shoulder pathology: comparison with magnetic resonance imaging with arthroscopic correlation. *J Shoulder Elbow Surg* 2010;19:14-20.

17. Omoumi P, Bafort AC, Dubuc JE, Malghem J, Vande Berg BC, Lecouvet FE. Evaluation of rotator cuff tendon tears: comparison of multidetector CT arthrography and 1.5-T MR arthrography. *Radiology* 2012;264:812-22.
18. Lecouvet FE, Simoni P, Koutaissoff S, Vande Berg BC, Malghem J, Dubuc JE. Multidetector spiral CT arthrography of the shoulder. Clinical applications and limits, with MR arthrography and arthroscopic correlations. *Eur J Radiol* 2008;68:120-36.
19. Fitzgerald M, Lawler SM, Lowe JT, Nelson R, Mantell MT, Jawa A. Computed tomography underestimates rotator cuff pathology in patients with glenohumeral osteoarthritis. *J Shoulder Elbow Surg* 2018;27:1451-55.
20. Akbari N, Ozen S, Senlikci HB, Haberal M, Cetin N. Ultrasound-guided versus blind subacromial corticosteroid and local anesthetic injection in the treatment of subacromial impingement syndrome: A randomized study of efficacy. *Jt Dis Relat Surg* 2020;31:115-22.
21. Sari A, Eroglu A. Comparison of ultrasound-guided platelet-rich plasma, prolotherapy, and corticosteroid injections in rotator cuff lesions. *J Back Musculoskelet Rehabil* 2020;33:387-96.
22. Pourcho AM, Colio SW, Hall MM. Ultrasound-Guided Interventional Procedures About the Shoulder: Anatomy, Indications, and Techniques. *Phys Med Rehabil Clin N Am* 2016;27:555-72.
23. Fritz B, Del Grande F, Sutter R, Beeler S, Peterson CK, Pfirrmann CWA. Value of MR arthrography findings for pain relief after glenohumeral corticosteroid injections in the short term. *Eur Radiol* 2019;29:6416-24.
24. de Jesus JO, Parker L, Frangos AJ, Nazarian LN. Accuracy of MRI, MR arthrography, and ultrasound in the diagnosis of rotator cuff tears: a meta-analysis. *AJR Am J Roentgenol* 2009;192:1701-7.
25. Hodler J, Kursunoglu-Brahme S, Snyder SJ, et al. Rotator cuff disease: assessment with MR arthrography versus standard MR imaging in 36 patients with arthroscopic confirmation. *Radiology* 1992;182:431-6.
26. Magee T. 3-T MRI of the shoulder: is MR arthrography necessary? *AJR Am J Roentgenol* 2009;192:86-92.
27. Huang T, Liu J, Ma Y, Zhou D, Chen L, Liu F. Diagnostic accuracy of MRA and MRI for the bursal-sided partial-thickness rotator cuff tears: a meta-analysis. *J Orthop Surg Res* 2019;14:436.
28. McCrum E. MR Imaging of the Rotator Cuff. *Magn Reson Imaging Clin N Am* 2020;28:165-79.
29. Liu F, Cheng X, Dong J, Zhou D, Han S, Yang Y. Comparison of MRI and MRA for the diagnosis of rotator cuff tears: A meta-analysis. *Medicine (Baltimore)* 2020;99:e19579.
30. Singer AD, Rosenthal J, Umpierrez M, Guo Y, Gonzalez F, Wagner E. A comparison of saline and gadolinium shoulder MR arthrography to arthroscopy. *Skeletal Radiol* 2020;49:625-33.
31. Helms CA, McGonegle SJ, Vinson EN, Whiteside MB. Magnetic resonance arthrography of the shoulder: accuracy of gadolinium versus saline for rotator cuff and labral pathology. *Skeletal Radiol* 2011;40:197-203.
32. Lee SY, Lee JK. Horizontal component of partial-thickness tears of rotator cuff: imaging characteristics and comparison of ABER view with oblique coronal view at MR arthrography initial results. *Radiology* 2002;224:470-6.
33. Roger B, Skaf A, Hooper AW, Lektrakul N, Yeh L, Resnick D. Imaging findings in the dominant shoulder of throwing athletes: comparison of radiography, arthrography, CT arthrography, and MR arthrography with arthroscopic correlation. *AJR Am J Roentgenol* 1999;172:1371-80.
34. Bergin D, Schweitzer ME. Indirect magnetic resonance arthrography. *Skeletal Radiol* 2003;32:551-8.
35. Lee JH, Yoon YC, Jung JY, Yoo JC. Rotator cuff tears noncontrast MRI compared to MR arthrography. *Skeletal Radiol* 2015;44:1745-54.
36. Lee JH, Yoon YC, Jee S. Diagnostic performance of indirect MR arthrography for the diagnosis of rotator cuff tears at 3.0 T. *Acta Radiol* 2015;56:720-6.
37. Kneeland JB, Middleton WD, Carrera GF, et al. MR imaging of the shoulder: diagnosis of rotator cuff tears. *AJR Am J Roentgenol* 1987;149:333-7.
38. Teefey SA, Rubin DA, Middleton WD, Hildebolt CF, Leibold RA, Yamaguchi K. Detection and quantification of rotator cuff tears. Comparison of ultrasonographic, magnetic resonance imaging, and arthroscopic findings in seventy-one consecutive cases. *J Bone Joint Surg Am* 2004;86-A:708-16.
39. Zlatkin MB, Iannotti JP, Roberts MC, et al. Rotator cuff tears: diagnostic performance of MR imaging. *Radiology* 1989;172:223-9.
40. Kim JY, Park JS, Rhee YG. Can Preoperative Magnetic Resonance Imaging Predict the Reparability of Massive Rotator Cuff Tears? *Am J Sports Med* 2017;45:1654-63.

41. Jung SW, Jin JW, Kim DH, et al. Diagnostic value of the axial view of magnetic resonance imaging to identify two-dimensional shapes of full-thickness rotator cuff tears. *Acta Radiol* 2020;61:1545-52.
42. Bureau NJ, Dussault RG, Keats TE. Imaging of bursae around the shoulder joint. *Skeletal Radiol* 1996;25:513-7.
43. Mayerhoefer ME, Breitenseher MJ, Roposch A, Treitl C, Wurnig C. Comparison of MRI and conventional radiography for assessment of acromial shape. *AJR Am J Roentgenol* 2005;184:671-5.
44. Chernchujit B, Kanokvaleewong C, Parate P, Boontanapibul K, Arirachakaran A, Kongtharvonskul J. A new method for measurement of the size of subacromial spurs of the shoulder by cassette tilt view. *Eur J Orthop Surg Traumatol* 2019;29:553-58.
45. Vlychou M, Dailiana Z, Fotiadou A, Papanagiotou M, Fezoulidis IV, Malizos K. Symptomatic partial rotator cuff tears: diagnostic performance of ultrasound and magnetic resonance imaging with surgical correlation. *Acta Radiol* 2009;50:101-5.
46. Toprak U, Turkoglu S, Aydogan C, et al. Diagnostic accuracy of ultrasound in subscapularis tendon abnormalities and the importance of operator experience. *Acta Orthop Traumatol Turc* 2020;54:423-29.
47. Liang W, Wu H, Dong F, Tian H, Xu J. Diagnostic performance of ultrasound for rotator cuff tears: a systematic review and meta-analysis. *Med Ultrason* 2020;22:197-202.
48. Park BK, Hong SH, Jeong WK. Effectiveness of Ultrasound in Evaluation of Fatty Infiltration in Rotator Cuff Muscles. *Clin Orthop Surg* 2020;12:76-85.
49. Okorooha KR, Mehran N, Duncan J, et al. Characterization of Rotator Cuff Tears: Ultrasound Versus Magnetic Resonance Imaging. *Orthopedics* 2017;40:e124-e30.
50. Soker G, Gulek B, Soker E, et al. Sonographic assessment of subacromial bursa distension during arm abduction: establishing a threshold value in the diagnosis of subacromial impingement syndrome. *J Med Ultrason (2001)* 2018;45:287-94.
51. Bredahl WH, Newman JS, Taljanovic MS, Adler RS. Power Doppler sonography in the assessment of musculoskeletal fluid collections. *AJR Am J Roentgenol* 1996;166:1443-6.
52. Kalayci CB, Kizilkaya E. Calcific tendinitis: intramuscular and intraosseous migration. *Diagn Interv Radiol* 2019;25:480-84.
53. Farin PU. Consistency of rotator-cuff calcifications. Observations on plain radiography, sonography, computed tomography, and at needle treatment. *Invest Radiol* 1996;31:300-4.
54. Arirachakaran A, Boonard M, Yamaphai S, Prommahachai A, Kesprayura S, Kongtharvonskul J. Extracorporeal shock wave therapy, ultrasound-guided percutaneous lavage, corticosteroid injection and combined treatment for the treatment of rotator cuff calcific tendinopathy: a network meta-analysis of RCTs. *Eur J Orthop Surg Traumatol* 2017;27:381-90.
55. De Zordo T, Ahmad N, Odegaard F, et al. US-guided therapy of calcific tendinopathy: clinical and radiological outcome assessment in shoulder and non-shoulder tendons. *Ultraschall Med* 2011;32 Suppl 1:S117-23.
56. Lanza E, Piccoli F, Intrieri C, et al. US-guided percutaneous irrigation of calcific tendinopathy of the rotator cuff in patients with or without previous external shockwave therapy. *Radiol Med* 2021;126:117-23.
57. Louwerens JKG, Sierevelt IN, Kramer ET, et al. Comparing Ultrasound-Guided Needling Combined With a Subacromial Corticosteroid Injection Versus High-Energy Extracorporeal Shockwave Therapy for Calcific Tendinitis of the Rotator Cuff: A Randomized Controlled Trial. *Arthroscopy* 2020;36:1823-33 e1.
58. Milman E, Pierce TP, Issa K, et al. Ultrasound-Guided Calcium Debridement of the Shoulder Joint: A Case Series. *Surg Technol Int* 2018;33:308-11.
59. Yoo JC, Koh KH, Park WH, Park JC, Kim SM, Yoon YC. The outcome of ultrasound-guided needle decompression and steroid injection in calcific tendinitis. *J Shoulder Elbow Surg* 2010;19:596-600.
60. Zhang T, Duan Y, Chen J, Chen X. Efficacy of ultrasound-guided percutaneous lavage for rotator cuff calcific tendinopathy: A systematic review and meta-analysis. *Medicine (Baltimore)* 2019;98:e15552.
61. Gatt DL, Charalambous CP. Ultrasound-guided barbotage for calcific tendonitis of the shoulder: a systematic review including 908 patients. *Arthroscopy* 2014;30:1166-72.
62. Sconfienza LM, Bandirali M, Serafini G, et al. Rotator cuff calcific tendinitis: does warm saline solution improve the short-term outcome of double-needle US-guided treatment? *Radiology* 2012;262:560-6.
63. Orlandi D, Mauri G, Lacelli F, et al. Rotator Cuff Calcific Tendinopathy: Randomized Comparison of US-guided Percutaneous Treatments by Using One or Two Needles. *Radiology* 2017;285:518-27.

64. Darrieutort-Laffite C, Varin S, Coiffier G, et al. Are corticosteroid injections needed after needling and lavage of calcific tendinitis? Randomised, double-blind, non-inferiority trial. *Ann Rheum Dis* 2019;78:837-43.
65. Dumoulin N, Cormier G, Varin S, et al. Factors Associated With Clinical Improvement and the Disappearance of Calcifications After Ultrasound-Guided Percutaneous Lavage of Rotator Cuff Calcific Tendinopathy: A Post Hoc Analysis of a Randomized Controlled Trial. *Am J Sports Med* 2021;49:883-91.
66. Vassalou EE, Klontzas ME, Plagou AP, Karantanas AH. Ultrasound-guided percutaneous irrigation of calcific tendinopathy: redefining predictors of treatment outcome. *Eur Radiol* 2021;31:2634-43.
67. Klontzas ME, Vassalou EE, Karantanas AH. Calcific tendinopathy of the shoulder with intraosseous extension: outcomes of ultrasound-guided percutaneous irrigation. *Skeletal Radiol* 2017;46:201-08.
68. Brinkman JC, Zaw TM, Fox MG, et al. Calcific Tendonitis of the Shoulder: Protector or Predictor of Cuff Pathology? A Magnetic Resonance Imaging-Based Study. *Arthroscopy* 2020;36:983-90.
69. Sill AP, Zaw T, Flug JA, et al. Calcific Tendinosis Reduces Diagnostic Performance of Magnetic Resonance Imaging in the Detection of Rotator Cuff Tears. *J Comput Assist Tomogr* 2022;46:219-23.
70. Flemming DJ, Murphey MD, Shekitka KM, Temple HT, Jelinek JJ, Kransdorf MJ. Osseous involvement in calcific tendinitis: a retrospective review of 50 cases. *AJR Am J Roentgenol* 2003;181:965-72.
71. Albano D, Coppola A, Gitto S, Rapisarda S, Messina C, Sconfienza LM. Imaging of calcific tendinopathy around the shoulder: usual and unusual presentations and common pitfalls. *Radiol Med* 2021;126:608-19.
72. Acid S, Le Corroller T, Aswad R, Pauly V, Champsaur P. Preoperative imaging of anterior shoulder instability: diagnostic effectiveness of MDCT arthrography and comparison with MR arthrography and arthroscopy. *AJR Am J Roentgenol* 2012;198:661-7.
73. Magee T. Imaging of the post-operative shoulder: does injection of iodinated contrast in addition to MR contrast during arthrography improve diagnostic accuracy and patient throughput? *Skeletal Radiol* 2018;47:1253-61.
74. Nashikkar PS, Rhee SM, Desai CV, Oh JH. Is Anatomical Healing Essential for Better Clinical Outcome in Type II SLAP Repair? Clinico-Radiological Outcome after Type II SLAP Repair. *Clin Orthop Surg* 2018;10:358-67.
75. Foti G, Mantovani W, Catania M, et al. Evaluation of glenoid labral tears: comparison between dual-energy CT arthrography and MR arthrography of the shoulder. *Radiol Med* 2020;125:39-47.
76. Bencardino JT, Gyftopoulos S, Palmer WE. Imaging in anterior glenohumeral instability. *Radiology* 2013;269:323-37.
77. Liu T, Ma J, Cao H, Hou D, Xu L. Evaluation of the diagnostic performance of the simple method of computed tomography in the assessment of patients with shoulder instability: a prospective cohort study. *BMC Med Imaging* 2018;18:45.
78. Shijith KP, Sood M, Sud AD, Ghai A. Is CT scan a predictor of instability in recurrent dislocation shoulder? *Chin J Traumatol* 2019;22:177-81.
79. Stevens KJ, Preston BJ, Wallace WA, Kerslake RW. CT imaging and three-dimensional reconstructions of shoulders with anterior glenohumeral instability. *Clin Anat* 1999;12:326-36.
80. Saito H, Itoi E, Sugaya H, Minagawa H, Yamamoto N, Tuoheti Y. Location of the glenoid defect in shoulders with recurrent anterior dislocation. *Am J Sports Med* 2005;33:889-93.
81. Sugaya H, Moriishi J, Dohi M, Kon Y, Tsuchiya A. Glenoid rim morphology in recurrent anterior glenohumeral instability. *J Bone Joint Surg Am* 2003;85-A:878-84.
82. Stefaniak J, Kubicka AM, Wawrzyniak A, Romanowski L, Lubiowski P. Reliability of humeral head measurements performed using two- and three-dimensional computed tomography in patients with shoulder instability. *Int Orthop* 2020;44:2049-56.
83. Ho A, Kurdziel MD, Koueiter DM, Wiater JM. Three-dimensional computed tomography measurement accuracy of varying Hill-Sachs lesion size. *J Shoulder Elbow Surg* 2018;27:350-56.
84. Mulleneers LIC, Van Rompaey H, Haloui B, Pouliart N. Determining On-/Off-track Lesions in Glenohumeral Dislocation Using Multiplanar Reconstruction Computed Tomography Is Easier and More Reproducible Than Using 3-dimensional Computed Tomography. *Am J Sports Med* 2021;49:137-45.
85. Younan Y, Wong PK, Karas S, et al. The glenoid track: a review of the clinical relevance, method of calculation and current evidence behind this method. *Skeletal Radiol* 2017;46:1625-34.
86. Makihara T, Abe M, Yamazaki M, Okamura K. Bone union of the transferred coracoid graft is the key factor affecting the extent of postoperative graft changes and the clinical results following the modified Bankart and Bristow procedure: a computed tomography scan study. *J Orthop Surg Res* 2019;14:84.

87. Vadala A, Lanzetti RM, De Carli A, et al. Latarjet procedure: evolution of the bone block and correspondent clinical relevance-a clinical and radiological study. *Musculoskelet Surg* 2017;101:113-20.
88. Arirachakaran A, Boonard M, Chaijenkij K, Pituckanotai K, Prommahachai A, Kongtharvonskul J. A systematic review and meta-analysis of diagnostic test of MRA versus MRI for detection superior labrum anterior to posterior lesions type II-VII. *Skeletal Radiol* 2017;46:149-60.
89. Symanski JS, Subhas N, Babb J, Nicholson J, Gyftopoulos S. Diagnosis of Superior Labrum Anterior-to-Posterior Tears by Using MR Imaging and MR Arthrography: A Systematic Review and Meta-Analysis. *Radiology* 2017;285:101-13.
90. Ajuied A, McGarvey CP, Harb Z, Smith CC, Houghton RP, Corbett SA. Diagnosis of glenoid labral tears using 3-tesla MRI vs. 3-tesla MRA: a systematic review and meta-analysis. *Arch Orthop Trauma Surg* 2018;138:699-709.
91. Cvitanic O, Tirman PF, Feller JF, Bost FW, Minter J, Carroll KW. Using abduction and external rotation of the shoulder to increase the sensitivity of MR arthrography in revealing tears of the anterior glenoid labrum. *AJR Am J Roentgenol* 1997;169:837-44.
92. Tirman PF, Bost FW, Steinbach LS, et al. MR arthrographic depiction of tears of the rotator cuff: benefit of abduction and external rotation of the arm. *Radiology* 1994;192:851-6.
93. Wang W, Huang BK, Sharp M, et al. MR Arthrogram Features That Can Be Used to Distinguish Between True Inferior Glenohumeral Ligament Complex Tears and Iatrogenic Extravasation. *AJR Am J Roentgenol* 2019;212:411-17.
94. Tiegs-Heiden CA, Rhodes NG, Collins MS, Fender QA, Howe BM. MR arthrogram of the postoperative glenoid labrum: normal postoperative appearance versus recurrent tears. *Skeletal Radiol* 2018;47:1475-81.
95. Major NM, Browne J, Domzalski T, Cothran RL, Helms CA. Evaluation of the glenoid labrum with 3-T MRI: is intraarticular contrast necessary? *AJR Am J Roentgenol* 2011;196:1139-44.
96. Ma YJ, West J, Nazaran A, et al. Feasibility of using an inversion-recovery ultrashort echo time (UTE) sequence for quantification of glenoid bone loss. *Skeletal Radiol* 2018;47:973-80.
97. Breighner RE, Endo Y, Konin GP, Gulotta LV, Koff MF, Potter HG. Technical Developments: Zero Echo Time Imaging of the Shoulder: Enhanced Osseous Detail by Using MR Imaging. *Radiology* 2018;286:960-66.
98. de Mello RAF, Ma YJ, Ashir A, et al. Three-Dimensional Zero Echo Time Magnetic Resonance Imaging Versus 3-Dimensional Computed Tomography for Glenoid Bone Assessment. *Arthroscopy* 2020;36:2391-400.
99. Yanke AB, Shin JJ, Pearson I, et al. Three-Dimensional Magnetic Resonance Imaging Quantification of Glenoid Bone Loss Is Equivalent to 3-Dimensional Computed Tomography Quantification: Cadaveric Study. *Arthroscopy* 2017;33:709-15.
100. Aygun U, Duran T, Oktay O, Sahin H, Calik Y. Comparison of Magnetic Resonance Imaging and Computed Tomography Scans of the Glenoid Version in Anterior Dislocation of the Shoulder. *Orthopedics* 2017;40:e687-e92.
101. Ogul H, Tas N, Ay M, Kose M, Kantarci M. Sonoarthrographic examination of posterior labrocapsular structures of the shoulder joint. *Br J Radiol* 2020;93:20190886.
102. Duchstein LDL, Jakobsen JR, Marker L, et al. The role of (18)F-FDG PET/CT in the diagnosis of frozen shoulder. *Knee Surg Sports Traumatol Arthrosc* 2021;29:210-15.
103. Sridharan R, Engle MP, Garg N, Wei W, Amini B. Focal uptake at the rotator interval or inferior capsule of shoulder on (18)F-FDG PET/CT is associated with adhesive capsulitis. *Skeletal Radiol* 2017;46:533-38.
104. Won KS, Kim DH, Sung DH, et al. Clinical correlation of metabolic parameters on (18)F-FDG PET/CT in idiopathic frozen shoulder. *Ann Nucl Med* 2017;31:211-17.
105. Ahn JH, Lee DH, Kang H, Lee MY, Kang DR, Yoon SH. Early Intra-articular Corticosteroid Injection Improves Pain and Function in Adhesive Capsulitis of the Shoulder: 1-Year Retrospective Longitudinal Study. *PM R* 2018;10:19-27.
106. Cho CH, Min BW, Bae KC, Lee KJ, Kim DH. A prospective double-blind randomized trial on ultrasound-guided versus blind intra-articular corticosteroid injections for primary frozen shoulder. *Bone Joint J* 2021;103-B:353-59.
107. Raeissadat SA, Rayegani SM, Langroudi TF, Khoiniha M. Comparing the accuracy and efficacy of ultrasound-guided versus blind injections of steroid in the glenohumeral joint in patients with shoulder adhesive capsulitis. *Clin Rheumatol* 2017;36:933-40.

108. Park GY, Park JH, Kwon DR, Kwon DG, Park J. Do the Findings of Magnetic Resonance Imaging, Arthrography, and Ultrasonography Reflect Clinical Impairment in Patients With Idiopathic Adhesive Capsulitis of the Shoulder? *Arch Phys Med Rehabil* 2017;98:1995-2001.
109. Mengiardi B, Pfirrmann CW, Gerber C, Hodler J, Zanetti M. Frozen shoulder: MR arthrographic findings. *Radiology* 2004;233:486-92.
110. Lee YT, Chun KS, Yoon KJ, et al. Correlation of Joint Volume and Passive Range of Motion With Capsulo-Synovial Thickness Measured by Contrast-Enhanced Magnetic Resonance Imaging in Adhesive Capsulitis. *PM R* 2018;10:137-45.
111. Pessis E, Mihoubi F, Feydy A, et al. Usefulness of intravenous contrast-enhanced MRI for diagnosis of adhesive capsulitis. *Eur Radiol* 2020;30:5981-91.
112. Yoon JP, Chung SW, Lee BJ, et al. Correlations of magnetic resonance imaging findings with clinical symptom severity and prognosis of frozen shoulder. *Knee Surg Sports Traumatol Arthrosc* 2017;25:3242-50.
113. Zhao W, Zheng X, Liu Y, et al. An MRI study of symptomatic adhesive capsulitis. *PLoS One* 2012;7:e47277.
114. Chi AS, Kim J, Long SS, Morrison WB, Zoga AC. Non-contrast MRI diagnosis of adhesive capsulitis of the shoulder. *Clin Imaging* 2017;44:46-50.
115. Tandon A, Dewan S, Bhatt S, Jain AK, Kumari R. Sonography in diagnosis of adhesive capsulitis of the shoulder: a case-control study. *J Ultrasound* 2017;20:227-36.
116. Kim DH, Cho CH, Sung DH. Ultrasound measurements of axillary recess capsule thickness in unilateral frozen shoulder: study of correlation with MRI measurements. *Skeletal Radiol* 2018;47:1491-97.
117. Kim DH, Choi YH, Oh S, Kim HJ, Chai JW. Ultrasound Microflow Imaging Technology for Diagnosis of Adhesive Capsulitis of the Shoulder. *J Ultrasound Med* 2020;39:967-76.
118. Teixeira PAG, Jaquet P, Bakour O, et al. CT arthrography of the intra-articular long head of biceps tendon: Diagnostic performance outside the labral-bicipital complex. *Diagn Interv Imaging* 2019;100:437-44.
119. Rol M, Favard L, Berhouet J. Diagnosis of long head of biceps tendinopathy in rotator cuff tear patients: correlation of imaging and arthroscopy data. *Int Orthop* 2018;42:1347-55.
120. De Maeseneer M, Boulet C, Pouliart N, et al. Assessment of the long head of the biceps tendon of the shoulder with 3T magnetic resonance arthrography and CT arthrography. *Eur J Radiol* 2012;81:934-9.
121. Petscavage-Thomas J, Gustas C. Comparison of Ultrasound-Guided to Fluoroscopy-Guided Biceps Tendon Sheath Therapeutic Injection. *J Ultrasound Med* 2016;35:2217-21.
122. Sconfienza LM, Chianca V, Messina C, Albano D, Pozzi G, Bazzocchi A. Upper Limb Interventions. *Radiol Clin North Am* 2019;57:1073-82.
123. Yiannakopoulos CK, Megaloikononimos PD, Foufa K, Gliatis J. Ultrasound-guided versus palpation-guided corticosteroid injections for tendinosis of the long head of the biceps: A randomized comparative study. *Skeletal Radiol* 2020;49:585-91.
124. Geannette C, Williams D, Berkowitz J, Miller TT. Ultrasound-Guided Biceps Tendon Sheath Injection: Spectrum of Preprocedure Appearances. *J Ultrasound Med* 2019;38:3267-71.
125. Zanetti M, Weishaupt D, Gerber C, Hodler J. Tendinopathy and rupture of the tendon of the long head of the biceps brachii muscle: evaluation with MR arthrography. *AJR Am J Roentgenol* 1998;170:1557-61.
126. Looock E, Michelet A, D'Utruy A, et al. Magnetic resonance arthrography is insufficiently accurate to diagnose biceps lesions prior to rotator cuff repair. *Knee Surg Sports Traumatol Arthrosc* 2019;27:3970-78.
127. Borrero CG, Costello J, Bertolet M, Vyas D. Effect of patient age on accuracy of primary MRI signs of long head of biceps tearing and instability in the shoulder: an MRI-arthroscopy correlation study. *Skeletal Radiol* 2018;47:203-14.
128. Kang Y, Lee JW, Ahn JM, Lee E, Kang HS. Instability of the long head of the biceps tendon in patients with rotator cuff tear: evaluation on magnetic resonance arthrography of the shoulder with arthroscopic correlation. *Skeletal Radiol* 2017;46:1335-42.
129. Beall DP, Williamson EE, Ly JQ, et al. Association of biceps tendon tears with rotator cuff abnormalities: degree of correlation with tears of the anterior and superior portions of the rotator cuff. *AJR Am J Roentgenol* 2003;180:633-9.
130. Dubrow SA, Streit JJ, Shishani Y, Robbin MR, Gobezie R. Diagnostic accuracy in detecting tears in the proximal biceps tendon using standard nonenhancing shoulder MRI. *Open Access J Sports Med* 2014;5:81-7.

131. Mohtadi NG, Vellet AD, Clark ML, et al. A prospective, double-blind comparison of magnetic resonance imaging and arthroscopy in the evaluation of patients presenting with shoulder pain. *J Shoulder Elbow Surg* 2004;13:258-65.
132. Kim JY, Rhee SM, Rhee YG. Accuracy of MRI in diagnosing intra-articular pathology of the long head of the biceps tendon: results with a large cohort of patients. *BMC Musculoskelet Disord* 2019;20:270.
133. Burke CJ, Mahanty SR, Pham H, et al. MRI, arthroscopic and histopathologic cross correlation in biceps tenodesis specimens with emphasis on the normal appearing proximal tendon. *Clin Imaging* 2019;54:126-32.
134. Nuelle CW, Stokes DC, Kuroki K, Crim JR, Sherman SL. Radiologic and Histologic Evaluation of Proximal Bicep Pathology in Patients With Chronic Biceps Tendinopathy Undergoing Open Subpectoral Biceps Tenodesis. *Arthroscopy* 2018;34:1790-96.
135. Khil EK, Cha JG, Yi JS, et al. Detour sign in the diagnosis of subluxation of the long head of the biceps tendon with arthroscopic correlation. *Br J Radiol* 2017;90:20160375.
136. Yoon JS, Kim SJ, Choi YR, Lee W, Kim SH, Chun YM. Medial Subluxation or Dislocation of the Biceps on Magnetic Resonance Arthrography Is Reliably Correlated with Concurrent Subscapularis Full-Thickness Tears Confirmed Arthroscopically. *Biomed Res Int* 2018;2018:2674061.
137. Baptista E, Malavolta EA, Gracitelli MEC, et al. Diagnostic accuracy of MRI for detection of tears and instability of proximal long head of biceps tendon: an evaluation of 100 shoulders compared with arthroscopy. *Skeletal Radiol* 2019;48:1723-33.
138. Strakowski JA, Visco CJ. Diagnostic and therapeutic musculoskeletal ultrasound applications of the shoulder. *Muscle Nerve* 2019;60:1-6.
139. Wengert GJ, Schmutzer M, Bickel H, et al. Reliability of high-resolution ultrasound and magnetic resonance arthrography of the shoulder in patients with sports-related shoulder injuries. *PLoS One* 2019;14:e0222783.
140. Iannotti JP, Jun BJ, Patterson TE, Ricchetti ET. Quantitative Measurement of Osseous Pathology in Advanced Glenohumeral Osteoarthritis. *J Bone Joint Surg Am* 2017;99:1460-68.
141. Siebert MJ, Chalian M, Sharifi A, et al. Qualitative and quantitative analysis of glenoid bone stock and glenoid version: inter-reader analysis and correlation with rotator cuff tendinopathy and atrophy in patients with shoulder osteoarthritis. *Skeletal Radiol* 2020;49:985-93.
142. Gimarc DC, Lee KS. Shoulder MR Imaging Versus Ultrasound: How to Choose. *Magn Reson Imaging Clin N Am* 2020;28:317-30.
143. Parada SA, Shaw KA, Antosh IJ, et al. Magnetic Resonance Imaging Correlates With Computed Tomography for Glenoid Version Calculation Despite Lack of Visibility of Medial Scapula. *Arthroscopy* 2020;36:99-105.
144. Lowe JT, Testa EJ, Li X, Miller S, DeAngelis JP, Jawa A. Magnetic resonance imaging is comparable to computed tomography for determination of glenoid version but does not accurately distinguish between Walch B2 and C classifications. *J Shoulder Elbow Surg* 2017;26:669-73.
145. Aronowitz JG, Harmsen WS, Schleck CD, Sperling JW, Cofield RH, Sanchez-Sotelo J. Radiographs and computed tomography scans show similar observer agreement when classifying glenoid morphology in glenohumeral arthritis. *J Shoulder Elbow Surg* 2017;26:1533-38.
146. Habermeyer P, Magosch P, Weiss C, et al. Classification of humeral head pathomorphology in primary osteoarthritis: a radiographic and in vivo photographic analysis. *J Shoulder Elbow Surg* 2017;26:2193-99.
147. Shukla DR, McLaughlin RJ, Lee J, Cofield RH, Sperling JW, Sanchez-Sotelo J. Intraobserver and interobserver reliability of the modified Walch classification using radiographs and computed tomography. *J Shoulder Elbow Surg* 2019;28:625-30.
148. Mantell MT, Nelson R, Lowe JT, Endrizzi DP, Jawa A. Critical shoulder angle is associated with full-thickness rotator cuff tears in patients with glenohumeral osteoarthritis. *J Shoulder Elbow Surg* 2017;26:e376-e81.
149. Kim YS, Jin HK, Lee HJ, Cho HL, Lee WS, Jang HJ. Is It Safe to Inject Corticosteroids Into the Glenohumeral Joint After Arthroscopic Rotator Cuff Repair? *Am J Sports Med* 2019;47:1694-700.
150. Samim M, Beltran L. The Postoperative Rotator Cuff. *Magn Reson Imaging Clin N Am* 2020;28:181-94.
151. Mohana-Borges AV, Chung CB, Resnick D. MR imaging and MR arthrography of the postoperative shoulder: spectrum of normal and abnormal findings. *Radiographics* 2004;24:69-85.
152. Ball CM. Arthroscopic rotator cuff repair: magnetic resonance arthrogram assessment of tendon healing. *J Shoulder Elbow Surg* 2019;28:2161-70.



153. Bancroft LW, Wasyliv C, Pettis C, Farley T. Postoperative shoulder magnetic resonance imaging. *Magn Reson Imaging Clin N Am* 2012;20:313-25, xi.
154. Micic I, Kholinne E, Kwak JM, Koh KH, Jeon IH. Osteolysis is observed around both bioabsorbable and nonabsorbable anchors on serial magnetic resonance images of patients undergoing arthroscopic rotator cuff repair. *Acta Orthop Traumatol Turc* 2019;53:414-19.
155. Hamano N, Yamamoto A, Shitara H, et al. Does successful rotator cuff repair improve muscle atrophy and fatty infiltration of the rotator cuff? A retrospective magnetic resonance imaging study performed shortly after surgery as a reference. *J Shoulder Elbow Surg* 2017;26:967-74.
156. Lhee SH, Singh AK, Lee DY. Does magnetic resonance imaging appearance of supraspinatus muscle atrophy change after repairing rotator cuff tears? *J Shoulder Elbow Surg* 2017;26:416-23.
157. Gulotta LV, Nho SJ, Dodson CC, Adler RS, Altchek DW, MacGillivray JD. Prospective evaluation of arthroscopic rotator cuff repairs at 5 years: part II--prognostic factors for clinical and radiographic outcomes. *J Shoulder Elbow Surg* 2011;20:941-6.
158. Gilat R, Atoun E, Cohen O, et al. Recurrent rotator cuff tear: is ultrasound imaging reliable? *J Shoulder Elbow Surg* 2018;27:1263-67.
159. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf>. Accessed September 30, 2022.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.