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**American College of Radiology  
ACR Appropriateness Criteria®**

**Clinical Condition:**      **Imaging After Shoulder Arthroplasty**

**Variant 1:**                      **Follow-up of the asymptomatic patient with a primary shoulder arthroplasty.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray shoulder	9		⊕
CT shoulder without IV contrast	1		⊕⊕⊕
CT shoulder with IV contrast	1		⊕⊕⊕
CT shoulder without and with IV contrast	1		⊕⊕⊕
MRI shoulder without IV contrast	1		○
MRI shoulder without and with IV contrast	1		○
Tc-99m bone scan shoulder	1		⊕⊕⊕
US shoulder	1		○
<b><u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate</b>			<b>*Relative Radiation Level</b>

**Variant 2:**                      **Symptomatic patient with a primary shoulder arthroplasty; unknown diagnosis. Initial study.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray shoulder	9	This procedure is performed if it has not been recently obtained.	⊕
CT shoulder without IV contrast	1		⊕⊕⊕
CT shoulder with IV contrast	1		⊕⊕⊕
CT shoulder without and with IV contrast	1		⊕⊕⊕
MRI shoulder without IV contrast	1		○
MRI shoulder without and with IV contrast	1		○
Tc-99m bone scan shoulder	1		⊕⊕⊕
US shoulder	1		○
<b><u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate</b>			<b>*Relative Radiation Level</b>

**Clinical Condition:**      **Imaging After Shoulder Arthroplasty**

**Variant 3:**                    **Evaluating patients with a painful primary shoulder arthroplasty: suspect aseptic loosening. Additional imaging following radiographs.**

<b>Radiologic Procedure</b>	<b>Rating</b>	<b>Comments</b>	<b>RRL*</b>
CT shoulder without IV contrast	8		☼☼☼
CT arthrography shoulder	5		☼☼
MRI shoulder without IV contrast	5	With appropriate metal reduction, this procedure may be helpful.	O
Tc-99m bone scan shoulder	5	The usefulness of this procedure depends on the interval between prosthesis placement and imaging.	☼☼☼
CT shoulder with IV contrast	1		☼☼☼
CT shoulder without and with IV contrast	1		☼☼☼
MRI shoulder without and with IV contrast	1		O
US shoulder	1		O
<b><u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate</b>			<b>*Relative Radiation Level</b>

**Clinical Condition:** Imaging After Shoulder Arthroplasty

**Variant 4:** Evaluating patients with a painful primary shoulder arthroplasty: suspect infection. Additional imaging following radiographs.

Radiologic Procedure	Rating	Comments	RRL*
Aspiration shoulder	9	If using fluoroscopy, may need US or CT to evaluate superficial soft tissues for signs of infection prior to aspiration.	Varies
In-111 WBC and Tc-99m sulfur colloid scan shoulder	7	This procedure should be considered if aspiration cannot be performed.	☼☼☼☼
CT shoulder with IV contrast	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating. Contrast may help with extent of infection or abscess.	☼☼☼
MRI shoulder without IV contrast	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	O
MRI shoulder without and with IV contrast	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	O
Tc-99m 3-phase bone scan shoulder	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	☼☼☼
US shoulder	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	O
CT shoulder without IV contrast	4		☼☼☼
CT shoulder without and with IV contrast	1		☼☼☼
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Variant 5:** Evaluating patients with a painful primary total shoulder arthroplasty: suspect fracture. Additional imaging following radiographs.

Radiologic Procedure	Rating	Comments	RRL*
CT shoulder without IV contrast	9		☼☼☼
MRI shoulder without IV contrast	5	With appropriate metal reduction, this procedure may be helpful.	O
Tc-99m bone scan shoulder	5	The usefulness of this procedure depends on the interval between prosthesis placement and imaging.	☼☼☼
CT shoulder with IV contrast	1		☼☼☼
CT shoulder without and with IV contrast	1		☼☼☼
MRI shoulder without and with IV contrast	1		O
US shoulder	1		O
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Clinical Condition:** Imaging After Shoulder Arthroplasty

**Variant 6:** Evaluating primary shoulder arthroplasty patients with possible rotator cuff tear. Additional imaging following radiographs.

Radiologic Procedure	Rating	Comments	RRL*
CT arthrography shoulder	8	This procedure is equivalent to US; only 1 procedure should be performed.	☼☼
US shoulder	8	This procedure is equivalent to CT arthrography; only 1 procedure should be performed.	O
MRI shoulder without IV contrast	7	This procedure can be performed if US and CT arthrography are not available.	O
MR arthrography shoulder	3		O
CT shoulder without IV contrast	1		☼☼☼
CT shoulder with IV contrast	1		☼☼☼
CT shoulder without and with IV contrast	1		☼☼☼
MRI shoulder without and with IV contrast	1		O
Tc-99m bone scan shoulder	1		☼☼☼
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Variant 7:** Evaluating primary shoulder arthroplasty patients with possible nerve injury. Additional imaging following radiographs.

Radiologic Procedure	Rating	Comments	RRL*
MRI shoulder without IV contrast	7	This procedure is equivalent to US; only 1 procedure should be performed.	O
US shoulder	7	This procedure is equivalent to MRI; only 1 procedure should be performed.	O
MRI shoulder without and with IV contrast	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	O
CT shoulder without IV contrast	4		☼☼☼
CT shoulder with IV contrast	1		☼☼☼
CT shoulder without and with IV contrast	1		☼☼☼
Tc-99m bone scan shoulder	1		☼☼☼
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

## IMAGING AFTER SHOULDER ARTHROPLASTY

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### **Summary of Literature Review**

#### **Introduction/Background**

There has been a rapid increase in the number of shoulder arthroplasties, including partial or complete humeral head resurfacing, hemiarthroplasty, total shoulder arthroplasty, and reverse total shoulder arthroplasty, performed in the United States over the past 2 decades [1]. The most recent published estimates have reported a 2.5-fold increase in the number of shoulder arthroplasties performed between 1998 and 2008, from 19,000 to 47,000 [1]. Overall, total shoulder arthroplasties are the most common type, having surpassed hemiarthroplasties in the last decade [1].

Most shoulder arthroplasties are performed for degenerative conditions. Humeral head resurfacing is indicated in patients with humeral head osteonecrosis, large Hill-Sachs deformity, or focal osteoarthritis. Hemiarthroplasties are typically performed in patients with osteoarthritis limited to the humeral head or in patients with comminuted humeral head fractures. Hemiarthroplasties are also recommended in patients with deficient glenoid bone stock and in patients with greater preoperative comorbidities since they require a shorter intraoperative time compared to total shoulder arthroplasty. Presently, total shoulder arthroplasty is recommended over hemiarthroplasty for advanced shoulder osteoarthritis because of its superior clinical outcome.

Reverse shoulder arthroplasties were first introduced in 1987 as a treatment option for patients with a deficient rotator cuff and have been used as a salvage procedure for patients with failed total shoulder arthroplasties [2,3]. Reverse shoulder arthroplasties are constructed differently from total shoulder arthroplasties to compensate for the lack of stabilization related to the deficient rotator cuff. The glenoid component is a round metal ball (referred to as the glenosphere) attached to a baseplate along the glenoid surface, and the humeral component has a cup-shaped articular margin secured by a metal stem [3]. The construct moves the center of rotation more medial and distal, which allows the deltoid muscle to serve as a main stabilizer of the arthroplasty and joint [3]. Additionally, the more distal and medial center of rotation decreases the risk of glenoid loosening [3,4].

The complication rate for shoulder arthroplasties has been reported to be as high as 39.8%, with revision rates up to 11% [5]. Postoperative abnormalities and associated conditions include patients' dissatisfaction, prosthetic loosening, glenohumeral instability, polyethylene wear, osteolysis, periprosthetic fracture, impingement (mainly with reverse total shoulder arthroplasties), tears of the rotator cuff tendons, infection, nerve injury, and deltoid dysfunction [2]. The most common complication for hemiarthroplasties has been erosion of the unresurfaced glenoid (20.6%), whereas glenoid loosening (14.3%) has been reported as the most common complication for total shoulder arthroplasties [5]. The rate of perioperative complications, such as blood loss, thromboembolism, and immediate postoperative infection, has been shown to be similar for both types of surgeries [6]. The most common complications associated with reverse total shoulder arthroplasties are scapular notching, dislocation, periprosthetic fractures, glenoid baseplate failure, and acromial fractures [7].

Symptoms related to postoperative difficulties, including activity-related pain, decreased range of motion, and apprehension, tend to vary. Some patients report immediate and persistent dissatisfaction, although others report a

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symptom-free postoperative period followed by increasing pain and decreasing shoulder function and mobility [8].

Imaging can play an important role in diagnosing postoperative complications of shoulder arthroplasties. The imaging algorithm should always begin with radiographs to assess the hardware components, alignment, and surrounding osseous and soft-tissue structures. The selection of the next imaging modality depends on a number of factors, including findings on the initial radiographic study, clinical suspicion of an osseous versus soft-tissue injury, or clinical suspicion of infection.

## **Overview of Imaging Modalities**

### *Radiography*

Radiography is the first and main imaging modality utilized in the evaluation of shoulder arthroplasty [8,9]. Radiographs are typically ordered within 3–6 weeks after surgery and consist of 2–4 radiographs, depending on the surgeon's preference. These may include anterior-posterior (AP), AP Grashey, scapular Y, and axillary views [8,9]. Intraoperative and immediate postoperative radiographs are also ordered by some surgeons, but their value, without specific indication, has been questioned due to limitations inherent to the portable nature of the exam, patients' difficulties in cooperating with the various views, and low impact on overall patient care [10]. In the symptomatic patient, however, radiographs are the first imaging of choice and should be performed before other more advanced cross-sectional imaging studies are performed.

### *Computed tomography*

Computed tomography (CT) plays an important role in the imaging evaluation of a patient with a possible acute (eg, fracture) or chronic (eg, loosening) shoulder arthroplasty complication that may be missed or incompletely evaluated with radiographs [8,11]. CT provides a better means of evaluating the hardware components and surrounding bone stock. Image degradation can occur due to beam hardening artifact and other hardware-related artifacts, especially with older CT scanners. The use of newer metal reduction CT software has decreased the artifact-related limitations, improving evaluation [12]. Furthermore, dual-energy CT, employing recent virtual noncalcium software, may provide useful information regarding the presence of marrow edema [13]. A CT arthrogram can be performed when there is suspicion of a rotator cuff tear and/or loosening of the hardware components [8]. CT can also be used to evaluate the hardware and surrounding soft tissues for infection and to aid in planning prior to image-guided joint aspiration.

### *Magnetic resonance imaging*

Magnetic resonance imaging (MRI) has inherently higher tissue-contrast resolution than CT and therefore is superior for assessing soft-tissue abnormalities following shoulder arthroplasty. Nevertheless, MRI has been infrequently used in the evaluation of a patient with a suspected postoperative complication of shoulder arthroplasty due to its high cost and metal artifact–related limitations. Evolving MRI methods with improved image quality and metal artifact reduction have rendered the modality a more feasible technique for the diagnosis of component loosening, rotator cuff tearing, infection, and, in the presence of hemiarthroplasty, glenoid cartilage wear [14-17].

### *Ultrasound*

Ultrasound (US) of the shoulder after arthroplasty is becoming increasingly more popular for the evaluation of soft-tissue disorders, including rotator cuff tears, biceps tendon pathology, and muscle atrophy, as the imaging quality is not limited by hardware-related artifact [18]. US can also assess the presence of joint effusion, bursal distention, and intra-articular and soft-tissue infection [19]. Other advantages of US include low cost as well as the ability for dynamic evaluation of the shoulder. A limitation is the restricted ability of US to evaluate any bone-related complications such as loosening [8].

### *Nuclear medicine imaging*

In infection imaging, indium In 111 white blood cell (WBC) imaging in conjunction with Tc-99m sulfur colloid marrow imaging should be sufficient. A Tc-99m methylene diphosphonate bone scan should generally not be necessary to confirm or exclude infection with the use of the other 2 agents.

The use of nuclear imaging in the evaluation of complications after arthroplasty has been limited to the evaluation of hip and knee arthroplasties, but the same principles can be applied to shoulder arthroplasties [8]. Tc-99m bone scan imaging is a highly sensitive modality for the diagnosis of periprosthetic fractures, as well as loosening and infection in the setting of normal radiographs, but it remains low in specificity as there is overlap in the imaging

findings of these abnormalities [8]. Furthermore, bone remodeling–related increased uptake can be seen at the site of arthroplasty for up to 1 year following surgery [8]. Indium-labeled WBC scintigraphy is a sensitive but nonspecific technique for the evaluation of periprosthetic infection [20]. The specificity of the technique can be increased when interpreted alongside Tc-99m sulfur colloid imaging as well as bone scan imaging [21,22]. The latter combination is inefficient, requiring 3 different tests over 2 days and increased expense and time loss until diagnosis to the patient.

#### *Arthrography*

Routine arthrography had been utilized for detecting rotator cuff tears in the setting of shoulder arthroplasty but its role has been nearly completely supplanted by cross-sectional imaging techniques such as US and CT post arthrography due to its inability to assess muscle quality, assess gradation of partial tearing, and differentiate between the torn rotator cuff muscles.

#### *Aspiration/arthrocentesis*

Imaging-guided aspiration procedures provide a minimally invasive means to sample fluid from the joint suspected of infection [23,24]. Aspiration should be considered when there is suspicion for an infected shoulder arthroplasty to avoid the destructive soft-tissue and bone changes that can result from an untreated infection. Shoulder aspiration can be completed with the use of fluoroscopy, US, MRI, and CT guidance. Arthrography is typically performed along with aspiration, when done under fluoroscopy and CT, to confirm the intra-articular origin of any aspirated fluid as well as to assess for any extension of the infectious process into adjacent bursae, sinus tracts, and abscesses [24].

### **Discussion of the Imaging Modalities by Variant**

#### **Variant 1: Follow-up of the asymptomatic patient with a primary shoulder arthroplasty.**

##### *Radiographs*

There is no consensus for radiographic follow-up of patients after shoulder arthroplasty. Most patients get an initial set of radiographs within 3–6 weeks after surgery [9]. The frequency of follow-up radiographs varies depending on the surgeon’s preference but usually accompanies their follow-up visits anywhere between 3 months and 1 year post surgery. Radiographs are also typically ordered for yearly follow-up examinations.

The risk for loosening increases over time, with notable radiographic changes associated with loosening found at least 5 years after surgery, most commonly involving the glenoid component [25]. Recent evidence of late complications requiring revision surgery, such as loosening, infection, and fracture, occurring up to 15 years postoperatively suggests the need for long-term radiographic follow-up when these complications are asymptomatic or their outcome can be affected by early detection on radiographs [8].

##### *Computed tomography*

CT examinations are not typically ordered for evaluation of the asymptomatic patient. CT has been found to better demonstrate radiolucent lines along the margins of prosthetic components associated with loosening when compared to radiographs [11]. CT can consistently demonstrate the incorporation of the glenoid component into the adjacent bone, a finding that has correlated with decreased hardware failure [26].

##### *Magnetic resonance imaging*

MRI examinations are not typically ordered for evaluation of the asymptomatic patient.

##### *Ultrasound*

US examinations are not typically ordered for evaluation of the asymptomatic patient.

##### *Bone scintigraphy*

Bone scintigraphy is not typically ordered for evaluation of the asymptomatic patient.

#### **Variant 2: Symptomatic patient with a primary shoulder arthroplasty; unknown diagnosis. Initial study.**

Radiographs should also be the first study ordered for the evaluation of the symptomatic patient with a primary shoulder arthroplasty.

Glenoid component loosening is the primary cause of failed total shoulder arthroplasties; thus the axillary view should be included in the series. Causes for glenoid component failure vary and depend on the age and sex of the patient, preoperative condition and etiology for the surgery, quality of underlying subchondral bone, type of glenoid component, and surgical technique. There is a high prevalence of radiographic radiolucencies around the



glenoid component, the presence and progression of which are linked to component failure. These have been reported to become more apparent at 5 years after implantation [25]. There are different grading systems for glenoid loosening, depending on whether the component is keeled [27,28] or pegged [29]. Evidence for glenoid loosening includes surrounding lucency >1.5–2 mm in width, migration (tilt or subsidence), or shifting of the component [9,28,30]. Loosening of the glenoid component has also been described in the setting of a reverse total shoulder arthroplasty and may be related to scapular notching [8,31].

Humeral component loosening is less common than glenoid loosening, encompassing approximately 15% of all shoulder prosthetic complications [5] and more likely to occur in the setting of a noncemented component, cuff arthropathy, rheumatoid arthritis, and osteoporosis [9]. Humeral component loosening has been associated with glenoid loosening; furthermore, a loose humeral component is considered infected until proven otherwise [32]. Radiographic findings suggestive of humeral components at risk for loosening include >2 mm (width) surrounding radiolucent lines, tilt, and subsidence [9]. The risk of humeral loosening may be more common in the setting of reverse total shoulder arthroplasties compared to total shoulder arthroplasties because of greater shear stress at the interface of the bone and stem in the reverse arthroplasty [31,33].

The risk for loosening increases over time, with notable radiographic changes associated with loosening found at least 5 years after surgery, most commonly involving the glenoid component [25]. Recent evidence of late complications requiring revision surgery, such as loosening, infection, and fracture, occurring up to 15 years postoperatively suggests the need for long-term radiographic follow-up when these complications are asymptomatic or their outcome can be affected by early detection on radiographs [8].

Radiographic evaluation for suspected infection typically include AP and axillary views to assess the integrity of the arthroplasty and alignment of the glenohumeral joint [2]. Several radiographic findings have been described in the setting of periprosthetic infection and include endosteal scalloping, periosteal reaction, generalized bone resorption, periprosthetic radiolucency, scattered osteolysis, and inferior subluxation of the humerus suggestive of an underlying joint effusion [3,34-38]. These findings are nonspecific and can also be seen in other etiologies such as mechanical loosening and osteolysis. In certain cases where the suspicion for infection is high, radiographs may be the only imaging modality that is appropriate before an intervention (eg, image-guided aspiration or surgical exploration) is performed.

The imaging evaluation for periprosthetic fracture typically begins with radiographs. These can be performed intraoperatively if a fracture is suspected to have occurred during the surgical procedure or in the early postoperative setting, usually consisting of a combination of AP, AP Grashey, scapular Y, and/or axillary views [8,9,39]. Care should be taken to obtain adequate coverage of the tip of the humeral prosthesis so as to allow exclusion of humeral fractures distal to the tip of the prosthesis. Radiographs of the scapula can be obtained if there is concern for fracture in the setting of a total reverse shoulder arthroplasty as well. The diagnosis of a periprosthetic fracture can be made on radiographs or other more advanced imaging modalities. Follow-up imaging can be done with interval radiographs to assess for healing. Nonunion or infected nonunion should be considered in the patient with a known fracture and persistent pain [8].

Radiographs are typically used as the initial imaging modality for a suspected rotator cuff tear and include a combination of AP, axillary, and/or trans-scapular Y views. On radiographs, superior rotator cuff (supraspinatus and/or infraspinatus) failure (also referred to as superior instability) can be suggested by superior migration of the humeral head component relative to the glenoid. A distance >5 mm, measured on an AP view, from the center of the humeral head to the center of the glenoid is consistent with superior migration [5,9].

Although radiographs cannot demonstrate a direct nerve injury, an injury can be suspected if bone or metallic fragments are seen along the expected course of the shoulder nerves (eg, axillary nerve injury can be inferred when a prosthetic component is displaced into the axillary recess).

#### *Computed tomography*

CT examinations are not typically ordered as the initial study for the symptomatic patient. CT has been found to better demonstrate radiolucent lines along the margins of prosthetic components, associated with loosening, when compared to radiographs [11]. CT can consistently demonstrate the incorporation of the glenoid component into the adjacent bone, a finding that has correlated with decreased hardware failure [26].

#### *Magnetic resonance imaging*

MRI examinations are not typically ordered as the initial study for the symptomatic patient.

### *Ultrasound*

US examinations are not typically ordered as the initial study for the symptomatic patient.

### *Bone scintigraphy*

Bone scintigraphy is not typically ordered as the initial study for the symptomatic patient.

### **Variant 3: Evaluating patients with a painful primary shoulder arthroplasty: suspect aseptic loosening. Additional imaging following radiographs.**

Aseptic loosening, also referred to as mechanical loosening, is used to describe a hardware abnormality that results from a noninfectious etiology. One of the most common causes of aseptic loosening is particle disease (eg, osteolysis), a foreign-body response to debris that results from wear and breakdown of the hardware components, such as the acetabular polyethylene liner, cement, and/or metallic elements. Particle disease can cause extensive, often asymptomatic, bone loss [40-42]. Although this process has been described extensively in the literature for hip arthroplasty, the literature on the topic is sparse in patients with shoulder arthroplasties [43,44]. In general, the imaging algorithm used for aseptic loosening can also be used for patients suspected of particle disease.

### *Computed tomography*

Metal reduction protocols and modifications in patient positioning have greatly enhanced the ability of CT to evaluate for complications associated with shoulder arthroplasties. Nevertheless, there are scant studies assessing the value of CT in patients with postoperative complications. In a few reports, each including a small group of patients, CT compared to radiographs has been found to better demonstrate imaging findings such as periprosthetic lucency, osteolysis, hardware malposition, and component migration as well as the degree of osseous incorporation along the glenoid, deficiency of which has been associated with the risk of failure [8,11,26]. Dual-energy virtual noncalcium techniques, although not yet specifically studied in the postoperative shoulder, may potentially provide useful information about marrow edema associated with the above abnormalities [13]. The addition of intra-articular or intravenous (IV) contrast does not typically improve evaluation [45].

### *Bone scintigraphy*

Tc-99m bone scan imaging is a highly sensitive modality for the diagnosis of aseptic loosening and osteolysis [8]. Its specificity is lower because the imaging findings seen in aseptic loosening can overlap with other hardware disorders, such as postsurgical bone remodeling, infection, and periprosthetic fractures [8]. The specificity of Tc-99m bone scan imaging increases in older prostheses once postoperative remodeling has quieted down.

### *Magnetic resonance imaging*

Given recent developments in metal reduction protocols for MRI and research studies showing the value of MRI in detecting soft-tissue pathology such as rotator cuff tears and, in the presence of hemiarthroplasty, glenoid cartilage wear, MRI may play a role in the evaluation of aseptic loosening [14-16].

### *Ultrasound*

US examinations are not typically ordered for evaluation of aseptic loosening.

### **Variant 4: Evaluating patients with a painful primary shoulder arthroplasty: suspect infection. Additional imaging following radiographs.**

Infection, including osteomyelitis and septic arthritis, after total shoulder arthroplasty is an uncommon albeit potentially devastating complication, with a prevalence of 0.7%–2.9%, and it is more commonly seen in males and a younger age group [2,46,47]. A 97% infection-free rate at 20 years has been reported. Predisposing underlying conditions may include rheumatoid arthritis, corticosteroid use, diabetes, repeated intra-articular steroid injections, and prior shoulder surgery [46]. Infection rates are higher in the setting of reverse total shoulder arthroplasties, with a range of 0.8%–10% [48]. Proposed causes for this higher prevalence include longer procedural time and steeper learning curve to perform the surgery, large dead space, multiple previous operations, and advanced patient age [48].

### *Aspiration*

Aspiration of the shoulder should be considered when there is suspicion for an infected shoulder arthroplasty clinically, with or without radiographic evidence of infection, to avoid the destructive soft-tissue and bone changes that can result from an untreated infection. Shoulder aspiration can be completed with the use of fluoroscopy, US, MRI, and CT guidance. Arthrography can be performed after the aspiration, when done under fluoroscopy or CT, if there is a clinical indication or request to evaluate for any extension of the infectious

process into adjacent bursae, sinus tract, or abscess [24].

#### *Bone scintigraphy*

The use of nuclear imaging for the evaluation of periprosthetic infection has been limited to the evaluation of hip and knee arthroplasties, but various clinical studies anecdotally suggest utilizing this modality in shoulder arthroplasties [8,49]. Tc-99m 3-phase bone scan imaging is a highly sensitive modality for the diagnosis of infection in the setting of normal radiographs but remains low in specificity as the imaging findings can overlap with other abnormalities such as mechanical loosening and osteolysis [8]. In addition, increased “abnormal” uptake can be seen at the site of arthroplasty, related to bone remodeling, for up to 1 year following surgery [8]. Tc-99m 3-phase bone scan imaging is also limited in its ability to assess the periprosthetic soft tissues for the presence of an abscess. Isolated indium-labeled WBC study is a sensitive but nonspecific technique for the evaluation of periprosthetic infection [20]. Its specificity can be increased when interpreted alongside Tc-99m sulfur colloid imaging or, less optimally, bone scan imaging; the latter may not be indicated if both indium WBC and sulfur colloid imaging have been performed [21,22].

#### *Computed tomography*

CT with metal reduction protocols can elucidate the findings seen on radiographs and can further narrow the differential diagnosis in a patient suspected of periprosthetic infection as well as assist in preoperative planning [2]. CT may play a more important role after removal of the hardware and debridement in a patient with infection as it can help quantify the amount of remaining bone that can be used for revision arthroplasty [2]. CT can also be used to evaluate the surrounding soft tissues for infection and to aid in planning prior to image-guided joint aspiration. Administration of IV contrast improves the evaluation of adjacent soft-tissue fluid collections/abscesses and sinus tracts.

#### *Magnetic resonance imaging*

MRI with metal reduction protocols can play a useful role in the diagnosis [14,15] and assessment of periprosthetic infection, particularly when other modalities fail in confirming the diagnosis. MRI can demonstrate osseous and soft-tissue abnormalities associated with periprosthetic infection [16,50]. MRI can depict marrow edema suggestive of osteomyelitis. It can depict bony destruction, which can be difficult to note on radiographs, related to osteomyelitis. MRI can also demonstrate joint effusions, adjacent soft-tissue edema, and fluid loculations suggestive of abscesses. Administration of IV contrast improves the evaluation of adjacent soft-tissue fluid collections/abscesses and sinus tracts.

#### *Ultrasound*

US examinations are increasingly being ordered for evaluation of periprosthetic infection in the setting of shoulder arthroplasty to evaluate for joint effusion and surrounding soft-tissue infection. US may be of use for the evaluation of a joint effusion, bursal distention, and the surrounding soft tissues for signs of infection including abscesses [18,49], which need aspiration and testing to determine the presence of infection and identification of the underlying microorganism. US is useful to evaluate the surrounding soft tissues for infection and to aid in planning prior to image-guided joint aspiration, in order to avoid seeding of a sterile joint effusion from overlying soft-tissue infection. A limiting factor is patient body habitus.

### **Variant 5: Evaluating patients with a painful primary total shoulder arthroplasty: suspect fracture. Additional imaging following radiographs.**

Periprosthetic fractures of the glenoid and humerus can occur intraoperatively as well as postoperatively. Complications related to surgical technique, such as excessive reaming or impaction, are the most common reasons for fractures in the intraoperative setting, with a reported incidence of 2.1% [5]. In the postoperative setting, a 1% incidence of periprosthetic fractures has been reported; patients’ other medical comorbidities (assessed using the Deyo-Charlson index) are found to be a significant risk factors [8,51]. Humeral fractures have been found to be more common than glenoid fractures. Fractures of the acromion and spine of the scapula are more common in the setting of reverse total shoulder arthroplasty and are thought to be related to an intraoperative complication or, more commonly, chronic stress [3].

#### *Computed tomography*

CT with metal reduction protocol can be used to further delineate a periprosthetic fracture seen on radiographs in terms of degree of displacement, extent, and comminution. CT can also be used when a fracture is suspected clinically but the radiographs are negative, such as in the setting of a suspected acromial stress fracture in the

patient with a reverse total shoulder arthroplasty [43]. Administration of IV or intra-articular contrast does not improve evaluation.

#### *Magnetic resonance imaging*

MRI is not typically ordered for the evaluation of possible periprosthetic fracture but can play a contributory role when fractures are occult on radiographs and/or CT examinations. MRI can identify the location of the fracture by detecting associated marrow edema and, not infrequently, an associated fracture line.

#### *Bone scintigraphy*

Tc-99m bone scan imaging is a highly sensitive modality for the diagnosis of periprosthetic fractures but remains low in specificity, as the imaging findings can overlap with other abnormalities such as loosening and infection [8]. In addition, increased “abnormal” uptake can be seen at the site of arthroplasty, related to bone remodeling, for up to 1 year following surgery, further complicating matters [8]. The specificity of Tc-99m bone scan imaging increases in older prostheses once postoperative remodeling has quieted down.

#### *Ultrasound*

US examinations are not typically ordered for evaluation of periprosthetic fracture in the setting of shoulder arthroplasty. Nevertheless, US is capable of detecting cortical discontinuity and step-off in the setting of a fracture post shoulder arthroplasty [52].

### **Variant 6: Evaluating primary shoulder arthroplasty patients with possible rotator cuff tear. Additional imaging following radiographs.**

The prevalence of rotator cuff tears after arthroplasty placement has been reported to be up to 1.3% [2]. Tears of the subscapularis tendon can present with clinical and radiographic signs of anterior shoulder instability, including varying degrees of anterior subluxation as well as frank dislocation of the humeral head component relative to the glenoid [5,8].

#### *Ultrasound*

US is a reliable option to evaluate rotator cuff tears in the setting of a shoulder arthroplasty [18]. As opposed to evaluation on MRI, there is no prosthesis-related artifact hindering visualization of the rotator cuff on US. Tears of the supraspinatus, infraspinatus, and subscapularis tendons can all be diagnosed with US, as can long-head biceps tendon and subacromial/subdeltoid bursal pathology [18]. US evaluation of the subscapularis tendon has been found to be more reliable than physical examination in the setting of prior tendon repair and arthroplasty placement [53]. A limiting factor is patient body habitus.

#### *Computed tomography*

The inherent limited tissue-contrast resolution of CT detracts from its ability to detect rotator cuff tears with or without shoulder arthroplasty. CT arthrography can be used to evaluate the rotator cuff and detect any associated pathology [8,54]. The technique, however, is inadequate in its ability to assess the extent of partial rotator cuff tears as well in identifying the exact location of the tear. The presence and degree of fatty muscle replacement can also be used as an indirect sign of a rotator cuff tear [55,56]. Administration of IV contrast does not improve evaluation.

#### *Magnetic resonance imaging*

MRI can be used to evaluate for rotator cuff tendon tearing in the setting of shoulder arthroplasty [15,16]. Advanced metal reduction techniques can reduce the prosthesis-related artifact and thus improve visualization of the rotator cuff tendons and any associated pathology [14,15]. Compared to the other imaging techniques, MRI can also provide a more global evaluation of the arthroplasty components as well as the surrounding soft tissues [14,15]. MRI with metal reduction techniques can also demonstrate failure of subscapularis tendon repair in the setting of arthroplasty, the most common location for rotator cuff pathology in this setting [15]. There are multiple techniques used to release the subscapularis tendon during arthroplasty placement, including tenotomy, osteotomy, and peel [8]. All of these techniques can predispose to loss of function and tearing of the subscapularis tendon and resultant pain and anterior instability, which can be difficult to diagnose on physical examination [8,53]. This underscores the importance of imaging in this setting. Administration of intra-articular contrast can improve the evaluation for partial-thickness articular-surface and full-thickness tears of the rotator cuff, although this is dependent on the degree of prosthesis-related artifact (and any reduction provided by advanced techniques). Administration of IV contrast does not significantly improve evaluation.

### *Bone scintigraphy*

Nuclear medicine examinations are not typically ordered for the evaluation of rotator cuff tendon abnormalities.

### **Variant 7: Evaluating primary shoulder arthroplasty patients with possible nerve injury. Additional imaging following radiographs.**

Nerve injuries in the setting of shoulder arthroplasty are relatively common, with a reported incidence of up to 4.3% for anatomic prostheses and up to 12% for reverse shoulder replacements [8]. The most common location for injury is the brachial plexus, followed by the axillary nerve and radial nerve [5].

### *Magnetic resonance imaging*

MRI can provide a direct evaluation of the brachial plexus as well as its branches as they course in the upper extremity [57,58]. Recent advances in MRI, including high-resolution neurography, can provide greater detail in the evaluation of these nerves, allowing for an earlier diagnosis [59,60]. Advanced metal reduction techniques can reduce the prosthesis-related artifact and thus improve visualization of the nerves in close proximity to the arthroplasty [14,15,54]. Similar to CT, MRI can demonstrate the typical findings of subacute and chronic denervation in the musculature, including muscle edema, fatty infiltration, and atrophy [61,62]. IV contrast is typically not necessary for imaging nerve disorders but can occasionally improve nerve visualization. Injured nerves have the potential to enhance on postcontrast imaging, as does acute and subacute denervated musculature.

### *Ultrasound*

US can provide a direct evaluation of the brachial plexus and its branches as well as the surrounding soft tissues [63-66]. The diagnosis of post-traumatic nerve injuries can be made using US, including stretch injuries, partial and complete transections, and neuromas [66]. As opposed to evaluation on MRI, there is no prosthesis-related artifact that would hinder visualization. A limiting factor is patient body habitus.

### *Computed tomography*

CT is limited in its ability to directly visualize the brachial plexus and its branches. Similar to radiographs, however, but with the advantage of cross-sectional imaging, CT can suggest a nerve injury when a bone or metallic fragment, a displaced prosthetic component, or hematoma are seen along the expected course of the shoulder nerves. CT can also show the typical findings of chronic denervation in the musculature, including fatty infiltration and atrophy [55,56]. The use of IV contrast does not typically improve evaluation of the nerve or musculature in this setting.

### *Bone scintigraphy*

Nuclear medicine examinations are not typically ordered for the evaluation of nerve injuries.

### **Summary of Recommendations**

- Radiographs should be the first study ordered for the evaluation of the symptomatic patient with a primary shoulder arthroplasty.
- Noncontrast CT, preferably with metal reduction software, should be the first study ordered when there is concern for loosening and/or periprosthetic fracture.
- Imaging-guided aspiration should be the first option when there is suspicion for septic arthritis. Additional imaging should be considered before aspiration to evaluate the surrounding soft tissues for signs of infection.
- If aspiration cannot be performed, an In-111 WBC/Tc-99m sulfur colloid scan should be considered.
- CT arthrography is a first-line imaging option to evaluate a patient with a suspected rotator cuff tear.
- US is a first-line imaging option to evaluate a patient with a suspected rotator cuff tear or nerve injury.
- MRI can be a useful examination to evaluate a patient with a suspected rotator cuff tear or nerve injury, although its value will depend on the use and quality of metal reduction applied during image acquisition.

### **Summary of Evidence**

Of the 66 references cited in the ACR Appropriateness Criteria® *Imaging After Total Shoulder Arthroplasty* document, 52 are categorized as diagnostic references including 1 well designed study, 3 good quality studies, and 11 quality studies that may have design limitations. Additionally, 14 references are categorized as therapeutic references including 5 good quality studies, and 1 quality study that may have design limitations. There are 45 references that may not be useful as primary evidence.

The 66 references cited in the ACR Appropriateness Criteria® *Imaging After Total Shoulder Arthroplasty* document were published from 1976-2015.

While there are references that report on studies with design limitations, 9 well designed or good quality studies provide good evidence.

### 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, both because of 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 to 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.

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”.

### Supporting Documents

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

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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.