American College of Radiology
ACR Appropriateness Criteria®

Imaging After Shoulder Arthroplasty

Variant: 1 Routine follow-up of the asymptomatic patient with a primary shoulder arthroplasty.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography shoulder	Usually Appropriate	☢
US shoulder	Usually Not Appropriate	O
MRI shoulder without and with IV contrast	Usually Not Appropriate	O
MRI shoulder without IV contrast	Usually Not Appropriate	O
3-phase bone scan with SPECT or SPECT/CT shoulder	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	☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢

Variant: 2 Symptomatic patient with a primary shoulder arthroplasty. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography shoulder	Usually Appropriate	☢
US shoulder	Usually Not Appropriate	O
MRI shoulder without and with IV contrast	Usually Not Appropriate	O
MRI shoulder without IV contrast	Usually Not Appropriate	O
3-phase bone scan with SPECT or SPECT/CT shoulder	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	☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢

Variant: 3 Symptomatic patient with a primary shoulder arthroplasty, infection not excluded. Additional imaging following radiographs.

Procedure	Appropriateness Category	Relative Radiation Level
Image-guided aspiration shoulder	Usually Appropriate	Varies
US shoulder	May Be Appropriate	O
MRI shoulder without and with IV contrast	May Be Appropriate	O
MRI shoulder without IV contrast	May Be Appropriate (Disagreement)	O
3-phase bone scan and WBC scan and sulfur colloid scan shoulder	May Be Appropriate	☢☢☢☢
3-phase bone scan and WBC scan and sulfur colloid scan with SPECT or SPECT/CT shoulder	May Be Appropriate	☢☢☢☢
WBC scan and sulfur colloid scan shoulder	May Be Appropriate (Disagreement)	☢☢☢☢

3-phase bone scan with SPECT or SPECT/CT shoulder	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	☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢

Variant: 4 Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected loosening. Additional imaging following radiographs.

Procedure	Appropriateness Category	Relative Radiation Level
MRI shoulder without IV contrast	Usually Appropriate	O
CT shoulder without IV contrast	Usually Appropriate	☢☢☢
US shoulder	May Be Appropriate (Disagreement)	O
3-phase bone scan with SPECT or SPECT/CT shoulder	May Be Appropriate	☢☢☢
MRI shoulder without and with IV contrast	Usually Not Appropriate	O
Bone scan shoulder	Usually Not Appropriate	☢☢☢
CT shoulder with IV contrast	Usually Not Appropriate	☢☢☢
CT shoulder without and with IV contrast	Usually Not Appropriate	☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢

Variant: 5 Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected rotator cuff tear or other soft tissue abnormality. Additional imaging following radiographs.

Procedure	Appropriateness Category	Relative Radiation Level
US shoulder	Usually Appropriate	O
MRI shoulder without IV contrast	Usually Appropriate	O
CT arthrography shoulder	Usually Appropriate	☢☢☢☢
MRI shoulder without and with IV contrast	Usually Not Appropriate	O
3-phase bone scan with SPECT or SPECT/CT shoulder	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	☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢

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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 [1,2]. 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 osteoarthrosis. Hemiarthroplasties are typically performed in patients with osteoarthrosis 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 because they require a shorter intraoperative time compared with total shoulder arthroplasty. Presently, total shoulder arthroplasty is recommended over hemiarthroplasty for advanced shoulder osteoarthrosis 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 [3,4]. 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 [4]. The construct moves the center of rotation medial and distal, which allows the deltoid muscle to serve as a main stabilizer of the arthroplasty and joint [4]. Additionally, the more medial and distal center of rotation decreases the risk of glenoid loosening [4,5].

The complication rate for shoulder arthroplasties has been reported to be as high as 39.8%, with revision rates up to 11% [6]. 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 [3]. 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 [6]. 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 [7]. The most common complications associated with reverse total shoulder arthroplasties are scapular notching, dislocation, periprosthetic fractures, glenoid baseplate failure, and acromial fractures [8,9].

Symptoms related to postoperative difficulties include activity-related pain, decreased range of motion, and apprehension. Some patients report immediate and persistent dissatisfaction, although others report a symptom-free postoperative period followed by increasing pain and decreasing shoulder function and mobility [10].

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

Special Imaging Considerations

Arthrography: Arthrography, using only radiographic or fluoroscopic images, had previously been utilized for detecting rotator cuff tears in the setting of shoulder arthroplasty. Because of its inability to assess muscle quality, gradation of partial tearing, and differentiate between the torn rotator cuff tendons, conventional radiographic arthrography has mostly been supplanted by cross-sectional imaging techniques such as CT arthrography, MR arthrography, and ultrasound (US).

Nuclear Medicine: The use of nuclear medicine in the evaluation of complications after arthroplasty has been limited to the evaluation of hip and knee arthroplasties. Because of limited literature on shoulder arthroplasties, these same physiologic principles can be applied to shoulder arthroplasties, and radionuclide imaging is not limited by metallic hardware [11].

Tc-99m-methylene diphosphonate (MDP) bone scans are useful in assessing shoulder arthroplasties, especially with normal radiographs and persistent concern for aseptic loosening, osteomyelitis, or periprosthetic fractures. Unfortunately, the specificity of bone scans is low, and new bone formation can also be seen in normal or abnormal postoperative bony remodeling and neuropathic arthropathy in addition to acute fractures, periprosthetic infection, or aseptic prosthetic loosening.

Typical bone scans are either a single or a 3-phase study. The standard single-phase bone scan involves imaging 2 to 3 hours after MDP administration. The 3-phase bone scan consists of a 1-minute radionuclide angiogram followed by immediate blood pool images and 2- to 3-hour delayed views. The 3-phase scan can be helpful in the assessment of acute fracture and differentiating acute osteomyelitis from cellulitis.

A positive 3-phase bone scan is often seen in neuropathic arthropathy. The use of radiolabeled white blood cells (WBC) with In-111 in conjunction with bone marrow imaging, utilizing Tc-99m sulfur colloid, can help to differentiate neuropathic reactive bone marrow from acute osteomyelitis. Serial bone scans can also assist in assessing postoperative bone remodeling and periprosthetic fracture from aseptic periprosthetic loosening.

The value of WBC and marrow imaging is not only to differentiate neuropathic arthropathy from acute osteomyelitis but also to differentiate aseptic loosening from acute osteomyelitis. Like neuropathic arthropathy, aseptic loosening will demonstrate spatially congruent WBC and marrow activity, consistent with reactive or hematopoietically active marrow.

However, in acute osteomyelitis, In-111-labeled WBCs will accumulate, and the marrow uptake will be suppressed, resulting in photopenia on sulfur colloid marrow scan, which is spatially incongruent with the WBC activity. This marrow suppression is a result of the acute infection, which destroys the marrow’s phagocytes, and, hence, the uptake of the marrow agent. Therefore, studies demonstrating WBC activity in the absence of corresponding marrow activity is consistent with osteomyelitis [11].

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 wherein each procedure provides unique clinical information to effectively manage the patient's care).

Discussion of Procedures by Variant

Variant 1: Routine follow-up of the asymptomatic patient with a primary shoulder arthroplasty.

Variant 1: Routine follow-up of the asymptomatic patient with a primary shoulder arthroplasty.
A. 3-phase bone scan with SPECT or SPECT/CT shoulder

A 3-phase bone scan is not typically ordered for evaluation of the asymptomatic patient. Although, single-photon emission computed tomography (SPECT)/CT can assess the primary osseointegration of a stemless shoulder prosthesis in the recent postoperative state [12].

Variant 1: Routine follow-up of the asymptomatic patient with a primary shoulder arthroplasty.
B. Bone scan shoulder

There is no relevant literature to support the use of a bone scan of the shoulder in the follow-up of the asymptomatic patient with a primary shoulder arthroplasty.

Variant 1: Routine follow-up of the asymptomatic patient with a primary shoulder arthroplasty.
C. CT shoulder

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

Variant 1: Routine follow-up of the asymptomatic patient with a primary shoulder arthroplasty.
D. Fluoride PET/CT skull base to mid-thigh

There is no relevant literature to support the use of fluoride PET/CT skull base to mid-thigh in the follow-up of the asymptomatic patient with a primary shoulder arthroplasty.

Variant 1: Routine follow-up of the asymptomatic patient with a primary shoulder arthroplasty.
E. MRI shoulder

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

Variant 1: Routine follow-up of the asymptomatic patient with a primary shoulder arthroplasty.
F. Radiography shoulder

Radiography is the first and main imaging modality utilized in the evaluation of shoulder arthroplasty [10,13]. Radiographs are typically ordered within 3 to 6 weeks after surgery and consist of 2 to 4 projections, depending on the surgeon's preference. These may include anterior-posterior, anterior-posterior Grashey, scapular Y, and axillary views [10,13]. Intraoperative and immediate postoperative radiographs are also ordered by some surgeons, but their benefit, without a specific indication, has been questioned because of limitations inherent to the portable nature of the examination, patients' difficulties in cooperating with the various views, and low impact on overall patient care [14]. 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 postsurgery. The routine use of radiographic imaging in the first postoperative year in asymptomatic patients has been called into question in a 2017 assessment [15].

Radiographs are also typically ordered for yearly follow-up examinations to assess interval changes in the bone surrounding the prosthesis [16]. The presence of scapular notching on postoperative radiographs of reverse total shoulder prostheses has been associated with poor clinical outcomes [17]. 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 [18]. 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 [10].

Variant 1: Routine follow-up of the asymptomatic patient with a primary shoulder arthroplasty.
G. US shoulder

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

Variant 2: Symptomatic patient with a primary shoulder arthroplasty. Initial imaging.

A symptomatic primary shoulder arthroplasty has a wide variety of potential etiologies that includes loosening, infection, periprosthetic fracture, and rotator cuff tear. 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% [6]. 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 significant risk factors [10,19]. 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 [4].

Variant 2: Symptomatic patient with a primary shoulder arthroplasty. Initial imaging.
A. 3-phase bone scan with SPECT or SPECT/CT shoulder

There is no relevant literature to support the use of a 3-phase bone scan with SPECT or SPECT/CT as a first-line imaging modality in the acutely symptomatic patient with a primary shoulder arthroplasty. Similar to bone scans, a 3-phase bone scan is highly sensitive for the detection of periprosthetic fractures but suffers from low specificity. Acute periprosthetic fractures are often 3-phase bone scan positive and demonstrate focal increased activity at the fracture site, which decreases over time, corresponding to fracture healing. Fracture hyperemia also typically resolves with the acute/subacute phases. The addition of SPECT or SPECT/CT improves diagnosis by allowing more accurate anatomical localization of new bone formation [20]. The specificity of Tc-99m bone scans for periprosthetic fractures increases in older prostheses once postoperative remodeling has decreased.

Variant 2: Symptomatic patient with a primary shoulder arthroplasty. Initial imaging.
B. Bone scan shoulder

There is no relevant literature to support the use of a bone scan as a first-line imaging modality in the acutely symptomatic patient with a primary shoulder arthroplasty. Tc-99m single- and 3-phase bone scans are very sensitive but with low specificity in the diagnosis of post arthroplasty fractures, and imaging findings can overlap with other abnormalities such as loosening and infection [21]. Without a radionuclide angiogram and blood pool phase, the single-phase bone scan will not depict the acute peri fracture hyperemia. Acute periprosthetic fractures are often 3-phase bone scan positive and demonstrate focal increased activity at the fracture site, which decreases over time, corresponding to fracture healing. Fracture hyperemia also typically resolves with the acute/subacute phases. Uncomplicated fracture healing may take up to 2 years before a bone scan normalizes [21,22]. In addition, increased bone uptake can be seen at the site of arthroplasty, related to postoperative bone remodeling for up to 1 year following surgery, which can further complicate matters [21]. The specificity of Tc-99m bone scan imaging for periprosthetic fracture increases in older prostheses once the postoperative remodeling has decreased and stabilized.

Variant 2: Symptomatic patient with a primary shoulder arthroplasty. Initial imaging.
C. CT shoulder

CT is not typically ordered for the initial evaluation of a symptomatic shoulder arthroplasty. CT with metal reduction protocol can be subsequently used to detect loosening and 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 [23].

Variant 2: Symptomatic patient with a primary shoulder arthroplasty. Initial imaging.
D. Fluoride PET/CT skull base to mid-thigh

There is no relevant literature to support the use of fluoride PET/CT as a first-line imaging modality in the acutely symptomatic patient with a primary shoulder arthroplasty.

Variant 2: Symptomatic patient with a primary shoulder arthroplasty. Initial imaging.
E. MRI shoulder

MRI is not typically ordered for the initial evaluation of a symptomatic shoulder arthroplasty but, in the opinion of the committee, 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. MRI also well delineates soft-tissue abnormalities in the setting of infection and rotator cuff injury.

Variant 2: Symptomatic patient with a primary shoulder arthroplasty. Initial imaging.
F. Radiography shoulder

Radiography is the first and main imaging modality utilized in the evaluation of both the symptomatic and asymptomatic shoulder arthroplasty [10,13]. Findings on radiographs can be used to diagnose and guide further assessment of both osseous and high-grade rotator cuff abnormalities. Radiographs are particularly helpful for the detection of scapular fractures that can occur with relatively minor trauma in patients with reverse shoulder prostheses [24].

Variant 2: Symptomatic patient with a primary shoulder arthroplasty. Initial imaging.
G. US shoulder

US examinations are not typically ordered as a first-line study for evaluation of pain in the setting of shoulder arthroplasty. Nevertheless, US provides assessment of the rotator cuff integrity and is capable of detecting cortical discontinuity and step-off in the setting of a fracture after shoulder arthroplasty [25].

Variant 3: Symptomatic patient with a primary shoulder arthroplasty, infection not excluded. 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% to 2.9%. Infection is more common in males and a younger age group [3,26,27]. A 97% infection-free rate at 20 years has been reported [28]. Predisposing underlying conditions may include rheumatoid arthritis, corticosteroid use, diabetes, repeated intra-articular steroid injections, and prior shoulder surgery [26].

Infection rates are higher in the setting of reverse total shoulder arthroplasties, with a range of 0.8% to 10% [29]. 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 [29].

Variant 3: Symptomatic patient with a primary shoulder arthroplasty, infection not excluded. Additional imaging following radiographs.
A. 3-phase bone scan and WBC scan and sulfur colloid scan shoulder

For infection imaging, In-111-labeled WBC with a Tc-99m sulfur colloid bone marrow study is a sensitive and specific test for acute osteomyelitis. An isolated In-111 WBC study is a sensitive but nonspecific technique for the evaluation of acute neutrophilic dominant periprosthetic infection [11]. Its specificity can be increased when interpreted in conjunction with a Tc-99m sulfur colloid study or, less optimally, a bone scan, which may not be indicated if both In-111 WBC and sulfur colloid studies have been performed [11,30].

Tc-99m 3-phase bone scan is a highly sensitive modality for identifying osteolysis and increased osteoblastic activity from postoperative bony remodeling, aseptic loosening, acute osteomyelitis, and periprosthetic fractures. The specificity of bone scans increases in older prostheses once postoperative remodeling has stabilized. Concordant increased labeled WBC and marrow activity is consistent with reactive marrow seen in postoperative change, aseptic loosening, and fractures. Postoperative change and fracture healing tend to decrease over time. Fracture confirmation can also be identified with anatomic imaging (eg, radiographs, CT with metal artifact reduction techniques). Normal uncomplicated postoperative change tends to decrease over time and up to 2 years or longer after surgery [21,22], whereas aseptic loosening generally tends to progress. Discordant activity of increased labeled WBC and a photopenic bone marrow is consistent with acute osteomyelitis.

Variant 3: Symptomatic patient with a primary shoulder arthroplasty, infection not

excluded. Additional imaging following radiographs.
B. 3-phase bone scan and WBC scan and sulfur colloid scan with SPECT or SPECT/CT shoulder

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 [30].

Tc-99m 3-phase bone scan is a highly sensitive modality for the detection of acute osteomyelitis in the setting of normal radiographs but remains low in specificity because the imaging findings can overlap with other abnormalities such as mechanical loosening and osteolysis [30]. In addition, increased bone uptake can be seen at the site of arthroplasty, related to postoperative bone remodeling, for up to 1 year following surgery [30]. A bone scan is also limited in its ability to assess the periprosthetic soft tissues for the presence of an abscess.

The addition of a bone scan SPECT/CT improves contrast resolution and anatomic localization of radiopharmaceutical uptake and provides a limited CT in the area of concern. A blood pool SPECT/CT over the targeted clinical area can be obtained immediately after the static blood pool images and further localizes foci of hyperemia [31-33]. At 2 to 3 hours after radiopharmaceutical administration and the standard bone scan images, a second SPECT/CT over the area(s) of interest can localize new bone formation [30] but remains nonspecific. A positive 3-phase bone scan can be seen in periprosthetic infection, periprosthetic fracture, and in the early postoperative state. Postoperative change and fracture healing tend to decrease over time. Fracture confirmation can also be identified with anatomic imaging (eg, radiographs, CT with metal artifact reduction techniques). Normal uncomplicated postoperative change tends to decrease over time and up to 2 years or longer after surgery [21,22], whereas aseptic loosening generally tends to progress. The specificity of bone scans increases in older prostheses once the postoperative remodeling has stabilized.

For infection imaging, In-111-labeled WBC with a Tc-99m sulfur colloid bone marrow study are sensitive and specific for acute osteomyelitis. An isolated In-111 WBC study is a sensitive but nonspecific technique for the evaluation of acute neutrophilic dominant periprosthetic infection [11]. Its specificity can be increased when interpreted in conjunction with a Tc-99m sulfur colloid study or, less optimally, a bone scan which may not be indicated if both In-111 WBC and sulfur colloid studies have been performed [11,30]. However, a positive 3-phase bone scan can be used as a “road map” to identify abnormal bone, which can then be specifically addressed on the subsequent labeled WBC and marrow studies.

The addition of SPECT/CT with the In-111 WBC and sulfur colloid scans increases contrast resolution and anatomic localization of radiopharmaceutical activity. Utilizing subtraction imaging on the SPECT/CT studies (subtracting the sulfur colloid from WBC images) can identify whether an area of concern on the bone scan is concordant with similar increased WBC and marrow activity (reactive marrow) or discordant (WBC activity with absent sulfur colloid activity), the latter consistent with an acute pyogenic process/osteomyelitis.

Variant 3: Symptomatic patient with a primary shoulder arthroplasty, infection not excluded. Additional imaging following radiographs.
C. 3-phase bone scan with SPECT or SPECT/CT shoulder

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 [30].

Tc-99m 3-phase bone scan is a highly sensitive modality for the detection of acute osteomyelitis 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 [30]. In addition, increased bone uptake can be seen at the site of arthroplasty, related to postoperative bone remodeling, for up to 1 year following surgery [30]. A bone scan is also limited in its ability to assess the periprosthetic soft tissues for the presence of an abscess.

The addition of SPECT or SPECT/CT improves anatomic localization of new bone formation [20] but remains nonspecific. A positive 3-phase bone scan can be seen in periprosthetic infection, periprosthetic fracture, and in the early postoperative state. Postoperative change and fracture healing tend to decrease over time. Fracture confirmation can also be identified with anatomic imaging (eg, radiographs, CT with metal artifact reduction techniques). Normal uncomplicated postoperative change tends to decrease over time and up to 2 years or longer after surgery [21,22], whereas aseptic loosening generally tends to progress. The specificity of bone scans increases in older prostheses once the postoperative remodeling has stabilized.

Variant 3: Symptomatic patient with a primary shoulder arthroplasty, infection not excluded. Additional imaging following radiographs.
D. Image-Guided Aspiration Shoulder

Aspiration of the shoulder should be performed 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. Imaging-guided aspiration procedures provide a minimally invasive means to sample fluid from the joint suspected of infection [34,35]. Shoulder joint aspiration has been shown to have a sensitivity of 33% and specificity of 98% [36]. Shoulder aspiration can be completed with the use of fluoroscopy, US, and CT guidance. MR guidance is possible but rarely utilized. Arthrography can be 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 [34].

Variant 3: Symptomatic patient with a primary shoulder arthroplasty, infection not excluded. Additional imaging following radiographs.
E. Bone Scan Shoulder

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 [30].

The standard Tc-99m bone scan is a sensitive modality for the identification of abnormal bone in acute osteomyelitis, particularly in the setting of normal radiographs. However, the 3-phase bone scan is often preferred to assess for associated hyperemia in acute fracture and acute osteomyelitis. Bone scans remain low in specificity as the imaging findings can overlap with other abnormalities, such as mechanical loosening with osteolysis [30], periprosthetic fracture, and postarthroplasty bone remodeling, which can be seen up to 1 year following surgery [30]. Postoperative change and fracture healing tend to decrease over time. Fracture confirmation can also be identified with anatomic imaging (eg, radiographs, CT with metal artifact reduction techniques). Normal uncomplicated postoperative change tends to decrease over time and up to 2 years or longer after surgery [21,22], whereas aseptic loosening generally tends to progress. The specificity of bone scans for periprosthetic fracture or infection increases in older prostheses once the postoperative remodeling has stabilized.

Variant 3: Symptomatic patient with a primary shoulder arthroplasty, infection not excluded. Additional imaging following radiographs.
F. CT Shoulder

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 [3]. CT may play a more important role after removal of the hardware and debridement in a patient with infection because it can help quantify the amount of remaining bone that can be used for revision arthroplasty [3]. CT can also be used to evaluate the surrounding soft tissues for infection and to aid in planning before image-guided joint aspiration. Administration of intravenous (IV) contrast improves the evaluation of adjacent soft-tissue fluid collections/abscesses and sinus tracts.

Variant 3: Symptomatic patient with a primary shoulder arthroplasty, infection not excluded. Additional imaging following radiographs.
G. Fluoride PET/CT skull base to mid-thigh

There is no relevant literature to support the use of fluoride PET/CT for the next imaging study of a symptomatic patient with a primary shoulder arthroplasty when infection has been not excluded.

Variant 3: Symptomatic patient with a primary shoulder arthroplasty, infection not excluded. Additional imaging following radiographs.
H. MRI Shoulder

MRI with metal reduction protocols can play a useful role in the diagnosis [37,38] and assessment of periprosthetic infection, particularly when other modalities fail to confirm the clinical suspicion of infection. MRI can demonstrate osseous and soft-tissue abnormalities associated with periprosthetic infection [28,39]. 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.

Variant 3: Symptomatic patient with a primary shoulder arthroplasty, infection not excluded. Additional imaging following radiographs.
I. US shoulder

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 [40-42], 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 before image-guided joint aspiration in order to avoid seeding of a sterile joint effusion from overlying soft-tissue infection.

Variant 3: Symptomatic patient with a primary shoulder arthroplasty, infection not

excluded. Additional imaging following radiographs.
J. WBC scan and sulfur colloid scan shoulder

For infection imaging, In-111 WBC imaging in conjunction with Tc-99m sulfur colloid marrow imaging is a sensitive and specific test. An isolated In-111-labeled WBC study is a sensitive but nonspecific technique for the evaluation of acute neutrophilic dominant periprosthetic infection [11]. 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 In-111 WBC and sulfur colloid imaging have been performed [11,21,30].

Variant 4: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected 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 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. Osteolysis can cause extensive, often asymptomatic, bone loss [43-45]. 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 [23,46].

Variant 4: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected loosening. Additional imaging following radiographs.
A. 3-phase bone scan with SPECT or SPECT/CT shoulder

Tc-99m 3-phase bone scan is a highly sensitive modality for the detection of acute osteomyelitis in the setting of normal radiographs but remains low in specificity because the imaging findings can overlap with other abnormalities, such as mechanical loosening with osteolysis and periprosthetic fracture [30]. In addition, increased bone uptake can be identified at the site of arthroplasty, related to postoperative bone remodeling, and seen for up to 1 year following surgery [30].

The addition of SPECT or SPECT/CT improves anatomic localization of active bone remodeling [20], however, remains nonspecific. A positive 3-phase bone scan can be seen in the early postoperative state, periprosthetic fracture, aseptic prosthetic loosening, and periprosthetic infection. Postoperative change and fracture healing tend to decrease over time. Fracture confirmation can also be identified with anatomic imaging (eg, radiographs, CT with metal artifact reduction techniques). SPECT/CT also has the potential to differentiate symptomatic from asymptomatic scapular notching associated with reverse shoulder prostheses [30]. Normal uncomplicated postoperative change tends to decrease over time and up to 2 years or longer after surgery [21,22], whereas aseptic loosening generally tends to progress. The specificity of bone scans for periprosthetic complications increases in older prostheses once the postoperative remodeling has stabilized.

Variant 4: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected loosening. Additional imaging following radiographs.
B. Bone scan shoulder

Tc-99m single-phase bone scan imaging is a sensitive modality for the diagnosis of loosening in the setting of normal radiographs but remains low in specificity because the imaging findings can overlap with other abnormalities such as postoperative bone remodeling, periprosthetic fracture, and infection [30]. Normal uncomplicated increased periprosthetic uptake related to postoperative bone remodeling tends to decrease over time and up 2 years or longer after surgery [21,30], whereas aseptic loosening generally tends to progress. The specificity of bone scans for periprosthetic fracture, loosening, or infection increases in older prostheses once the postoperative remodeling has stabilized.

Variant 4: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected loosening. Additional imaging following radiographs.
C. CT shoulder

CT plays an important role in the imaging evaluation of a patient with potential loosening that may be missed or incompletely evaluated with radiographs [10,47]. CT provides a better means of evaluating the hardware components and surrounding bone stock [48]. CT can also assess changes in component alignment over time [49]. Image degradation can occur because of 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 [50-52]. Furthermore, dual-energy CT, employing virtual noncalcium software, may provide useful information regarding the presence of marrow edema [53]. CT can also be used to evaluate the bone density around prostheses, which may be predictive of loosening [54].

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 benefit of CT in patients with postoperative complications. In a few reports, each including a small group of patients, CT compared with 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 [10,47,55]. Evaluation of bone graft resorption remains limited on CT because of metal artifact [56]. Dual-energy CT 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 [53]. The addition of intra-articular or IV contrast does not typically improve evaluation [57].

Variant 4: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected loosening. Additional imaging following radiographs.
D. Fluoride PET/CT skull base to mid-thigh

There is no relevant literature to support the use of fluoride PET/CT after radiographs in a symptomatic patient with a primary shoulder arthroplasty and infection was excluded.

Variant 4: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected loosening. Additional imaging following radiographs.
E. MRI shoulder

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, and, in the presence of hemiarthroplasty, glenoid cartilage wear [37-39,58].

Because of developments in metal reduction protocols for MRI and research studies showing the benefit of MRI, it can be effective in the evaluation of aseptic loosening [37-39].

Variant 4: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected loosening. Additional imaging following radiographs.
F. US shoulder

US is limited in the ability to evaluate bone-related complications such as loosening [10].

Variant 5: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected rotator cuff tear or other soft tissue abnormality. Additional imaging following radiographs.

The prevalence of rotator cuff tears after arthroplasty placement has been reported to be up to 1.3% [3]. 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 [6,10].

Variant 5: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected rotator cuff tear or other soft tissue abnormality. Additional imaging following radiographs.
A. 3-phase bone scan with SPECT or SPECT/CT shoulder

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

Variant 5: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected rotator cuff tear or other soft tissue abnormality. Additional imaging following radiographs.
B. Bone scan shoulder

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

Variant 5: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected rotator cuff tear or other soft tissue abnormality. Additional imaging following radiographs.
C. CT arthrography shoulder

The inherent limited tissue-contrast resolution of CT detracts from its ability to detect rotator cuff tears. A CT arthrogram can be performed when there is suspicion of a rotator cuff tear [10]. CT arthrography can be an effective modality to evaluate the rotator cuff and detect any associated pathology [10,59]. The technique, however, is relatively weak in its ability to assess the extent of partial rotator cuff tears as well in identifying the exact location of the tear when compared with MRI. The presence and degree of fatty muscle replacement can also be used as an indirect sign of a rotator cuff tear [60,61]. Administration of IV contrast does not improve evaluation.

Variant 5: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected rotator cuff tear or other soft tissue abnormality. Additional imaging following radiographs.
D. CT shoulder

The inherent limited tissue-contrast resolution of CT detracts from its ability to detect rotator cuff tears. CT shows promise in assessing the location of the glenoid and humeral components of reverse shoulder prostheses in the setting of soft-tissue impingement [62]. Administration of IV contrast does not improve evaluation.

Variant 5: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected rotator cuff tear or other soft tissue abnormality. Additional imaging following radiographs.
E. Fluoride PET/CT skull base to mid-thigh

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

Variant 5: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected rotator cuff tear or other soft tissue abnormality. Additional imaging following radiographs.
F. MRI shoulder

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, and, in the presence of hemiarthroplasty, glenoid cartilage wear [37-39,58].

MRI can be used to evaluate for rotator cuff tendon tearing in the setting of shoulder arthroplasty [38,39]. Advanced metal reduction techniques can reduce the prosthesis-related artifact and thus improve visualization of the rotator cuff tendons and any associated pathology [37,38]. Compared with the other imaging techniques, MRI can also provide a more global evaluation of the arthroplasty components as well as the surrounding soft tissues [37,38]. 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 [38].

There are multiple techniques used to release the subscapularis tendon during arthroplasty placement, including tenotomy, osteotomy, and peel [10]. 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 [10,63]. 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.

Variant 5: Symptomatic patient with a primary shoulder arthroplasty, infection excluded. Suspected rotator cuff tear or other soft tissue abnormality. Additional imaging following radiographs.
G. US shoulder

US is a reliable option to evaluate rotator cuff tears in the setting of a shoulder arthroplasty [41]. 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 [41]. 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 [63]. Integrity of the subscapularis tendon after reverse shoulder prosthesis placement is also well assessed by US, although the clinical relevance of this integrity is currently unclear [64].

Summary of Recommendations

- **Variant 1**: Shoulder radiographs are usually appropriate for the routine follow-up of asymptomatic patients with a primary shoulder arthroplasty.
- **Variant 2**: Shoulder radiographs are usually appropriate for the initial imaging of

symptomatic patients with a primary shoulder arthroplasty.
- **Variant 3**: Following radiographs, image-guided shoulder aspiration is usually appropriate in patients with a primary shoulder arthroplasty when infection has not been excluded. In this setting, the panel did not agree on recommending MRI shoulder without IV contrast or WBC shoulder scan or sulfur colloid scan. There is insufficient medical literature to conclude whether or not these patients would benefit from these procedures. Imaging with these procedures is controversial in this patient population but may be appropriate.
- **Variant 4**: Following radiographs, MRI shoulder without IV contrast or CT shoulder without IV contrast is usually appropriate in patients with a primary shoulder arthroplasty when loosening is suspected and infection has been excluded. In this setting, the panel did not agree on recommending US of the shoulder. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure. Imaging with this procedure is controversial in this patient population but may be appropriate.
- **Variant** 5: Following radiographs, US shoulder or MRI shoulder without IV contrast or CT arthrography shoulder is usually appropriate in patients with a primary shoulder arthroplasty when a rotator cuff tear or other soft-tissue abnormality is suspected and infection has been excluded. 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, please go to the ACR website at https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria.

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.

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	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 (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

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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.

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