American College of Radiology
ACR Appropriateness Criteria®
Imaging After Shoulder Arthroplasty

Variant: 1 Adult. Asymptomatic shoulder prosthesis. Routine surveillance.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography shoulder	Usually Appropriate	☢
US shoulder	Usually Not Appropriate	O
Image-guided aspiration shoulder	Usually Not Appropriate	Varies
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	☢☢☢
3-phase bone scan and WBC scan and sulfur colloid scan shoulder	Usually Not Appropriate	☢☢☢☢
3-phase bone scan and WBC scan and sulfur colloid scan with SPECT or SPECT/CT shoulder	Usually Not Appropriate	☢☢☢☢
CT arthrography shoulder	Usually Not Appropriate	☢☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
WBC scan and sulfur colloid scan shoulder	Usually Not Appropriate	☢☢☢☢

Variant: 2 Adult. Symptomatic shoulder prosthesis. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography shoulder	Usually Appropriate	☢
US shoulder	Usually Not Appropriate	O
Image-guided aspiration shoulder	Usually Not Appropriate	Varies
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	☢☢☢
3-phase bone scan and WBC scan and sulfur colloid scan shoulder	Usually Not Appropriate	☢☢☢☢
3-phase bone scan and WBC scan and sulfur colloid scan with SPECT or SPECT/CT shoulder	Usually Not Appropriate	☢☢☢☢
CT arthrography shoulder	Usually Not Appropriate	☢☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
WBC scan and sulfur colloid scan shoulder	Usually Not Appropriate	☢☢☢☢

Variant: 3 Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography

performed. Next imaging study.

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

<u>Variant: 4</u> Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.

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

<u>Variant: 5</u> Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
US shoulder	Usually Appropriate	O
MRI shoulder without IV contrast	Usually Appropriate	O

CT arthrography shoulder	Usually Appropriate	☢☢☢☢
Image-guided aspiration shoulder	Usually Not Appropriate	Varies
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	☢☢☢
3-phase bone scan and WBC scan and sulfur colloid scan shoulder	Usually Not Appropriate	☢☢☢☢
3-phase bone scan and WBC scan and sulfur colloid scan with SPECT or SPECT/CT shoulder	Usually Not Appropriate	☢☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
WBC scan and sulfur colloid scan shoulder	Usually Not Appropriate	☢☢☢☢

Panel Members

Donna G. Blankenbaker, MD[a], Nicholas C. Nacey, MD[b], Cristy N. French, MD[c], Matthew A. Frick, MD[d], Ricardo D. Garza-Gongora, MD[e], Steven J. Hattrup, MD[f], Molly Kresin, DO[g], Mary Kristin Lowry, MD[h], Megan Mills, MD[i], Michael G. Fox, MD, MBA[j]

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, conventional total shoulder arthroplasty, and reverse total shoulder arthroplasty performed in the United States over the past 2 decades [1]. 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]. An estimated 193,500 arthroplasty procedures were performed nationwide in 2022 [3].

The ever-improving success rates of shoulder arthroplasty could be attributed to advancements in endoprosthesis design, improvements in the biomechanics of endoprosthetic components, and improvements in surgical techniques [4]. 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. 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 [5, 6]. 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 [6]. 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 [6].

The complication rate for shoulder arthroplasties has been reported to be as high as 68%, with revision rates up to 11% [2]. 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 [5]. The most common complication for hemiarthroplasties has been erosion of the unresurfaced glenoid (20.6%), whereas glenoid loosening (32%) has been reported as the most common complication for total shoulder arthroplasties [7]. The most common complications associated with reverse total shoulder arthroplasties are scapular notching, dislocation, periprosthetic fractures, glenoid baseplate failure, and scapular spine and acromion fractures [8, 9].

Special Imaging Considerations

Arthrography: Arthrography using only radiographic or fluoroscopic images has previously been used for detecting rotator cuff tears in the setting of shoulder arthroplasty. Because of its inability to assess muscle quality, determine 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 prostheses. Because of limited literature on shoulder arthroplasties, these same physiologic principles can be applied to shoulder prostheses, and radionuclide imaging is not limited by metallic hardware [10].

Tc-99m-methylene diphosphonate (MDP) bone scans are useful in assessing shoulder prostheses, 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, using 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 [10].

Single-photon emission computed tomography (SPECT)/CT and Tc-99m bisphosphonate bone scans have been used to detect periprosthetic infections. These methods are highly sensitive but lack specificity [4]. By combining the metabolic information of nuclear studies with cross-sectional anatomical CT imaging, SPECT/CT imaging has significantly enhanced our ability to detect infections. Tc-99m bisphosphonate SPECT/CT can accurately diagnose mechanical complications associated with shoulder arthroplasty. These include glenoiditis after hemiarthroplasty, loosening of the glenoid after shoulder arthroplasty, and notching of the scapula with reserve shoulder arthroplasty.

Fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT is used to identify cases of periprosthetic infections by detecting increased metabolic activity at the interface between the bone and prosthesis. Moreover, elevated FDG activity in the glenoid and humeral components and hypermetabolic axillary lymphadenopathy might indicate potential infection. Although FDG-PET is highly sensitive for detecting infected prostheses, its specificity is limited [4].

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:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.

The goal of imaging is to detect early complications following shoulder arthroplasty. This imaging information helps to initiate the appropriate treatment plan sooner, which can improve patient outcome by early detection of implant failure, infection, or other complications. The imaging information benefits the patient by reducing potential delay in appropriate treatment and improved outcomes.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
A. 3-phase bone scan and WBC scan and sulfur colloid scan shoulder

There is no relevant literature to support the use of a 3-phase bone scan and WBC scan and sulfur colloid scan of the shoulder in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
B. 3-phase bone scan and WBC scan and sulfur colloid scan with SPECT or SPECT/CT shoulder

There is no relevant literature to support the use of a 3-phase bone scan and WBC scan and sulfur colloid scan with SPECT or SPECT/CT of the shoulder in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
C. 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 SPECT/CT can assess the primary osseointegration of a stemless shoulder prosthesis in the recent postoperative state [18].

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
D. Bone scan shoulder

There is no relevant literature to support the use of a bone scan of the shoulder in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
E. CT arthrography shoulder

There is no relevant literature to support the use of CT arthrography of the shoulder in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
F. CT shoulder with IV contrast

There is no relevant literature to support the use of CT of the shoulder with IV contrast in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
G. CT shoulder without and with IV contrast

There is no relevant literature to support the use of CT of the shoulder without and with IV contrast in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
H. CT shoulder without IV contrast

There is no relevant literature to support the use of CT of the shoulder without IV contrast in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
I. 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 routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.

J. Image-guided aspiration shoulder

There is no relevant literature to support the use of imaging-guided shoulder aspiration in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
K. MRI shoulder without and with IV contrast

There is no relevant literature to support the use of MRI shoulder with and without intravenous (IV) contrast in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
L. MRI shoulder without IV contrast

There is no relevant literature to support the use of MRI shoulder without IV contrast in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
M. Radiography shoulder

Radiography is the most useful imaging modality in the evaluation of shoulder prostheses [11, 12]. 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 [11, 12]. 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 [13]. 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 [14].

Radiographs are also typically ordered for yearly follow-up examinations to assess interval changes in the bone surrounding the prosthesis [15]. The presence of scapular notching on postoperative radiographs of reverse total shoulder prostheses has been associated with poor clinical outcomes [16]. 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 [17]. Cranial humeral migration indicating failure of the rotator cuff, and progressive glenoid wear in hemiarthroplasty patients can be assessed. 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 [11].

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
N. US shoulder

There is no relevant literature to support the use of US of the shoulder in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 1:Adult. Asymptomatic shoulder prosthesis. Routine surveillance.
O. WBC scan and sulfur colloid scan shoulder

There is no relevant literature to support the use of WBC scan and sulfur colloid scan in the routine surveillance of the asymptomatic patient with a primary shoulder prosthesis.

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.

The goal of imaging is to detect early complications following shoulder arthroplasty in the painful shoulder. This imaging information helps to initiate the appropriate treatment plan sooner, which can improve patient outcome by early detection of implant failure, infection, periprosthetic fracture, or other complications. The imaging information benefits the patient by reducing potential delay in appropriate treatment and hastening patient recovery.

A symptomatic primary shoulder prosthesis 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% [19]. 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 [11, 20]. 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 [6].

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
A. 3-phase bone scan and WBC scan and sulfur colloid scan shoulder

There is no relevant literature to support the use of a 3-phase bone scan and WBC scan and sulfur colloid scan of the shoulder is not typically ordered for the initial evaluation of a symptomatic shoulder prosthesis.

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
B. 3-phase bone scan and WBC scan and sulfur colloid 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 prosthesis. 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 use of labeled WBCs scan paired with sulfur colloid bone imaging has shown high specificity and sensitivity and may be the preferred nuclear imaging modality for diagnosing prosthetic joint infection [4]. The addition of SPECT or SPECT/CT improves diagnosis by allowing more accurate anatomical localization of new bone formation [24]. SPECT/CT is a promising tool that combines morphologic and metabolic information for assessing mechanical bone stress. Therefore, early detection of stress reaction through SPECT/CT can help prevent stress fractures. The specificity of Tc-99m bone scans for periprosthetic fractures increases in older prostheses once postoperative remodeling has decreased.

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
C. 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 prosthesis. 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 [24]. SPECT/CT is a promising tool that combines morphologic and metabolic information for assessing mechanical bone stress. Therefore, early detection of stress reaction through SPECT/CT can help prevent stress fractures. The specificity of Tc-99m bone scans for periprosthetic fractures increases in older prostheses once postoperative remodeling has decreased.

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
D. 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 prosthesis. 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 [25]. Without a radionuclide angiogram and blood pool phase, the single-phase bone scan will not depict the acute perifracture 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 [25, 26]. 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 [25]. 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:Adult. Symptomatic shoulder prosthesis. Initial imaging.
E. CT arthrography shoulder

CT arthrography is not typically ordered for the initial evaluation of a symptomatic shoulder prosthesis. 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. Additionally, osseous integration around the prothesis can be assessed [29, 30].

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
F. CT shoulder with IV contrast

CT shoulder with IV contrast is not typically ordered for the initial evaluation of a symptomatic shoulder prosthesis.

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
G. CT shoulder without and with IV contrast

CT shoulder without and with IV contrast is not typically ordered for the initial evaluation of a symptomatic shoulder prosthesis.

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
H. CT shoulder without IV contrast

CT shoulder without IV contrast is not typically ordered for the initial evaluation of a symptomatic shoulder prosthesis. 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 [27]. Additionally, osseous integration around the prothesis can be assessed [28]. CT provides excellent detection in the evaluation of heterotopic ossification, which can impact patient outcomes [28, 29]. CT is more sensitive than radiography for detection and extent of radiolucent lines about the prothesis, which may be helpful if radiographs are negative and clinical suspicion persists [2]. CT is more sensitive in evaluating various bone lesions compared with radiography [2].

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
I. 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 is not typically ordered for the initial evaluation of a symptomatic shoulder prosthesis.

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
J. Image-guided aspiration shoulder

There is no relevant literature to support the use of image-guided aspiration of the shoulder as a first-line imaging technique in the acutely symptomatic patient with a primary shoulder prosthesis. If there is high clinical suspicion for an infected prosthesis, arthrocentesis should be performed for laboratory analysis of the fluid [2]. US guidance for performing arthrocentesis allows the identification of pockets of fluid and can minimize trauma associated with the procedure.

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
K. MRI shoulder without and with IV contrast

MRI shoulder without and with IV contrast is not typically ordered for the initial evaluation of a symptomatic shoulder prosthesis; however, it can play a contributory role when there is a concern for infection as MRI well delineates soft tissue abnormalities.

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
L. MRI shoulder without IV contrast

MRI shoulder without IV contrast is not typically ordered for the initial evaluation of a symptomatic shoulder prosthesis; however, it can play a contributory role when fractures are occult on radiographs and/or CT examinations. MRI metal reduction techniques and vendor-specific through plane artifact reduction sequences can help assess the periprosthetic bone. 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, neural injury, infection, and deltoid dysfunction [2].

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
M. Radiography shoulder

Radiography is the most useful modality in the evaluation of both the symptomatic and asymptomatic shoulder prostheses [11, 12]. Findings on radiographs can be used to diagnose and guide further assessment of both osseous and high-grade rotator cuff abnormalities. Standard radiographs can effectively demonstrate prosthesis loosening, cranial humeral migration—indicating failure of the rotator cuff—periprosthetic fractures (acute or stress related), and progressive glenoid wear in hemiarthroplasty patients [4]. Radiographs are particularly helpful

for the detection of scapula fractures that can occur with relatively minor trauma in patients with reverse shoulder prostheses [21].

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
N. 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 rotator cuff integrity, long head of the biceps tendon pathology and intraarticular infection, and US is capable of detecting cortex discontinuity and step-off in the setting of a fracture after shoulder arthroplasty [4, 22, 23]. Nerve damage is a relatively rare complication after arthroplasty and brachial plexopathy can occur, especially during placement of a reverse total shoulder prosthesis from stretching of the brachial plexus. MRI and/or US may be performed in the evaluation of fatty infiltration or injury of the deltoid muscle and the surrounding soft tissue structures [7].

Variant 2:Adult. Symptomatic shoulder prosthesis. Initial imaging.
O. WBC scan and sulfur colloid scan shoulder

There is no relevant literature to support the use of WBC scan and sulfur colloid scan of the shoulder is not typically ordered for the initial evaluation of a symptomatic shoulder prosthesis.

Variant 3:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.

The goals of imaging are to further evaluate for complications following shoulder arthroplasty. This imaging information helps to initiate the appropriate treatment plan sooner, which can improve patient outcome by early detection of infection or other complications such as implant failure or periprosthetic fracture. The imaging information benefits the patient by reducing potential delay in appropriate treatment and hastening patient recovery.

Infection, including osteomyelitis and septic arthritis, after total shoulder arthroplasty is an uncommon, though albeit a potentially devastating complication, with a prevalence of 0.7% to 2.9%. Infection is more common in males and a younger age group [5, 31, 32]. A 97% infection-free rate at 20 years has been reported [33]. Predisposing underlying conditions may include rheumatoid arthritis, corticosteroid use, diabetes, repeated intraarticular steroid injections, and prior shoulder surgery [31].

Infection rates are higher in the setting of reverse total shoulder prostheses, with a range of 0.8% to 10% [34]. 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 [34].

Variant 3:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.
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 [10]. 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 [10, 44].

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 [25, 26], 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:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.
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 prostheses, but various clinical studies anecdotally suggest using this modality in shoulder prostheses [44].

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 [44]. In addition, increased bone uptake can be seen at the site of the prosthesis, related to postoperative bone remodeling, for up to 1 year following surgery [44]. 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 [45-47]. 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 [44], 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 [25, 26], 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 is a 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 [10]. 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 [10, 44]. 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. Using 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:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.
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 prostheses, but various clinical studies anecdotally suggest using this modality in shoulder prostheses [44].

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 [44]. In addition, increased bone uptake can be seen at the site of the prosthesis, related to postoperative bone remodeling, for up to 1 year following surgery [44]. 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 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 [25, 26], whereas aseptic loosening generally tends to progress. The specificity of bone scans increases in older prostheses once the postoperative remodeling has stabilized.

Variant 3:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.
D. Bone scan shoulder

The use of nuclear imaging for the evaluation of periprosthetic infection has been limited to the evaluation of hip and knee protheses, but various clinical studies anecdotally suggest using this modality in shoulder prostheses [44].

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 [44], periprosthetic fracture, and post arthroplasty bone remodeling, which can be seen up to 1 year following surgery [44]. 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 [25, 26], 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:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.
E. CT arthrography shoulder

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

Variant 3:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.
F. CT shoulder with IV contrast

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 [5]. 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 [5]. 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 IV contrast improves the evaluation of adjacent soft tissue fluid collections/abscesses and sinus tracts.

Variant 3:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.
G. CT shoulder without and with IV contrast

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 [5]. 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 [5]. 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 IV contrast improves the evaluation of adjacent soft tissue fluid collections/abscesses and sinus tracts. This technique is typically not performed for this clinical scenario.

Variant 3:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.
H. CT shoulder without IV contrast

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 [5]. 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 [5]. 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 IV contrast improves the evaluation of adjacent soft tissue fluid collections/abscesses and sinus tracts.

Variant 3:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.

I. 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 for the next imaging study of a symptomatic patient with a primary shoulder prosthesis when infection has been not excluded [48].

Variant 3:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.

J. Image-guided aspiration shoulder

Image-guided aspiration of the shoulder in a patient with a symptomatic shoulder prosthesis when infection is not excluded can aid in making the diagnosis of joint infection [2, 38]. Synovial fluid profile, which includes elevated synovial neutrophil percentage, WBC count, and alpha defensin level is seen with periprosthetic joint injection along with elevated erythrocyte sedimentation rate and C-reactive protein [39, 40]. US, CT, MRI, or fluoroscopic guidance can be used to access the joint. The suspicion of infection should be increased in the presence of radiographic findings suggestive of humeral or glenoid component loosening. Aspiration and culture of fluid from the glenohumeral joint are recommended to exclude infection in cases where loosening is encountered [4].

Variant 3:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.

K. MRI shoulder without and with IV contrast

MRI with metal reduction protocols can play a useful role in the diagnosis [41, 42] and assessment of periprosthetic infection, particularly when other modalities fail to confirm the clinical suspicion of infection [40]. MRI can demonstrate osseous and soft tissue abnormalities associated with periprosthetic infection [33, 43]. 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:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.

L. MRI shoulder without IV contrast

MRI with metal reduction protocols can play a useful role in the diagnosis [41, 42] and assessment of periprosthetic infection, particularly when other modalities fail to confirm the clinical suspicion of infection [40]. MRI can demonstrate osseous and soft tissue abnormalities associated with periprosthetic infection [33, 43]. 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:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.

M. 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 [35-37], which may need aspiration with laboratory cultures 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:Adult. Symptomatic shoulder prosthesis. Infection not excluded. Radiography performed. Next imaging study.
N. 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 [10]. 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 [10, 25, 44].

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.

The goal of imaging is to detect loosening of the shoulder prosthesis as a source of shoulder pain. This imaging information helps to initiate the appropriate treatment plan sooner, which can improve patient outcome by reducing immobility. The imaging information benefits the patient by reducing potential delay in appropriate treatment and hastening patient recovery.

Aseptic loosening is used to describe a hardware abnormality that results from a noninfectious etiology. Loosening is the most common complication of all total shoulder arthroplasties (39%) with loosening of the glenoid component (32%) more common than loosening of the humeral component (7%) [7]. 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 polyethylene, cement, and/or metallic elements. Osteolysis can cause extensive, often asymptomatic, bone loss [49-52]. 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 [27, 53].

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
A. 3-phase bone scan and WBC scan and sulfur colloid scan 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 periprosthestic fracture [44]. 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 [44]. A bone scan is also limited in its ability to assess the periprosthetic soft tissues for the presence of an abscess.

For infection imaging, In-111-labeled WBC with a Tc-99m sulfur colloid bone marrow study is a 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 [10]. 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 [10, 44]. 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 or SPECT/CT improves anatomic localization of active bone remodeling; 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 [44]. Normal uncomplicated postoperative change tends to decrease over time and up to 2 years or longer after surgery [25, 26], 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:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
B. 3-phase bone scan and WBC scan and sulfur colloid 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 periprosthestic fracture [44]. 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 [44]. A bone scan is also limited in its ability to assess the periprosthetic soft tissues for the presence of an abscess.

For infection imaging, In-111-labeled WBC with a Tc-99m sulfur colloid bone marrow study is a 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 [10]. 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 [10, 44]. 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 or SPECT/CT improves anatomic localization of active bone remodeling; 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 [44]. Normal uncomplicated postoperative change tends to decrease over time and up to 2 years or longer after surgery [25, 26], 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.

The addition of SPECT/CT with the In-111 WBC and sulfur colloid scans increases contrast resolution and anatomic localization of radiopharmaceutical activity. Using 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 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
C. 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 as the imaging findings can overlap with other abnormalities such as mechanical loosening and osteolysis [44]. In addition, increased bone uptake can be seen at the site of the prosthesis, related to postoperative bone remodeling, for up to 1 year following surgery [44]. A bone scan is also limited in its ability to assess the periprosthetic soft tissues for the presence of an abscess.

For infection imaging, In-111-labeled WBC with a Tc-99m sulfur colloid bone marrow study is a 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 [10]. 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 [10, 44]. 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 or SPECT/CT improves anatomic localization of new bone formation 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 [25, 26], whereas aseptic loosening generally tends to progress. The specificity of bone scans increases in older prostheses once the postoperative remodeling has stabilized.

The addition of SPECT/CT with the In-111 WBC and sulfur colloid scans increases contrast resolution and anatomic localization of radiopharmaceutical activity. Using 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 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
D. 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 [44]. Normal uncomplicated increased periprosthetic uptake related to postoperative bone remodeling tends to decrease over time and up 2 years or longer after surgery [25, 44], 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. This technique is typically not performed for this clinical scenario.

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
E. CT arthrography shoulder

CT arthrography has a high positive predictive value (87.5%) in the prediction of gross component loosening based on the finding of contrast between the component and bone-cement interface reliably predicting gross glenoid component loosening [63]. However, CT arthrography has a low negative predictive value (50%), and, therefore the prediction of component stability based on the absence of contrast between the glenoid component and the bone-cement interface does not always reflect true stability [63].

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
F. CT shoulder with IV contrast

CT plays an important role in the imaging evaluation of a patient with potential loosening that may be missed or incompletely evaluated with radiographs [11, 55]. CT provides a better means of evaluating the hardware components and surrounding bone stock [7]. CT can also assess changes in component alignment over time [56]. 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 [57-59]. Furthermore, dual-energy CT, employing virtual noncalcium software, may provide useful information regarding the presence of marrow edema [60]. CT can also be used to evaluate the bone density around prostheses, which may be predictive of loosening [61]. CT is more sensitive than radiography for detection and extent of radiolucent lines about the prothesis, which may be helpful if radiographs are negative and clinical suspicious persists [2]. CT is more sensitive in evaluating various bone lesions compared with radiography [2].

Metal reduction protocols and modifications in patient positioning have greatly enhanced the ability of CT to evaluate for complications associated with shoulder prostheses. 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 [11, 55, 62]. Evaluation of bone graft resorption remains limited on CT because of metal artifact although has been shown to be reliable in determination of graft incorporation [29]. 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 [60]. The addition of intraarticular or IV contrast does not typically improve evaluation [63]; specifically, IV contrast does not contribute in the evaluation of loosening.

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely.

Suspected loosening. Radiography performed. Next imaging study.
G. CT shoulder without and with IV contrast

CT plays an important role in the imaging evaluation of a patient with potential loosening that may be missed or incompletely evaluated with radiographs [11, 55]. CT provides a better means of evaluating the hardware components and surrounding bone stock [7]. CT can also assess changes in component alignment over time [56]. 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 [57-59]. Furthermore, dual-energy CT, employing virtual noncalcium software, may provide useful information regarding the presence of marrow edema [60]. CT can also be used to evaluate the bone density around prostheses, which may be predictive of loosening [61]. CT is more sensitive than radiography for detection and extent of radiolucent lines about the prothesis, which may be helpful if radiographs are negative and clinical suspicious persists [2]. CT is more sensitive in evaluating various bone lesions compared with radiography [2].

Metal reduction protocols and modifications in patient positioning have greatly enhanced the ability of CT to evaluate for complications associated with shoulder prostheses. 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 [11, 55, 62]. Evaluation of bone graft resorption remains limited on CT because of metal artifact although has been shown to be reliable in determination of graft incorporation [29]. 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 [60]. The addition of intraarticular or IV contrast does not typically improve evaluation [63]; specifically, IV contrast does not contribute in the evaluation of loosening.

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
H. CT shoulder without IV contrast

CT plays an important role in the imaging evaluation of a patient with potential loosening that may be missed or incompletely evaluated with radiographs [11, 55]. CT provides a better means of evaluating the hardware components and surrounding bone stock [7]. CT can also assess changes in component alignment over time [56]. 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 [57-59]. Furthermore, dual-energy CT, employing virtual noncalcium software, may provide useful information regarding the presence of marrow edema [60]. CT can also be used to evaluate the bone density around prostheses, which may be predictive of loosening [61]. CT is more sensitive than radiography for detection and extent of radiolucent lines about the prothesis, which may be helpful if radiographs are negative and clinical suspicious persists [2]. CT is more sensitive in evaluating various bone lesions compared with radiography [2].

Metal reduction protocols and modifications in patient positioning have greatly enhanced the ability of CT to evaluate for complications associated with shoulder prostheses. 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 [11, 55, 62]. Evaluation of bone graft resorption remains limited on CT because of metal artifact although has been shown to be reliable in determination of graft incorporation [29]. 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 [60].

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
I. 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 after radiographs in a symptomatic patient with a primary shoulder prosthesis and infection was excluded.

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
J. Image-guided aspiration shoulder

There is no relevant literature to support the use of image-guided aspiration of the shoulder in a patient with a symptomatic shoulder prosthesis when infection is excluded.

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
K. MRI shoulder without and with IV contrast

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 [41-43, 54].

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 [41-43]. Contrast is not typically used once infection is excluded.

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
L. MRI shoulder without IV contrast

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 [41-43, 54].

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 [41-43].

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
M. US shoulder

There is no relevant literature to support the use of US of the shoulder for the next imaging study of a symptomatic patient with a primary shoulder prosthesis when infection has been excluded or

unlikely due to the limited the ability to evaluate bone-related complications such as loosening [11].

Variant 4:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected loosening. Radiography performed. Next imaging study.
N. WBC scan and sulfur colloid scan shoulder

There is no relevant literature to support the use of WBC scan and sulfur colloid scan of the shoulder in the initial imaging follow-up of the symptomatic patient with a primary shoulder prosthesis.

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.

The goal of imaging is to detect myotendinous injury or other soft tissue abnormality as the source of shoulder pain following shoulder arthroplasty. This imaging information helps to initiate the appropriate treatment plan sooner, which can improve patient outcome by reducing the duration of immobility. The imaging information benefits the patient by avoiding potential delay in appropriate treatment and hastening patient recovery.

The prevalence of rotator cuff tears after prosthesis placement has been reported to be up to 1.3% [5]. 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 [7, 11, 19]. Rates of failure of the subscapularis following shoulder arthroplasty have been reported to range between 6.7% and 47.2% [7].

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.
A. 3-phase bone scan and WBC scan and sulfur colloid scan shoulder

There is no relevant literature to support the use of 3-phase bone scan and WBC scan and sulfur colloid scan after radiographs in a symptomatic patient with a primary shoulder prosthesis and suspected rotator cuff tear or other soft tissue abnormality suspected.

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.
B. 3-phase bone scan and WBC scan and sulfur colloid scan with SPECT or SPECT/CT shoulder

There is no relevant literature to support the use of 3-phase bone scan and WBC scan and sulfur colloid scan with SPECT or SPECT/CT shoulder after radiographs in a symptomatic patient with a primary shoulder prosthesis and suspected rotator cuff tear or other soft tissue abnormality suspected.

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.
C. 3-phase bone scan with SPECT or SPECT/CT shoulder

There is no relevant literature to support the use of 3-phase bone scan with SPECT or SPECT/CT

shoulder after radiographs in a symptomatic patient with a primary shoulder prosthesis and suspected rotator cuff tear or other soft tissue abnormality suspected.

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.
D. Bone scan shoulder

There is no relevant literature to support the use of bone scan after radiographs in a symptomatic patient with a primary shoulder prosthesis and suspected rotator cuff tear or other soft tissue abnormality suspected.

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.
E. 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 [11]. CT arthrography can be an effective modality to evaluate the rotator cuff and detect any associated pathology [11, 66]. 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. CT arthrography is not able to diagnose interstitial or bursal surface tears. The presence and degree of fatty muscle replacement can also be used as an indirect sign of a rotator cuff tear [67, 68]. Anterior subluxation and anterior extravasation of intraarticular contrast with loss of the subscapularis contour can identify subscapularis tears [7].

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.
F. CT shoulder with IV contrast

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 [69]. Administration of IV contrast does not improve evaluation.

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.
G. CT shoulder without and with IV contrast

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 [69]. Administration of IV contrast does not improve evaluation.

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.
H. CT shoulder without IV contrast

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 [69].

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.

I. 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 after radiographs in a symptomatic patient with a primary shoulder prosthesis in the evaluation of rotator cuff tendon abnormalities.

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.

J. Image-guided aspiration shoulder

There is no relevant literature to support the use of image-guided aspiration of the shoulder in a patient with a symptomatic shoulder prosthesis when infection is excluded in the evaluation of rotator cuff tendon abnormalities.

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.

K. MRI shoulder without and with IV contrast

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 [40-43, 54].

MRI can be used to evaluate for rotator cuff tendon tearing in the setting of shoulder arthroplasty [42, 43]. Advanced metal reduction techniques can reduce the prosthesis-related artifact and thus improve visualization of the rotator cuff tendons and any associated pathology [41, 42] [40]. 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 [41, 42]. 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 [42]. The degree of tendon retraction and muscle edema/atrophy can also be assessed [7].

There are multiple techniques used to release the subscapularis tendon during arthroplasty placement, including tenotomy, osteotomy, and peel [11]. 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 [11, 64]. This underscores the importance of imaging in this setting. Administration of intraarticular 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:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.

L. MRI shoulder without IV contrast

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 [40-43, 54].

MRI can be used to evaluate for rotator cuff tendon tearing in the setting of shoulder arthroplasty [42, 43]. Advanced metal reduction techniques can reduce the prosthesis-related artifact and thus improve visualization of the rotator cuff tendons and any associated pathology [40-42]. 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 [41, 42]. 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 [42]. The degree of tendon retraction and muscle edema/atrophy can also be assessed [7].

There are multiple techniques used to release the subscapularis tendon during arthroplasty placement, including tenotomy, osteotomy, and peel [11]. 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 [11, 64]. This underscores the importance of imaging in this setting. Administration of intraarticular 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).

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.
M. US shoulder

US is a reliable option to evaluate rotator cuff tears in the setting of a shoulder arthroplasty [36]. 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 [4, 36]. US evaluation of the subscapularis tendon has been found to be more reliable than physical examination in the setting of prior tendon repair and prosthesis placement [64]. 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 [65].

Variant 5:Adult. Symptomatic shoulder prosthesis. Infection excluded or considered unlikely. Suspected rotator cuff tear or other soft tissue abnormality. Radiography performed. Next imaging study.
N. WBC scan and sulfur colloid scan shoulder

There is no relevant literature to support the use of WBC scan and sulfur colloid scan of the shoulder in a patient with a symptomatic shoulder prosthesis when infection is excluded in the evaluation of rotator cuff tendon abnormalities.

Summary of Highlights

This is a summary of the key recommendations from the variant tables. Refer to the complete narrative document for more information.

- Variants 1 and 2: In the routine surveillance of the asymptomatic shoulder prosthesis and symptomatic shoulder prosthesis, radiography is recommended as the initial imaging technique.
- Variant 3: For the initial evaluation of the symptomatic shoulder prosthesis when infection is a consideration, US is usually appropriate in the assessment of a joint effusion, bursal distension, and soft tissue abscess and can be complemented by image-guided shoulder aspiration, which is also usually appropriate in making the diagnosis of a joint infection. Alternative procedures that may be appropriate include MRI without IV contrast and MRI without and with IV contrast, which can demonstrate joint infection, fluid collections/abscesses, and sinus tracts. CT of the shoulder with IV contrast and CT of the shoulder without IV contrast using metal reduction protocols are also alternatives that may be appropriate to narrow the differential diagnosis in a patient suspected of periprosthetic infection. Alternative procedures that may also be appropriate include a 3-phase bone scan with SPECT or SPECT/CT of the shoulder, which is sensitive but not specific in detecting acute osteomyelitis, but can be complemented by a WBC scan and sulfur colloid scan to increase specificity in the diagnosis of an acute pyogenic process/osteomyelitis.
- Variant 4: Following radiography, when infection is excluded or considered unlikely, MRI and CT of the shoulder without IV contrast are the next imaging studies that are usually appropriate in evaluating symptomatic shoulder prosthesis. MRI will show component loosening, fractures, and rotator cuff tears, whereas CT is complementary in the evaluation of loosening, surrounding bone stock, fractures, hardware malposition, component migration, and degree of osseous incorporation. Alternative procedures that may be appropriate include 3-phase bone scan with SPECT or SPECT/CT, which is nonspecific, or CT arthrography, which can demonstrate gross component loosening based on detecting contrast between the component and bone-cement interface.
- Variant 5: For imaging the symptomatic shoulder prosthesis when a suspected rotator cuff tear or other soft tissue abnormality is of concern, US, MRI without IV contrast, and CT arthrography of the shoulder are all usually appropriate as the next imaging study. US and MRI are reliable options to evaluate rotator cuff tears and the surrounding soft tissues and may complement each other. CT arthrography may be an alternative in the assessment of full-thickness rotator cuff tears although CT arthrography is not able to diagnose interstitial or bursal surface tears.

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.

Gender Equality and Inclusivity Clause

The ACR acknowledges the limitations in applying inclusive language when citing research studies that predates the use of the current understanding of language inclusive of diversity in sex, intersex, gender, and gender-diverse people. The data variables regarding sex and gender used in

the cited literature will not be changed. However, this guideline will use the terminology and definitions as proposed by the National Institutes of Health.

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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[a]University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin. [b]Panel Chair, University of Virginia Health System, Charlottesville, Virginia. [c]Penn State Health Milton S. Hershey Medical Center, Hershey, Pennsylvania. [d]Mayo Clinic, Rochester, Minnesota. [e]Baylor College of Medicine and Baylor Scott & White Health, Central Texas, Temple, Texas. [f]Mayo Clinic Arizona, Phoenix, Arizona, Orthopedic Surgeon. [g]Mayo Clinic Arizona, Glendale, Arizona, PCP - Family practice. [h]University of Colorado Anschutz Medical Campus, Aurora, Colorado. [i]University of Utah, Salt Lake City, Utah. [j]Specialty Chair, Mayo Clinic Arizona, Phoenix, Arizona.