American College of Radiology
ACR Appropriateness Criteria®
Imaging after Total Hip Arthroplasty

Variant: 1   Routine follow-up of the asymptomatic patient after hip arthroplasty.

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

Variant: 2   Symptomatic patient with hip prosthesis. Initial imaging.

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

Variant: 3   Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.

Procedure	Appropriateness Category	Relative Radiation Level
CT hip without IV contrast	Usually Appropriate	☢☢☢
MRI hip without IV contrast	May Be Appropriate	O
US hip	Usually Not Appropriate	O
Image-guided aspiration hip	Usually Not Appropriate	Varies
MRI hip without and with IV contrast	Usually Not Appropriate	O
Bone scan hip	Usually Not Appropriate	☢☢☢
Bone scan with SPECT or SPECT/CT hip	Usually Not Appropriate	☢☢☢
CT hip with IV contrast	Usually Not Appropriate	☢☢☢
CT hip without and with IV contrast	Usually Not Appropriate	☢☢☢

Procedure	Appropriateness Category	Relative Radiation Level
Bone scan and gallium scan hip	Usually Not Appropriate	☢☢☢☢
Bone scan and gallium scan with SPECT or SPECT/CT hip	Usually Not Appropriate	☢☢☢☢
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
WBC scan and sulfur colloid scan hip	Usually Not Appropriate	☢☢☢☢

Variant: 4   Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.

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

Variant: 5   Symptomatic hip arthroplasty patient, infection excluded. Additional imaging following radiographs.

Procedure	Appropriateness Category	Relative Radiation Level
MRI hip without IV contrast	Usually Appropriate	O
CT hip without IV contrast	Usually Appropriate	☢☢☢
Image-guided anesthetic injection hip	May Be Appropriate	Varies
Bone scan with SPECT or SPECT/CT hip	May Be Appropriate	☢☢☢
Radiographic arthrography hip	Usually Not Appropriate	☢
MRI hip without and with IV contrast	Usually Not Appropriate	O
Bone scan hip	Usually Not Appropriate	☢☢☢
CT arthrography hip	Usually Not Appropriate	☢☢☢
CT hip with IV contrast	Usually Not Appropriate	☢☢☢
CT hip without and with IV contrast	Usually Not Appropriate	☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢

Variant: 6   Evaluation of symptomatic hip arthroplasty patient with metal-on-metal prosthesis or findings suggesting trunnionosis. Question of adverse reaction to metal debris. Additional imaging following radiographs.

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

Procedure	Appropriateness Category	Relative Radiation Level
US hip	May Be Appropriate	O
CT hip without IV contrast	May Be Appropriate	☢☢☢
MRI hip without and with IV contrast	Usually Not Appropriate	O
CT hip with IV contrast	Usually Not Appropriate	☢☢☢
CT hip without and with IV contrast	Usually Not Appropriate	☢☢☢

Variant: 7 **Hip arthroplasty patient with trochanteric pain. Suspect abductor injury, or trochanteric bursitis, or other soft tissue abnormality. Additional imaging following radiographs.**

Procedure	Appropriateness Category	Relative Radiation Level
US hip	Usually Appropriate	O
MRI hip without IV contrast	Usually Appropriate	O
Image-guided anesthetic +/- corticosteroid injection hip joint or surrounding structures	May Be Appropriate	Varies
Radiographic arthrography hip	Usually Not Appropriate	☢
MRI hip without and with IV contrast	Usually Not Appropriate	O
CT hip with IV contrast	Usually Not Appropriate	☢☢☢
CT hip without and with IV contrast	Usually Not Appropriate	☢☢☢
CT hip without IV contrast	Usually Not Appropriate	☢☢☢

Panel Members

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Summary of Literature Review

Introduction/Background

It has been approximately 60 years since Sir John Charnley introduced the modern era of hip replacement surgery [1]. Approximately 370,000 primary total hip arthroplasties (THAs) were performed in the United States in 2014 [2]. Sloan et al [2] estimated that the volume of primary THAs would increase to 635,000 procedures annually by 2030.

Over the years, modifications have been made to attempt to decrease complications such as loosening and wear with additional fixation techniques (eg, osseointegration) and articular surfaces (eg, metal on highly cross-linked polyethylene, antioxidant doped polyethylene liners, metal-on-metal [MoM], ceramic on polyethylene, and ceramic on ceramic articulations) [3-5].

Second-generation MoM prostheses were introduced in the late 1990s [6]. These prostheses were preferentially used for younger patients with osteoarthritis [7]. However, reports of high short-term failure rates led to recalls and decreased use [8,9]. These articulations (and also metal to metal articulations at the head neck [trunnion] and neck stem articulations of modular components) may result in the release of metal particles and metal ions leading to macroscopic necrosis, osteolysis,

large sterile hip effusions, and periprosthetic solid and cystic masses termed "pseudotumors" [10]. The umbrella terms adverse local tissue reaction (ALTR) and adverse reaction to metal debris (ARMD) have been used to refer to the spectrum of findings in failed metal on metal articulations [11-13]. The term metallosis refers to infiltration of metallic wear debris into periprosthetic structures [14].

The most common causes for surgical revision of THA from 2012 to 2019 as reported in the American Academy of Orthopaedic Surgeons American Joint Replacement Registry were infection and inflammatory reaction (19.3%), instability (17.4%), and aseptic loosening (15.8%) [15-17]. Wear or osteolysis was the cause for revision in 7.5%.

The imaging studies used to follow uncomplicated primary hip prostheses and to assess several prosthesis-related complications are reviewed. Separate discussions pertinent to imaging of MoM prostheses are included.

Special Imaging Considerations

Ultrasound (US): US has been used for assessment of soft tissues adjacent to hip arthroplasties and, in contrast to MRI and CT, is not affected by prosthetic artifacts. US may be limited in its ability to assess deep soft tissues.

Metal artifact reduction sequences (MARS)-MRI: MARS-MRI enable soft tissues around the prosthetic hip such as the pseudocapsule, tendons, and neurovascular structures to be assessed. Reviews of some MARS-MRI techniques are available in the literature [18-21].

Metal artifact reduction (MAR)-CT: Metallic hip prostheses, particularly cobalt chrome components, produce artifacts on CT scanning that can obscure adjacent structures. As reviewed by Roth et al [22], these artifacts are related to both the prosthesis (eg, type of metal and geometry) and the scanning parameters. Several techniques have been used to reduce these artifacts (termed MAR) **[22,23]**.

Fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT Skull Base to Mid-Thigh and Fluoride PET/CT Skull Base To Mid-Thigh: PET studies (using either FDG or fluoride) may be tailored to focus imaging of the area of interest, such as the hip, rather than including the entire region of the skull base to mid-thigh. Many of the investigations included in this document were performed before the widespread availability of PET/CT, and consequently, they were performed as PET studies without CT.

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 after hip arthroplasty.

Follow-up after THA usually continues throughout the patient's life. Imaging of asymptomatic patients after hip arthroplasty is intended to identify failure of prostheses to find those in need of early intervention [24]. However, most patients requiring revision are symptomatic [24].

Variant 1: Routine follow-up of the asymptomatic patient after hip arthroplasty.
A. Bone scan hip

Periprosthetic uptake can be present for a year or more after prosthetic insertion [25-27]. Therefore, bone scintigraphy of the hip for routine surveillance of asymptomatic hip arthroplasties is not supported.

Variant 1: Routine follow-up of the asymptomatic patient after hip arthroplasty.
B. Bone scan with SPECT or SPECT/CT hip

Data on the normal evolution of periprosthetic uptake on single-photon emission computed tomography (SPECT) or SPECT/CT of the hip following hip arthroplasty are lacking [28].

However, on planar bone scintigraphy, persistent periprosthetic uptake can be present for more than 1 year following implantation [25-27]. Consequently, bone scintigraphy with SPECT or SPECT/CT is not supported for routine surveillance of asymptomatic hip arthroplasties.

Variant 1: Routine follow-up of the asymptomatic patient after hip arthroplasty.
C. CT hip

There are no recent studies advocating routine CT scanning of the hip for asymptomatic patients with conventional or MoM prostheses.

Variant 1: Routine follow-up of the asymptomatic patient after hip arthroplasty.
D. Fluoride PET/CT skull base to mid-thigh

It can take a year or more for periprosthetic uptake to normalize around a hip prosthesis [29,30]. Therefore, fluoride PET/CT skull base to mid-thigh is not supported for routine surveillance of asymptomatic hip arthroplasties.

Variant 1: Routine follow-up of the asymptomatic patient after hip arthroplasty.
E. MRI hip

MRI for asymptomatic non-MoM hips: MRI is generally not indicated in routine follow-up of asymptomatic patients with non-MoM prostheses. However, the MRI findings in asymptomatic patients are being investigated [19,31-33].

MARS-MRI for asymptomatic MoM prostheses: Pseudotumors consistent with ARMD have been reported on MRI in patients without pain following MoM arthroplasties [6,33-38]. Thus, MRI may be beneficial in this group.

In a series of MoM hip resurfacing arthroplasties, clinical outcomes and radiographic screening

underestimated the presence of pseudotumors and supported the use of MRI for screening [38]. Similarly, Koff et al [33] performed 4 yearly MRI examinations of patients with surface replacement prostheses and found evidence of ALTRs in high-functioning individuals without pain. They concluded that MRI should be considered as part of the routine patient follow-up protocol to allow early detection and follow-up of ALTRs. In 2 series, comparison of MRI results to histologic findings showed the sensitivity of MRI for pseudotumors to be 85% and 71%, respectively, and the specificity to be 59% and 87%, respectively [39,40]. Sensitivity was greater when the MRI examination was performed within 3 months of the revision surgery (88%) [39].

Combined US and MARS-MRI studies: Comparison to surgical results suggests combining US and MARS-MRI improves accuracy. Small numbers of lesions detected on US are not visible on MRI, and some lesions seen on MRI are not apparent on US [35,36,41].

Variant 1: Routine follow-up of the asymptomatic patient after hip arthroplasty.
F. Radiography hip

Follow-up radiographs for asymptomatic non-MoM total hip prostheses: Radiographs have been the imaging mainstay for following THA [42]. Review of serial radiographs is useful for identifying subtle changes, emphasizing the need for baseline radiographs. However, Hart et al [43] followed postoperative patients with THAs undergoing routine follow-up, excluding patients with complications of fracture, dislocation, or infection or who had died. Of the 423 patients studied, 414 had radiographs at 6 to 12 weeks and 276 had follow-up radiographs at 1 year. No THA case was identified in which clinical management was changed by the radiographic examination in this time period. This suggested to the authors that, in asymptomatic patients, some follow-up radiographs might be omitted.

Radiographs for follow-up of asymptomatic MoM total hip prostheses: The FDA recommends routine long-term follow-up of patients with MoM hip implants, typically to occur every 1 to 2 years [44]. This includes appropriate radiographs. Serial radiographs are helpful to assess subtle changes [42]. Radiographs can be used to assess component position, component loosening, bone quality, osteolysis, fracture, dislocation or subluxation, femoral neck narrowing, and medial femoral calcar erosion [36,45]. The latter may be an indicator of ARMD, warranting cross-sectional imaging (positive predicative value [PPV] 0.83) [45].

Variant 1: Routine follow-up of the asymptomatic patient after hip arthroplasty.
G. US hip

US for follow-up of asymptomatic non-MoM total hip prostheses: A few studies have investigated US to assess asymptomatic patients with metal-on-polyethylene (MoP) bearings [41,46]. Nishii et al [41] concluded that US seemed a promising noninvasive tool for detection of ARMD pseudotumors. However, there are no recent studies indicating the use of US for routine surveillance of nonmetal on metal prostheses.

US for follow-up of asymptomatic MoM total hip prostheses: US may be beneficial as asymptomatic patients may show imaging changes of or associated with ARMD [46]. US can be used to detect pseudotumors (solid or cystic) and other findings seen with ARMD such as joint effusions, bursal collections, and synovitis [36,47-49]. Williams et al [46] proposed high-resolution US surveillance of all asymptomatic patients with a MoM implant that is known to result in high serum metal ion levels.

Low et al [50] prospectively followed 152 asymptomatic MoM hip resurfacing arthroplasties at a mean of 4.3 years using US. Progression of findings occurred in 19%, and new pseudotumors developed in 10%. No asymptomatic hip resurfacing arthroplasty patient with both a normal initial US and low blood metal ions (<2 ug/L) developed pseudotumors within 5 years of initial assessment, and, therefore, they concluded this patient subgroup did not require repeat follow-up within 5 years [50].

In a series of 82 hips (82 patients undergoing revision of MoM arthroplasties), Lainiala et al [51] found US had a sensitivity of 83% (95% confidence interval [CI], 63-93) and a specificity of 92% (95% CI, 82-96) for detecting trochanteric region pseudotumors and a sensitivity of 79% (95% CI, 62-89) and a specificity of 94% (95% CI, 83-98) for detecting iliopsoas-region pseudotumors.

Comparison of US with MRI: A summary of studies comparing US to MARS-MRI as the reference standard for detecting ARMD shows sensitivities for US of 69% to 100% and specificities of 83% to 96% [36]. Kwon et al [52] found that US was valid and useful for detecting interval changes in lesion size and grade in comparison with MARS-MRI.

Combined US and MARS-MRI studies: Comparison to surgical results suggests combining US and MARS-MRI improves accuracy. Small numbers of lesions detected on US are not visible on MRI and some lesions seen on MRI are not apparent on US [36,41,52].

Variant 2: Symptomatic patient with hip prosthesis. Initial imaging.

Variant 2: Symptomatic patient with hip prosthesis. Initial imaging.
A. Bone scan hip

There is insufficient evidence to support the use of bone scan of the hip as the initial imaging procedure in the evaluation of the symptomatic hip arthroplasty.

Variant 2: Symptomatic patient with hip prosthesis. Initial imaging.
B. Bone scan with SPECT or SPECT/CT hip

There is insufficient evidence to support the use of bone scans with SPECT or SPECT/CT of the hip as the initial imaging procedure in the evaluation of the symptomatic hip arthroplasty.

Variant 2: Symptomatic patient with hip prosthesis. Initial imaging.
C. CT hip

There is insufficient evidence to support the use of CT of the hip as the initial imaging procedure in the evaluation of the symptomatic hip arthroplasty. A possible exception might be for detection of a ceramic acetabular liner fracture where case reports suggest CT to be more sensitive than radiographs [53].

Variant 2: Symptomatic patient with hip prosthesis. Initial imaging.
D. Fluoride PET/CT skull base to mid-thigh

There is insufficient evidence to support the use of fluoride PET/CT skull base to mid-thigh as the initial imaging procedure in the evaluation of the symptomatic hip arthroplasty.

Variant 2: Symptomatic patient with hip prosthesis. Initial imaging.
E. Image-guided aspiration hip

There is no relevant literature to support the use of image-guided aspiration of the hip as the initial imaging procedure in the evaluation of the symptomatic hip arthroplasty.

Variant 2: Symptomatic patient with hip prosthesis. Initial imaging.
F. MRI hip

Non-MoM hip prostheses: There is insufficient evidence to support the use of MRI of the hip as the initial imaging modality for the patient with a symptomatic non-MoM arthroplasty.

MoM hip prostheses: Because radiographs may be normal in patients with symptomatic pseudotumors [54], advanced imaging has been supported. Based on literature review, Petscavage-Thomas and Ha [49] suggested MARS-MRI as the first-line of imaging for detection of ARMD.

Variant 2: Symptomatic patient with hip prosthesis. Initial imaging.
G. Radiography hip

Radiographs are usually the first imaging modality for assessment of a patient with a symptomatic hip prosthesis.

Non-MoM hip prostheses: The literature indicates that radiographs are usually the first imaging modality for assessment of a patient with a symptomatic hip prosthesis. Comparison radiographs are useful; however, an assessment of stem loosening on comparison studies may be suboptimal due to variables such as differences in hip flexion or rotation [55].

Some radiographic features such as increased femoral head and stem offset suggest the need for additional imaging for ARMD due to trunnionosis [56]. Metallosis may be identified around nonmetal on metal prostheses due to trunnionosis or following severe liner wear and/or liner dislocation or fracture [14,57-59]. However, Chang et al [14] found that in more than half of patients with surgically proven metallosis, radiographs did not show metal density in the soft tissues preoperatively.

Radiographs are neither sensitive nor specific for infection. Normal radiographs do not exclude infection; half of the patients in a series of 20 infected hip prostheses reviewed by Tigges et al were normal [60]. Lucencies suggesting aseptic loosening or focal osteolysis may be present in infected hips [60]. Progression of lucency may be rapid in cases of infection. Periostitis was seen in 2 cases.

Stumpe et al [61] reviewed radiographs of 35 patients with painful total hip replacements: 9 with septic, 21 with aseptic prosthetic loosening, and 5 without loosening. Rapid progression of osteolysis, rapid component migration, and/or irregular periprosthetic osteolysis were used to diagnose infection. For 2 readers, a sensitivity of 89% and 78%, specificity of 50% and 65%, and accuracy of 60% and 69% were found.

In a review, Fritz et al [18] noted that radiographs are usually the first imaging modality for patients with postoperative lateral hip pain. Radiographs help assess the presence of periprosthetic fractures, avulsions of the greater trochanter, and heterotopic ossification [18]. Radiographs showing >2 mm surface irregularities of the greater trochanter have been reported with abductor tendon abnormalities and peritendinous edema on MRI [62]. However, a review of 38 cases of greater trochanter pain syndrome and 100 controls showed the findings of trochanteric surface irregularities including spurs protruding 2 mm were associated with a 24.7% PPV, 64.0% sensitivity, 25.7% specificity, 74.3% false-positive rate, 36.0% false-negative rate, and 65.3% negative predicative value (NPV) for clinical greater trochanteric pain syndrome [63].

MoM hip prostheses: The FDA notes that in the symptomatic patient following insertion of a MoM prosthesis, radiographs in conjunction with nonimaging information, may disclose the need for revision [44]. Metallosis resulting from severe wear of a metal on metal articulation may occasionally be identified on radiographs [64]. Component position can be assessed [65].

Matharu et al [54] found hips with resurfacing arthroplasties and symptomatic pseudotumors were more likely than those without pseudotumors to have abnormal radiographs (80.0% compared with 63.4%). Radiographic features that predicted revision for pseudotumors included high inclination, acetabular or femoral osteolysis, and acetabular loosening. In that study, 20% of hip resurfacing prostheses with pseudotumors at revision surgery had normal radiographic features [54]. Based on these findings, Matharu et al [54] concluded that radiographs were important and useful in all follow-up protocols to assess MoM hip resurfacing prostheses. Petscavage-Thomas and Ha [49] concluded on literature review that cross-sectional imaging, particularly MRI, is still beneficial even in the presence of normal radiographs.

Variant 2: Symptomatic patient with hip prosthesis. Initial imaging.
H. US hip

Non-MoM hip prostheses: There is insufficient evidence to support the use of US of the hip as the initial imaging modality for the patient with a symptomatic non-MoM prosthesis.

US for MoM hip prostheses: In a series of 82 hips (82 patients) undergoing revision of MoM prostheses, Lainiala et al [51] found the sensitivity of US examination to be 83% with a specificity of 92% for pseudotumors in the trochanteric region and a sensitivity of 79% and a specificity of 94% for identifying pseudotumors in the iliopsoas region.

Matharu et al [66] studied a series of 40 MoM hip resurfacing arthroplasties (39 patients) undergoing revision surgery who had preoperative imaging with both US and MARS-MRI. Comparison with operatively identified pseudotumors showed US to have a sensitivity of 90.9% and a specificity of 42.9% compared with an MRI sensitivity of 93.9% and a specificity 57.1%. The PPV was similar (88.2% US, 91.2% MRI) but the NPV was higher for MRI (66.7% on MRI, 50.0% for US) [66].

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.

If a fracture is suspected clinically but is not demonstrated or not fully characterized on radiographs, additional imaging may be necessary. Fracture location, component stability (stable versus loose), and femoral bone stock are features that can influence management and that can be assessed on imaging [67-70].

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.
A. Bone scan and gallium scan hip

There is insufficient evidence to support the use of combined bone and gallium scan of the hip in the evaluation of the symptomatic hip prosthesis in the setting of acute injury.

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.
B. Bone scan and gallium scan with SPECT or SPECT/CT hip

There is insufficient evidence to support the use of combined bone and gallium scan with SPECT or SPECT/CT hip in the evaluation of the symptomatic hip prosthesis in the setting of acute injury.

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.
C. Bone scan hip

There is insufficient evidence to support the use of the bone scan of the hip in the evaluation of the symptomatic hip prosthesis in the setting of acute injury.

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.
D. Bone scan with SPECT or SPECT/CT hip

There is insufficient evidence to support the use of the bone scan with SPECT or SPECT/CT of the hip in the evaluation of the symptomatic hip prosthesis in the setting of acute injury.

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.
E. CT hip

Nonenhanced multidetector CT of the hip has been suggested for fracture detection when radiographs are negative or equivocal and there is high suspicion for periprosthetic fracture or when additional fracture characterization is needed for treatment planning [22,70]. There is no relevant literature documenting additional benefit of CT with IV contrast, relative to noncontrast CT for fracture detection/assessment. Contrast may be helpful if there is a question of vascular injury [23].

The reported efficacy of CT to provide information regarding component loosening (for treatment planning) when a fracture is present is inconsistent [68,71]. Case reports suggest CT to be more sensitive than radiographs for detecting fracture of a ceramic liner [53].

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.
F. FDG-PET/CT skull base to mid-thigh

There is insufficient evidence to support the use of FDG-PET/CT skull base to mid-thigh in the evaluation of the symptomatic hip prosthesis in the setting of acute injury.

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.
G. Fluoride PET/CT skull base to mid-thigh

There is insufficient evidence to support the use of fluoride PET/CT skull base to mid-thigh in the evaluation of the symptomatic hip prosthesis in the setting of acute injury.

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.
H. Image-guided aspiration hip

There is insufficient evidence to support the use of image-guided aspiration of the hip in the evaluation of the symptomatic hip prosthesis in the setting of acute injury.

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.
I. MRI hip

MRI can demonstrate femoral periprosthetic fractures and stress reactions [18]. However, a nondisplaced fracture may be difficult to see on MRI if there is only mild associated marrow edema, and susceptibility artifact from the prosthesis may obscure the pertinent findings [72]. Pelvic fractures can be demonstrated. There is no relevant literature documenting the additional benefit of MRI with IV contrast, relative to noncontrast MRI, for fracture detection.

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.
J. US hip

US is limited in its ability to detect periprosthetic fracture [73].

Variant 3: Symptomatic hip arthroplasty patient, history of acute injury. Additional imaging following radiographs.
K. WBC scan and sulfur colloid scan hip

There is insufficient evidence to support the use of white blood cell (WBC) and sulfur colloid of the hip imaging in the evaluation of the symptomatic hip prosthesis in the setting of acute injury.

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.

Ong et al [74] found the incidence of infection after THA in the Medicare population for 1997 and 2006 to be 1.63% within 2 years and 0.59% between 2 and 10 years. The identification of periprosthetic infection is critical to choosing appropriate treatment but diagnosis can be challenging [75]. Guidelines for patient evaluation have been developed [76]. A definition of periprosthetic infection has been proposed by the musculoskeletal infection society that includes major and minor criteria but not specifically imaging criteria [75].

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
A. Bone scan and gallium scan hip

The most recent data on bone and gallium scans for diagnosing periprosthetic hip infection are more than 25 years old because this test has been largely replaced by labeled leukocyte and marrow imaging and FDG-PET [77-79].

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
B. Bone scan and gallium scan with SPECT or SPECT/CT hip

There is no relevant literature to support the use of bone and gallium scan with SPECT or SPECT/CT of the hip as these tests have been replaced by leukocyte and bone marrow imaging and FDG-PET for diagnosing periprosthetic hip infection.

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
C. Bone scan hip

Bone scan of the hip is sensitive but not specific for periprosthetic hip infection. Performing the test as a 3-phase bone scan does not improve accuracy, with reported sensitivity and specificity ranging from 29% to 88% and 50% to 92%, respectively [61,80-82].

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
D. Bone scan with SPECT or SPECT/CT hip

Schweizer et al [83] retrospectively studied 58 total hip prostheses, including 31 symptomatic and 27 asymptomatic prostheses, with bone scan with SPECT/CT. SPECT/CT identified the cause of pain in 19 (61%) of the 31 symptomatic devices. No pathology-specific uptake pattern was observed. Although periprosthetic uptake was significantly higher in symptomatic individuals than in asymptomatic individuals, a normal result did not exclude pathology.

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
E. CT hip

In a 2002 study, Cyteval et al [84] prospectively reviewed helical noncontrast CT scans of 65 painful prosthetic hips with diagnosis confirmed by surgery. Infection was present in 12. Fluid collections in muscles and perimuscular fat demonstrated a 41% sensitivity and a 100% specificity for infection (PPV 100%, NPV 88%, accuracy 89%). Joint distension was 83% sensitive and 96% specific with a PPV of 83%, NPV of 96%, and accuracy of 94%. Thus, fluid collections in muscles and perimuscular fat had a 100% PPV, and absence of joint distention had a 96% NPV for infection. In the same study, periostitis was 100% specific but only 16% sensitive for infection. (PPV 100%, NPV 84%, accuracy 85%) [84]. A more recent study by Isern-Kebschull et al [85] confirmed that findings on noncontrast multidetector CT could differentiate delayed periprosthetic joint infection from aseptic loosening or granulomas. Intravenous (IV) contrast may be of help in defining abscess [23].

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
F. FDG-PET/CT skull base to mid-thigh

Reported results for diagnosing periprosthetic hip infection have been inconsistent. In some investigations, the test has been both sensitive (81%-95%) and specific (89%-94%) for infection [82,86-90]. The results of other investigations; however, have been less satisfactory, with sensitivity and specificity ranging from 64% to 100% and 38% to 68% [91-93]. Delank et al [94] reported that although a negative FDG-PET excludes infection, a positive result could not accurately differentiate infection from aseptic inflammation. Kiran et al [92] performed preoperative FDG-PET/CT on 130 painful cemented hip arthroplasties and reported a sensitivity of 95% and a specificity of 38% for periprosthetic infection. In this investigation, the false-positive rate of FDG PET/CT compared with culture alone was 77%.

Comparisons of FDG-PET with conventional nuclear medicine studies have been contradictory. Some investigators have reported that FDG-PET is more accurate than bone scintigraphy and labeled leukocyte and marrow imaging, whereas other investigators have reported the opposite results [61,82,87,88,95,96].

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
G. Fluoride PET/CT skull base to mid-thigh

Based on the available data, fluoride PET/CT does not appear to offer any advantages over FDG-PET/CT or 3-phase bone scintigraphy for diagnosing periprosthetic hip infection [97-100].

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
H. Image-guided aspiration hip

Although both false-positive and false-negative results may occur, joint aspiration with synovial

fluid analysis remains probably the most useful test for confirming the presence or absence of infection and identifying the causative organism [101]. A meta-analysis by Carli et al [102] yielded a mean sensitivity of 68.6% and a specificity of 96.4% for joint aspiration culture. Hip aspiration can be performed using fluoroscopic, US, or CT guidance or without image guidance [103-105]. Contrast injection has been described for CT arthrography following joint aspiration [106].

Specific tests of retrieved synovial fluid such as alpha-defensin and polymerase chain reaction for bacteria and leukocyte esterase are beyond the scope of this review [107].

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
I. MRI hip

MRI can demonstrate soft tissue and bone features associated with periprosthetic infection, including inflammatory synovitis that may have a lamellated appearance [108], soft tissue edema, lymphadenopathy, fluid collections, bone marrow edema, and periosteal reaction [72,109-112].

IV contrast can be used to differentiate phlegmon from abscess and to define sinus tracts and communicating fluid collections [72]. However, IV contrast is generally not necessary to make the diagnosis of infection [72]. Evaluation of 19 patients suspected of having infection showed noncontrast MRI to be highly reproducible in the detection, localization, quantification, and characterization of fluid collections [113].

Galley et al [110] used optimized MRI sequences and found irregular soft tissue mass, soft tissue edema, bone destruction, and fistulas to be significant features of periprosthetic infection, with sensitivities of 47.4% to 100% and specificities of 73.1% to 100.0%. Albano et al [109] found lymph node assessment (of the affected compared to the unaffected hip) identified infected implants with high accuracies (up to 93.1%). Galley et al [110] found periosteal reaction, capsular edema, and intramuscular edema after THA at 1.5T MRI with MAR to have high accuracy in the evaluation of periprosthetic joint infection (86%-91% accuracy). Schwaiger et al [112] were able to distinguish patients with infection from those with loosening using MRI features. Soft tissue edema (sensitivity, 86.7% and specificity, >73.3%), abnormalities at both acetabular and femoral components (sensitivity/specificity, 66.7%/93.3%-100%), and enlarged lymph nodes (80%/86.7%) enabled this differentiation.

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
J. Radiographic arthrography hip

There is no recent literature to support the current use of conventional arthrography of the hip in the evaluation of periprosthetic infection.

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
K. US hip

Detection of joint effusion, fluid collections, and sinus tracts is possible with US, and, therefore, this modality is helpful in identifying infection [47]. Some discrepancy regarding the reliability and threshold for detecting effusion on US has been noted [47,114]. van Holsbeeck et al [115] used US to evaluate 15 asymptomatic patients with total hip replacements and 33 patients who had pain in the hip after arthroplasty and radiologic findings consistent with component loosening (6 of whom

had infection). All patients with intraarticular effusion and extraarticular extension had infection (100% specificity).

Variant 4: Symptomatic hip arthroplasty patient, infection not excluded. Additional imaging following radiographs.
L. WBC scan and sulfur colloid scan hip

The role of combined leukocyte and marrow imaging for diagnosing periprosthetic hip infection has been studied by several investigators. Specificity has consistently been high, ranging from 88% to 100%. Sensitivity has been more variable, ranging from 33% to 100% [88,95,96,116,117].

Variant 5: Symptomatic hip arthroplasty patient, infection excluded. Additional imaging following radiographs.

This variant includes wear, loosening, and osteolysis.

Variant 5: Symptomatic hip arthroplasty patient, infection excluded. Additional imaging following radiographs.
A. Bone scan hip

Loosening: Temmerman et al [118,119] reported that when infection had been excluded, bone scintigraphy could diagnose aseptic loosening in the acetabular and femoral components, with sensitivities and specificities ranging from 81% to 88% and 50% to 74% versus 81% to 85% and 74% to 85%, respectively, for radiographs. Hill et al [80] reviewed the results of 3-phase bone scans performed on 100 patients with a painful hip prosthesis. They reported that an abnormal scan could not differentiate aseptic loosening from infection. Although a normal result excluded aseptic loosening and infection, the ability of the bone scan to identify or exclude other conditions such as wear, osteolysis, and soft tissue abnormalities as the cause of the patient's symptoms was not addressed. There is insufficient evidence to support the use of planar bone scans in the symptomatic hip arthroplasty patient in whom infection is excluded.

Variant 5: Symptomatic hip arthroplasty patient, infection excluded. Additional imaging following radiographs.
B. Bone scan with SPECT or SPECT/CT hip

In 37 painful hip arthroplasties, the results of the bone scan with SPECT/CT were comparable to those of MRI for detecting polyethylene wear, periprosthetic fracture, infection, and aseptic loosening. MRI detected 21 soft tissue abnormalities, 14 tendon lesions (12 tendonopathies, 2 tears), 6 bursitis, and 1 pseudotumor. In contrast, bone scan with SPECT/CT found 1 soft tissue abnormality: iliopsoas tendinopathy, which also was identified on MRI [120].

In another investigation, the results of bone SPECT/CT changed patient management in 13 of 19 (68%) patients with painful MoM hip prostheses, all of whom had undergone previous extensive diagnostic workup including radiographs, CT, and MRI that failed to identify the cause of pain. Bone SPECT/CT was positive in 4 cases of loosening and negative for hip pathology in 6 cases in which possible non–hip causes of pain (all in the spine) were identified. In 3 cases, a negative result guided the surgeon to seek alternative management options. The authors concluded that bone SPECT/CT is useful in patients with painful MoM arthroplasties in whom the cause of the pain is not identified after conventional clinical, laboratory, and imaging evaluation [121].

Variant 5: Symptomatic hip arthroplasty patient, infection excluded. Additional imaging following radiographs.
C. CT arthrography hip

Arthrography of the hip may be combined with CT [106]. However, most CT examinations of prostheses are not routinely performed with either IV or intraarticular contrast, particularly now that MAR algorithms for CT have been introduced [22,23].

Variant 5: Symptomatic hip arthroplasty patient, infection excluded. Additional imaging following radiographs.
D. CT hip

Liner wear: Liner wear may be detected on CT as thinning of the liner contour, development of a gap between a ceramic head and liner [22], shift of femoral head position within the acetabulum, and, in severe cases, metallic deposits in the soft tissues from contact between the femoral head and acetabular metal backing [122,123].

Loosening: Gillet et al [124] compared radiographs and CT with MAR (CT-MAR) for the diagnosis of component loosening. The sensitivity of CT for acetabular or femoral loosening was higher than for radiographs (33.3% and 51.5% for 2 readers for radiographs and 84.85 % for CT). The specificity of both radiographic and CT examinations was high and similar (96.9% and 100% for 2 readers for radiographs and 96.9% and 95.4% for CT). An advantage of CT is its ability to define the amount of the acetabular ingrowth surface that is in contact with bone [22].

Osteolysis: Osteolysis due to wear typically results in expansile well-defined lucent lesions. Helical CT with metal-artifact reduction is more sensitive than radiographs for identifying and quantifying osteolysis after THA [125]. Walde et al [126] confirmed CT to be more sensitive than radiographs for periacetabular lesion detection in a cadaver model (74.7% sensitivity for CT, 51.7% sensitivity for radiographs). Comparison of CT and MRI demonstrated that for lesions of all sizes, CT was less sensitive than MRI (CT, 74.7% sensitive and MRI, 95.4% sensitive) [126].

Most CT examinations of prostheses are not routinely performed with either IV or intraarticular contrast, particularly now that MAR algorithms for CT have been introduced [22,23].

Variant 5: Symptomatic hip arthroplasty patient, infection excluded. Additional imaging following radiographs.
E. Fluoride PET/CT skull base to mid-thigh

Although most investigations have focused on the ability of fluoride PET/CT to differentiate between aseptic loosening and periprosthetic infection, normal asymptomatic controls were included in several of them. Kobayashi et al [98] reported that increased periprosthetic uptake was present in all cases of loosening and infection but in only 1 (3.7%) of 27 controls. Kumar et al [99] reported that 10 of 12 (83.3%) asymptomatic hip prostheses demonstrated no periprosthetic uptake, whereas periprosthetic uptake was present around all 28 aseptically loosened and all 16 infected devices. Choe at al [97] reported that 3 of 17 (17.6%) control hip prostheses demonstrated minor periprosthetic uptake and the mean SUV_{max} (4) was significantly less than that of aseptic loosening (7) and infection (11); *P* < .01 and *P* < .001, respectively.

Variant 5: Symptomatic hip arthroplasty patient, infection excluded. Additional imaging following radiographs.
F. Image-guided anesthetic injection hip

Intraarticular anesthetic has been used to evaluate painful THAs, primarily to differentiate referred pain (especially from the spine) from pain originating in the hip [127]. Significant pain relief after intraarticular anesthetic injection suggests an intraarticular cause [128,129]. Lack of improvement is

thought to be unhelpful and warrants follow-up [129,130].

Variant 5: Symptomatic hip arthroplasty patient, infection excluded. Additional imaging following radiographs.
G. MRI hip

Wear: MRI is thought to be the most helpful tool for assessing the severity of intracapsular wear-induced synovitis [131]. On MRI, polyethylene wear-induced synovitis appears as low to intermediate signal intensity material that may distend the joint and extend into adjacent bursae [18].

Loosening: Burge et al [132] compared MRI with MAR techniques to radiographs with findings assessed at revision surgery. MRI was shown to be more sensitive than radiography for assessment of component loosening. For acetabular component loosening, MRI showed a sensitivity of 83% and a specificity of 98% compared with radiographs (sensitivity of 26% and specificity of 100%). For femoral component loosening, the sensitivity of MRI was 75% and the specificity 100%, whereas radiographs showed a sensitivity of 20% and a specificity of 100%. Backer et al [120] evaluated MRI and SPECT/CT for assessing loosening and found the sensitivity, specificity, PPV, and NPV of MRI were 86%, 88%, 60%, and 100% and of SPECT/CT were 93%, 97%, 90%, and 100%, respectively.

Osteolysis: There is some discrepancy in the literature regarding whether CT or MRI is the optimal study for detecting osteolysis. This may be related to technical factors. Potter et al [133] compared MRI appearances and surgical findings in 15 hips. In all operated cases, osteolysis found on MRI was confirmed at surgery.
Walde et al [126] evaluated CT and MRI for the detection of osteolytic lesions in a cadaver model. For lesions of all sizes, CT was 74.7% sensitive and MRI was 95.4% sensitive. The sensitivity of radiographs was only 51.7%.

However, Robinson et al [134] demonstrated a reduced sensitivity (27%) and specificity (1%) of MARS-MRI in comparison with CT-MAR for detecting osteolysis associated with painful MoM hip prostheses.

There is insufficient literature documenting an additional benefit of MRI with IV contrast, relative to noncontrast MRI, in this population.

Variant 5: Symptomatic hip arthroplasty patient, infection excluded. Additional imaging following radiographs.
H. Radiographic arthrography hip

Loosening: There is no recent relevant literature regarding the use of arthrography of the hip in the evaluation of component loosening. Older studies had suggested a selective role for arthrography for further analysis when there was hip pain and a question of loosening and negative or equivocal radiographs [135,136]. However, this examination appears to be little used currently.

Variant 6: Evaluation of symptomatic hip arthroplasty patient with metal-on-metal prosthesis or findings suggesting trunnionosis. Question of adverse reaction to metal debris. Additional imaging following radiographs.

Changes due to ARMD may occur months or years after surgery and can be symptomatic or asymptomatic [7,137]. The results of revision surgery may be poor, and early identification of soft

tissue changes of ARMD is thought to be important to improve outcome [7,138]. Investigators have sought to identify clinical, laboratory (eg, cobalt and chrome ion levels in the blood), and patient features that could identify patients with or likely to develop ARMD so that revision or close follow-up could be performed. These are outside the scope of this document. Imaging remains a critical resource although its optimal utilization is still being clarified.

Variant 6: Evaluation of symptomatic hip arthroplasty patient with metal-on-metal prosthesis or findings suggesting trunnionosis. Question of adverse reaction to metal debris. Additional imaging following radiographs.
A. CT hip

Overall, CT is less able than MRI to detect changes associated with ARMD. Noncontrast CT may be considered following other imaging modalities to assess osteolysis.

Robinson et al [134] found a sensitivity of 44% for CT in comparison with MARS-MRI for ARMD pseudotumor detection in patients with unexplained painful MoM prostheses. Also, the detected pseudotumors could not be classified as to structure using CT. Thus, the authors concluded that CT would not be a suitable alternative for MARS-MRI and another study such as US may be considered.

CT is also less able to detect muscle atrophy. In comparison with MARS-MRI, CT demonstrated a high rate of false-negative examinations for identifying muscle atrophy (sensitivity of 81%, specificity of 37%) [134].

Although, Walde et al [126] demonstrated in a cadaver model that MRI could detect osteolysis with greater sensitivity than CT. Robinson et al [134] demonstrated a reduced sensitivity (27%) and specificity (1%) of MARS-MRI in comparison with CT-MAR for detecting osteolysis associated with painful MoM hip prostheses.

Variant 6: Evaluation of symptomatic hip arthroplasty patient with metal-on-metal prosthesis or findings suggesting trunnionosis. Question of adverse reaction to metal debris. Additional imaging following radiographs.
B. MRI hip

MARS-MRI has been used as a reference standard for imaging of the soft tissues around prosthetic hips [134,139].

ARMD Pseudotumors: MRI allows demonstration, localization, measurement, follow-up, determination of solid or cystic composition, and classification of pseudotumors associated with ARMD [36]. Invasion of adjacent soft tissues, muscle atrophy, and tendon avulsions can also be assessed [36,40,131].

Mahajan et al [140] found a difference in the appearance of pseudotumors depending on the site of corrosion. The MoP group demonstrated the highest proportion of thick-walled cystic masses (56.7% in head-neck taper corrosion MoP and 46.5% in dual taper corrosion MoP versus 28.7% in MoM), whereas the MoM group had the highest proportion of thin-walled cystic masses [140]. Weber et al [141] found no significant difference between the MRI appearances of symptomatic and asymptomatic MoP ARMD.

Several studies have compared MARS-MRI with surgically proven ARMD pseudotumors. Sensitivity

ranged from 71% to 93.9%. Specificity ranged from 42.9% to 87% [39,40,66].

Lainiala et al [39] found a higher sensitivity for detecting ARMD pseudotumors for studies performed within 3 months before revision surgery (88% sensitivity, 78% specificity), and a lower sensitivity for studies obtained >1 year before revision surgery (sensitivity 29%, specificity 97%). It was suggested that studies >1 year not be used for clinical decision making or planning revision surgery.

Combined US and MARS-MRI studies: Comparison to surgical results suggests combining US and MARS-MRI improves accuracy. Small numbers of lesions detected on US are not visible on MRI, and some lesions seen on MRI are not apparent on US [41,52].

Wear: MRI is the most accurate imaging method for assessing wear induced synovitis [131]. Synovial characteristics may reflect the implant type and wear severity [9,142].

Osteolysis: As noted above, there are conflicting reports regarding the optimal study for detecting osteolysis. Walde et al [126] demonstrated in a cadaver model that MRI could detect osteolysis with greater sensitivity than CT. The sensitivity for detecting lesions was 51.7% for radiography, 74.7% for CT, and 95.4% for MRI. CT was more accurate; however, than MRI for measuring lesion volume [126].
Robinson et al [134]; however, demonstrated a reduced sensitivity (27%) and specificity (1%) of MARS-MRI in comparison with CT-MAR for detecting osteolysis associated with painful MoM hip prostheses. Morozov et al [143] evaluated 20 symptomatic patients with MoP prostheses with corrosion at the head-neck taper. Comparison of MRI and surgical findings found MRI to have limited sensitivity for either acetabular (11.1% sensitivity) or femoral (33.3% sensitivity) osteolysis [143].

There is insufficient literature documenting the additional benefit of MRI with IV contrast, relative to noncontrast MRI, in this population.

Variant 6: Evaluation of symptomatic hip arthroplasty patient with metal-on-metal prosthesis or findings suggesting trunnionosis. Question of adverse reaction to metal debris. Additional imaging following radiographs.
C. US hip

US can be used to detect ARMD pseudotumors (solid or cystic) and other findings seen with ARMD such as joint effusions, bursal collections, capsular and bursal thickening, and synovitis [36]. Kwon et al [52] found that US was valid and useful for detecting interval changes in lesion size and grade in comparison with MARS-MRI.

A summary of studies comparing US to MARS-MRI as the reference standard for detecting ARMD shows sensitivities for US of 69% to 100% and specificities of 83% to 96% [36].

In a series of 82 hips (82 patients) undergoing revision of MoM prostheses, Lainiala et al [51] found a sensitivity of 83% and specificity of 92% for US examination of pseudotumors in the trochanteric region and a sensitivity of 79% and specificity of 94% for identifying pseudotumors in the iliopsoas region.

Matharu et al [66] studied a series of 40 MoM hip resurfacing arthroplasties in 39 patients

undergoing revision surgery who had preoperative imaging with both US and MARS-MRI. Comparison with operatively identified pseudotumors showed US to have a sensitivity of 90.9% and a specificity of 42.9% compared with an MRI sensitivity of 93.9% and specificity of 57.1%. The PPV was similar (88.2% US, 91.2% MRI), but the NPV was higher for MRI (66.7% on MRI, 50.0% for US) [66].

Combined US and MARS-MRI studies: Comparison to surgical results suggests combined US and MARS-MRI improves accuracy. Small numbers of lesions detected on US are not visible on MRI, and some lesions seen on MRI are not apparent on US [41,52].

Variant 7: Hip arthroplasty patient with trochanteric pain. Suspect abductor injury, or trochanteric bursitis, or other soft tissue abnormality. Additional imaging following radiographs.

Postoperative greater trochanter pain may be due to greater trochanteric bursitis, or other etiologies such as gluteus minimus or medius tendinitis, or tears or avulsion [73]. Trochanteric bursitis is reported to occur in up to 17% of hips after THA and may be related to the surgical approach [144,145].

Variant 7: Hip arthroplasty patient with trochanteric pain. Suspect abductor injury, or trochanteric bursitis, or other soft tissue abnormality. Additional imaging following radiographs.
A. CT hip with IV contrast

CT is less optimal than MRI for assessing soft tissues [22]. Fractures and fluid collections can be identified on CT.

Variant 7: Hip arthroplasty patient with trochanteric pain. Suspect abductor injury, or trochanteric bursitis, or other soft tissue abnormality. Additional imaging following radiographs.
B. Image-guided anesthetic +/- corticosteroid injection hip joint or surrounding structures

If trochanteric bursitis is thought to be a source of pain, Robbins et al [144] suggest the bursa may be injected with either lidocaine alone as a diagnostic test, or in combination with a corticosteroid as a therapeutic measure.

Variant 7: Hip arthroplasty patient with trochanteric pain. Suspect abductor injury, or trochanteric bursitis, or other soft tissue abnormality. Additional imaging following radiographs.
C. MRI hip without and with IV contrast

MRI can be used to assess peritrochanteric structures including the gluteus minimus and medius muscles, abductor tendons, and the trochanteric bursa [146,147]. There is no relevant literature documenting the additional benefit of MRI with IV contrast, relative to noncontrast MRI, in this population.

Pfirrmann et al [147] compared the MRI findings about the greater trochanter in 25 patients after primary THA without pain and 39 patients with trochanteric pain and abductor weakness. Although several abnormalities were seen in both symptomatic and asymptomatic groups, defects of the abductor tendons and fatty atrophy of the gluteus medius muscle and the posterior part of the gluteus minimus muscle were uncommon in asymptomatic patients. Comparison of MRI findings with findings at surgical revision in 14 patients confirmed all MRI tendon findings.

Joint distension and decompression of synovitis into the greater trochanteric bursa and fluid undermining the hip abductors can be assessed on MARS-MRI [72]. Weber et al [141] noted that extracapsular disease associated with ARMD could be misinterpreted as trochanteric bursitis.

Variant 7: Hip arthroplasty patient with trochanteric pain. Suspect abductor injury, or trochanteric bursitis, or other soft tissue abnormality. Additional imaging following radiographs.
D. Radiographic arthrography hip

Weakness or detachment of the abductor muscles may occur after THA using an anterolateral approach [148]. Avulsion of the reattached gluteus medius can provide a communication between the hip joint and the trochanteric bursa that can be documented on arthrography [148]. Ylinen et al [148] found that all 14 patients with this communication had abductor avulsion at revision surgery. A negative study did not exclude disruption (sensitivity 60.1%, specificity 100%). The failure of contrast to extend to the trochanteric region in these cases was attributed to blocking of its flow by a fibrous capsule.

Variant 7: Hip arthroplasty patient with trochanteric pain. Suspect abductor injury, or trochanteric bursitis, or other soft tissue abnormality. Additional imaging following radiographs.
E. US hip

US can identify tendinopathy, partial tear, and complete tears/avulsion of the gluteus medius tendon in nonsurgical and postsurgical patients [47,73]. Bancroft and Blankenbaker [149] noted the postsurgical appearance of repaired gluteal tendons will vary depending on the type of procedure performed, but continuity of the reattached tendon should be present and can be demonstrated on US. Garcia et al [150] used US to evaluate the abductor tendons after THA using a lateral transgluteal approach. They found abductor tendon tears in half of patients with positive Trendelenburg signs (4 of 8) and in 3 of 26 patients with negative Trendelenburg tests. No comparison to surgical revision was available.

US can detect trochanteric bursitis [47]. According to Douis et al [47], differentiation between bursitis and gluteus medius tendinosis may be difficult, and the 2 may coexist.

Summary of Highlights

- **Variant 1**: Radiography hip is usually appropriate for routine follow-up of the asymptomatic patient after hip arthroplasty.
- **Variant 2**: Radiography hip is usually appropriate for the initial imaging of a symptomatic hip prosthesis.
- **Variant 3**: In the setting of acute injury, CT hip without IV contrast is usually appropriate as the next imaging study of a symptomatic hip prosthesis following radiography.
- **Variant 4**: In the setting of a symptomatic hip prosthesis assessed with radiography in which infection is not excluded, image-guided aspiration hip, or MRI hip without IV contrast, or WBC scan and sulfur colloid scan hip is usually appropriate as the next imaging study. These are complementary procedures (ie, more than one procedure may be ordered. Joint aspiration with synovial fluid analysis remains probably the most useful test for confirming the presence or absence of infection and identifying the causative organism.

- **Variant 5**: In the setting of a symptomatic hip prosthesis evaluated with radiography and when infection has been excluded, CT hip or MRI hip without IV contrast is usually appropriate as the next imaging study. These procedures are equivalent alternatives (ie, only one procedure will usually be ordered to provide the clinical information to effectively manage the patient's care). Choice will depend on local preference/expertise.
- **Variant 6**: MRI hip without IV contrast is usually appropriate following radiographs for the evaluation of symptomatic hip arthroplasty patient with MoM prosthesis or findings suggesting trunnionosis when there is question of adverse reaction to metal debris.
- **Variant 7**: In the setting of a hip arthroplasty patient with trochanteric pain that has been evaluated with radiography, US hip or MRI hip without IV contrast is usually appropriate for suspected abductor injury, or trochanteric bursitis, or other soft tissue abnormality. 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.

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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