American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Imaging After Total Hip Arthroplasty**

Variant 1: **Follow-up of the asymptomatic patient with a total hip arthroplasty.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray hip	9		☢☢☢
CT hip without IV contrast	1	This procedure can be considered in late follow-up.	☢☢☢
CT hip with IV contrast	1		☢☢☢
CT hip without and with IV contrast	1		☢☢☢
MRI hip without IV contrast	1		O
MRI hip without and with IV contrast	1		O
Tc-99m bone scan hip	1		☢☢☢
US hip	1	This procedure can be used as a screening test for metal-on-metal prostheses.	O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 2: **Total hip arthroplasty, evaluating suspected component malposition.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray hip	9		☢☢☢
CT hip without IV contrast	6		☢☢☢
Fluoroscopy hip	4		Varies
CT hip with IV contrast	1		☢☢☢
CT hip without and with IV contrast	1		☢☢☢
MRI hip without IV contrast	1		O
MRI hip without and with IV contrast	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Imaging After Total Hip Arthroplasty**

Variant 3: **Evaluating patients with a painful primary total hip arthroplasty: infection not excluded.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray hip	9	This procedure is complementary to other studies.	☢☢☢
Aspiration hip	9	This procedure is the best test for excluding infection.	Varies
Aspiration and arthrography hip	6		Varies
CT hip with IV contrast	5		☢☢☢
MRI hip without and with IV contrast	5		O
In-111 WBC and Tc-99m sulfur colloid scan hip	5	This procedure is often considered the best imaging test for infection.	☢☢☢☢
CT hip without IV contrast	4		☢☢☢
MRI hip without IV contrast	4		O
Tc-99m bone scan hip	4		☢☢☢
Tc-99m bone scan and Ga-67 scan hip	4		☢☢☢☢
FDG-PET hip	4		☢☢☢
F-18 fluoride PET hip	3		☢☢☢
US hip	3		O
CT hip without and with IV contrast	1		☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 4: **Evaluating patients with a painful primary total hip arthroplasty: suspect aseptic loosening (infection excluded).**

Radiologic Procedure	Rating	Comments	RRL*
X-ray hip	9		☢☢☢
CT hip without IV contrast	5		☢☢☢
Tc-99m bone scan hip	5		☢☢☢
X-ray arthrography hip	5		☢
Tc-99m nuclear arthrography hip	4		☢☢☢
FDG-PET hip	3		☢☢☢
F-18 fluoride PET hip	3		☢☢☢
Image-guided anesthetic injection of hip	3	A positive study usually indicates an articular cause for pain.	Varies
MRI hip without IV contrast	3		O
CT hip with IV contrast	1		☢☢☢
CT hip without and with IV contrast	1		☢☢☢
MRI hip without and with IV contrast	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Imaging After Total Hip Arthroplasty**

Variant 5: **Evaluating suspected particle disease (aggressive granulomatous disease, infection excluded).**

Radiologic Procedure	Rating	Comments	RRL*
X-ray hip	9	This procedure is complementary to other studies.	☢☢☢
CT hip without IV contrast	8	This procedure is an alternative to MRI.	☢☢☢
MRI hip without IV contrast	7	This procedure is an alternative to CT.	O
MRI hip without and with IV contrast	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	O
Tc-99m bone scan hip	3		☢☢☢
CT hip with IV contrast	1		☢☢☢
CT hip without and with IV contrast	1		☢☢☢
FDG-PET hip	1	Very limited data is available.	☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 6: **Evaluating patients with a painful primary metal-on-metal total hip arthroplasty or surface replacement: evaluate for aseptic lymphocyte-dominated vasculitis-associated lesion.**

Radiologic Procedure	Rating	Comments	RRL*
MRI hip without IV contrast	8		O
US hip	6		O
X-ray hip	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	☢☢☢
MRI hip without and with IV contrast	5	Gadolinium contrast is usually not needed but may define areas of necrosis.	O
Aspiration hip	5	This procedure can detect metallosis.	Varies
CT hip without IV contrast	3		☢☢☢
CT hip with IV contrast	3		☢☢☢
CT hip without and with IV contrast	1		☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Imaging After Total Hip Arthroplasty**

Variant 7: **Total hip arthroplasty, trochanteric pain; suspect abductor injury or trochanteric bursitis.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray hip	9	This procedure is complementary to other studies.	☢☢☢
MRI hip without IV contrast	8	This procedure is an alternative to US.	O
US hip	7	This procedure is an alternative to MRI.	O
CT hip without IV contrast	3		☢☢☢
X-ray arthrography hip	3		☢
MRI hip without and with IV contrast	2		O
CT hip with IV contrast	1		☢☢☢
CT hip without and with IV contrast	1		☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 8: **Total hip arthroplasty; suspect iliopsoas bursitis or tendinitis.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray hip	9	This procedure is complementary to other studies.	☢☢☢
MRI hip without IV contrast	8	This procedure is an alternative to US.	O
US hip	8	This procedure is an alternative to MRI.	O
Injection anesthetic iliopsoas tendon	6		Varies
CT hip without IV contrast	4	This procedure is useful to assess component position.	☢☢☢
CT hip with IV contrast	1		☢☢☢
CT hip without and with IV contrast	1		☢☢☢
MRI hip without and with IV contrast	1		O
X-ray arthrography hip	1		☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Imaging After Total Hip Arthroplasty**

Variant 9: **Total hip arthroplasty, suspect nerve damage.**

Radiologic Procedure	Rating	Comments	RRL*
MRI hip without IV contrast	9	MR neurography protocols may be used.	O
X-ray hip	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	☢☢☢
US hip	4		O
CT hip without IV contrast	2		☢☢☢
MRI hip without and with IV contrast	2		O
CT hip with IV contrast	1		☢☢☢
CT hip without and with IV contrast	1		☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 10: **Total hip arthroplasty, evaluate heterotopic bone.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray hip	9		☢☢☢
CT hip without IV contrast	7	This procedure is complementary to radiography when additional detail is needed.	☢☢☢
Tc-99m bone scan hip	5	The panel noted this procedure is not often currently used for evaluating heterotopic bone.	☢☢☢
MRI hip without IV contrast	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating. Neurovascular structures may be delineated.	O
US hip	4		O
CT hip with IV contrast	1		☢☢☢
CT hip without and with IV contrast	1		☢☢☢
MRI hip without and with IV contrast	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Imaging After Total Hip Arthroplasty**

Variant 11: **Total hip arthroplasty, suspect periprosthetic fracture.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray hip	9		☢☢☢
CT hip without IV contrast	8	This procedure is complementary to radiography for more detail or if radiograph is negative.	☢☢☢
Tc-99m bone scan hip	5	This is no longer a primary imaging test, but this procedure can be useful when cross-sectional imaging is negative.	☢☢☢
MRI hip without IV contrast	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	O
CT hip with IV contrast	1		☢☢☢
CT hip without and with IV contrast	1		☢☢☢
MRI hip without and with IV contrast	1		O
US hip	1		O
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

IMAGING AFTER TOTAL HIP ARTHROPLASTY

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Summary of Literature Review

Introduction/Background

The number of primary total hip arthroplasties performed in the United States was 220,000 in 2003 and this number is expected to rise to 572,000 by 2030 [1]. Results are often long lasting, with approximately 87% survival after 10 years [2]. Revisions are most often due to instability/dislocation, mechanical loosening, or infection [3]. Metal-on-metal prostheses can be associated with additional complications, including tissue hypersensitivity reaction.

Patients with loosening or infection usually (but not always) have pain, whereas those with particle disease and resulting osteolysis or with metal hypersensitivity can be asymptomatic. Pain patterns can suggest the correct diagnosis, but complications can be difficult to identify clinically. Therefore, understanding the use of imaging is of particular importance.

All symptomatic patients should undergo radiography. Availability of old radiographs to compare to new ones facilitates the diagnosis of subtle changes such as can occur in loosening, particle disease, or infection.

Overview of Imaging Modalities

Radiography: Radiography is the standard first examination for evaluating total hip arthroplasties [2]. Radiographs are used clinically to evaluate component position and wear [4,5]. Radiographic features of loosening can be present even if symptoms are absent. Prior to revision surgery, standard views and additional views (such as the Lowenstein lateral view or oblique views) can be helpful [6].

Arthrography: Fluoroscopy, computed tomography (CT), or ultrasound (US) can be used for needle placement. Contrast instilled into the joint can detect sinus tracts, and fistulae and collections that connect to the joint and can help evaluate component loosening [7]. Fluid sampling can be done at the time of arthrography.

Computed tomography: Imaging with a metal prosthesis (or especially with bilateral metal prostheses) in place using older scanners and techniques resulted in significant image degradation due to artifacts. Newer equipment and imaging protocols, however, have decreased artifact and can aid in assessment of the bone, cement, and soft tissues around metal components [8-10]. Osteolysis, implant position, hardware integrity, wear, fractures, heterotopic ossification, hematomas, and fluid collections can be assessed [7,11]. Dual-energy CT can reduce artifacts due to metal prostheses and reduce the radiation dose [7,8,12].

Quantitative CT: Quantitative CT allows the remodeling of trabecular and cortical bone near an acetabular or femoral component to be assessed [13,14]. However, this remains largely a research tool.

Magnetic resonance imaging (MRI): Improvements in MRI techniques have enabled useful information to be obtained even around total hip replacements [7,15-25]. Structures such as the joint capsule, intra-articular content, muscles, nerves, vessels, and tendons can be evaluated [7].

Dual-energy x-ray absorptiometry: This technique has been used to measure changes in bone density around

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femoral and acetabular components. Bone density changes associated with various component designs can be studied [26,27]. However, dual-energy x-ray absorptiometry scanning after total hip arthroplasty (THA) remains largely a research tool.

Bone scan: Bone scans are sensitive indicators of a failed arthroplasty but are not able to reliably indicate the cause of failure [28]. Thus, the absence of increased uptake on the bone scan is thought to be strong evidence against a prosthetic complication such as loosening or infection.

Gallium scan: Gallium-67 citrate accumulates not only in areas of infection but also in areas of new bone formation and in aseptic inflammation. Therefore, gallium scans are usually compared to bone scans to identify areas of disproportionately increased or geographically disparate activity on the 2 scans [28].

Labeled leukocyte (WBC) and WBC/Tc-99m sulfur colloid bone marrow scanning: Leukocytes, labeled or unlabeled, accumulate in a number of infectious processes, including acute osteomyelitis, acute exacerbations of chronic osteomyelitis, septic arthritis, and abscesses. Leukocytes also accumulate in bone marrow, the normal distribution of which can be variable. "Orthopedic hardware, fractures, neuropathic joints, and heterotopic bone alter the 'normal' distribution of marrow, making it difficult to differentiate labeled leukocyte uptake in unusually located, but otherwise normal, marrow from uptake in infection" [29]. Combining marrow scans with WBC scans can help distinguish WBC uptake due to variations in marrow distribution from uptake due to infection [29]. Both radiopharmaceuticals accumulate in bone marrow but only WBCs accumulate in infection [29]. The addition of marrow imaging to WBC scanning has improved accuracy (primarily by decreasing false-positive results) to about 90%, but false-negative cases (decreased sensitivity) can occur [30].

Nuclear arthrography: Intra-articular injection of radiopharmaceuticals was first used for evaluation of femoral component loosening, but later procedural changes allowed both acetabular and femoral components to be evaluated. When performed simultaneously with bone scanning, the nuclear arthrography component of the examination is performed with various indium-111 complexes. These complexes, however, are not approved for use in the United States.

Fluorine-18-fluoro-deoxyglucose (FDG) positron emission tomography (PET): Increased uptake of FDG reflects increased glucose metabolism [31]. Increased uptake is seen in infected prostheses as well as in the setting of aggressive granulomatous disease due to increased energy demand. Overall accuracy for detecting these complications is 89% [32]. FDG-PET requires only 1 injection and results are available within 4 hours, but the test is not universally available and is more expensive than the 3-phase bone scan [32].

^{18}F-fluoride sodium fluoride (^{18}F-fluoride) is an exquisitely sensitive bone-seeking PET radiopharmaceutical used to identify skeletal abnormalities. Uptake of ^{18}F-fluoride depends on blood flow and bone remodeling, similar to the uptake mechanism of Tc-99m-MDP, but with superior pharmacokinetic characteristics, including faster blood clearance and twofold higher uptake in bone. Nearly all causes of increased new bone formation produce increased ^{18}F-fluoride uptake. ^{18}F-fluoride uptake can be quantified by calculating the standardized uptake value (SUV) [33]. Data on ^{18}F-fluoride-PET imaging of hip arthroplasties are limited. Potential uses include diagnosing avascular necrosis following hip resurfacing arthroplasty [34,35], analyzing metabolic bone responses to prosthetic implants to obtain information about implant stability [36], and differentiating the aseptically loosened from the infected prosthesis [37].

US: This technique is useful for imaging soft tissues around a hip prosthesis, including effusion, collections, synovial thickening, tissue hyperemia, tendons, and bursae [38]. The "normal" sonographic appearances after THA have been described [39]. US can also be used to guide joint aspiration or synovial biopsy.

This review presents information on the usefulness of various imaging procedures in patients with THA for surveillance and for the assessment of certain complications.

Discussion of the Imaging Modalities by Variant

Variant 1: Follow-up of the asymptomatic patient with a total hip arthroplasty.

Early postoperative radiographs: Radiographs *shortly after* surgery are usually recommended to identify surgical complications and provide a baseline for future evaluation. They are particularly important after revision surgery. Immediate postoperative examination can demonstrate complications such as dislocation, fracture, or screw penetration; but the rate of these is low, can be clinically suspected, and postoperative radiographs using portable equipment may be technically suboptimal for their assessment. Studies by Mulhall et al [40] and by Ndu et al [41]

concluded that the routine postoperative radiographic examination is better performed in the radiology suite.

Late radiographic follow-up is usually advocated to identify osteolysis [42] or loosening [43]. Since aggressive osteolysis occurs most often several years postoperatively, a hiatus in obtaining radiographs has been suggested, but the exact timing of follow-up examination varies [42,44]. One review of 18,486 primary total hip arthroplasties found radiological follow-up in order to monitor component loosening to be unnecessary in asymptomatic patients in the first 5 postoperative years [43].

The value of postoperative radiographs generally has been questioned. One reason is their limited sensitivity for detecting osteolysis [9]. Another is the low number of revisions shown to have been performed (4 individuals, 3.6%) at a tertiary referral center for an asymptomatic indication [45], and the third is based on cost-benefit analysis [46]. Bolz et al [46] evaluated 3 follow-up strategies for 7 years after primary total hip replacement: 2 yearly routine follow-ups; Arthroplasty Society of Australia strategy of a minimum follow-up after 3 months, at 1 to 2 years, and then no follow-up for 7 years; and a third strategy of no follow-up. The no–follow-up strategy costs were lower and health benefits slightly higher at 7 years.

Patients with metal-on-metal prostheses may need a different schedule. Regarding clinical follow-up, the United States Food and Drug Administration recommends that "If a patient with a metal-on-metal ... hip implant is asymptomatic and has a well-functioning hip, follow-up should occur periodically (typically 1 to 2 years)" [47].

CT for surveillance: Stulberg et al [48] suggest a CT scan at 5–7 years postoperatively in young, active patients with uncemented components or in older, less active patients with hybrid prostheses and radiographic evidence of wear or osteolysis to establish a baseline. Follow-up would depend on the findings. Contrast is not needed.

MRI: Cooper et al [49] found reactive synovitis on noncontrast, technically optimized MRI in 13 of 33 asymptomatic patients with hip prostheses (39%) at an average of 23 months after surgery. However, the long-term significance of this finding is not certain.

Mistry et al [50] evaluated 20 asymptomatic patients (22 THAs, 10 with metal-on-polyethylene and 12 with metal-on-metal designs). The mean time to examination was 46 months for metal-on-polyethylene and 70 months for metal-on-metal designs. At least 6 of 12 metal-on-metal prostheses demonstrated abnormal periprosthetic soft-tissue collections. Again, the ultimate significance of this finding is uncertain. The Arthroplasty Society of Australia in 2012 recommended that any patient who has a metal-on-metal articulation in a conventional stemmed total hip replacement with a head size ≥36 mm should be reviewed annually with symptom review, radiography, and soft-tissue imaging [44]. According to the FDA, for patients with metal-on-metal prostheses, if the orthopedic surgeon feels the hip is functioning properly and the patient is asymptomatic, there is no clear need to routinely check metal ion levels in the blood or to perform soft-tissue imaging (such as MRI) [47].

Bone scan: Bone scan appearances after THA are variable, reflecting the stress on the adjacent bone as well as any complications that occur. One study of asymptomatic *cemented* total hip prostheses indicated that persistent increased uptake could be seen at the tip of the femoral stem in about 10% of patients up to 3 years after surgery, at the greater trochanter in 20%, and at the acetabulum in 12% at 2 years [51]. Uptake around the femoral shaft decreased by 9 months after surgery. These authors recommend that a baseline bone scan be obtained between 9 and 12 months after surgery.

Normal bone scan appearances after *uncemented* THAs depend on the type of prosthetic components used. In 25 uncomplicated porous-coated total hip prostheses examined with 3-phase bone scanning serially over 2 years, the delayed bone images showed focal uptake at the tip of the femoral component at some time during the study [52].

WBC scans: In this same investigation, increased In-111 WBC activity at the tip of the femoral component was present around 80% of prostheses. The authors noted that baseline 3-phase bone scans and In-111 WBC scans are of value [52], although this does not appear to be usual practice currently.

US: The role of sonography for routine surveillance of metal-on-polyethylene prostheses is unclear. It can be helpful in detecting masses seen in association with metal-on-metal arthroplasties (see below).

Variant 2: Total hip arthroplasty, evaluating suspected component malposition.

Radiographs: Radiographs are the usual method for evaluating component positions such as acetabular inclination, acetabular anteversion, lateral offset, and varus or valgus stem angle [2,53].

Specialized projections have been suggested for some assessments. A modified Budin view (obtained sitting), for example, has been shown to be reliable and valid for the measurement of femoral component anteversion [54].

Several methods have been described for assessing acetabular component anteversion on radiographs. Positioning for radiographic examination may be important. Also, the delineation of the reference plane is important in assessing the accuracy of radiographic methods for determining acetabular anteversion on anteroposterior (AP) radiographs in comparison to CT. Lu et al [55] found radiographic assessment of acetabular component anteversion to be reliable and accurate in comparison to CT. Nho et al [56] found excellent reliability and various measures correlated well with CT measurements. McArthur et al [57] found that although "CT allows for accurate measurement of acetabular component version; …when properly positioned, cross-table lateral radiograph-derived measurements are similarly accurate." Marx et al [58] found, however, that for exact calculation of anteversion, CT may be necessary.

CT: A CT scan can augment radiographic assessment, document acetabular overhang, and better define the position of acetabular fixation screws [10]. Murray [59] has reviewed the various definitions of acetabular orientation, and Ghelman et al [60] found CT to be more accurate than cross-table radiographs in measuring "planar" ("radiographic") acetabular component anteversion. However, recent work indicates that acetabular inclination affects the CT measurement of acetabular anteversion, and a method for correction for inclination has been developed using reformatted images [61].

Variant 3: Evaluating patients with a painful primary total hip arthroplasty: infection not excluded.

Infection occurs in 1%–2% of primary total hip arthroplasties and is even more frequent after revision procedures [62]. Ong et al [63] found that the incidence of infection was 1.63% within 2 years and 0.59% between 2 and 10 years in the Medicare population. Confirmation of infection of failed hip prostheses can be difficult since organisms may be inaccessible, residing in a biofilm [64,65]. As summarized by Spangehl et al [62], no test is perfectly sensitive and specific for the diagnosis. Recent definition of periprosthetic joint infection has included major and minor criteria but not specifically imaging criteria [66]. Nonetheless, imaging studies can be performed.

Radiography: Normal radiographs do not exclude infection. One study evaluated radiographs of 20 infected THAs and found half to be normal [67]. Loosening occurring within the first 2 years after surgery suggests infection.

CT: A prospective study of 65 patients with painful total hip arthroplasties using helical CT has shown that periosteal new bone formation was always associated with infection (100% specificity) but had only 16% sensitivity [68]. Soft-tissue findings were more accurate. Fluid collections in muscles and perimuscular fat had a 100% positive predictive value (sensitivity, 41%; specificity, 100%). The absence of joint distension had a 96% negative predictive value (sensitivity, 83%; specificity, 96%). Tomas et al [69] found that, in addition to using CT for guidance for joint aspiration, findings of periprosthetic fluid collections, acetabular malposition, and >1 mL of aspirated fluid were significantly higher in infected as compared to noninfected hip prostheses.

MRI: MRI in patients with infection can demonstrate joint effusion, edema and enhancement of synovial and extracapsular soft tissues and bone, the presence of extracapsular collections, bone destruction, and adenopathy [7]. In a group of patients with painful total hip arthroplasties thought to be infected, Aliprandi et al [70] were able to use MRI to identify and characterize fluid collections as being serous, purulent, or bloody and to detect soft-tissue edema and fistulous tracts. A "lamellated," hyperintense appearance of the synovial tissue has been reported as having high predictive value for infection in knee arthroplasty patients [71], and this finding has also been demonstrated in the hip [7].

Bone scan: Bone scans are sensitive but not specific for periprosthetic hip infection [72]. Larikka et al [73] noted that if a bone scan is normal, no additional WBC scans are needed. Tehranzadeh et al [74] found that a negative bone scan makes infection or loosening very unlikely, as bone scans were both 100% sensitive and specific in 15 surgically proven cases (5 with infection).

In multiple studies, sensitivities for evaluating hip prosthesis infection using bone scan range from 44% to 100% and specificities from 77% to 100% [28,74-78]. Love et al [28] indicate that the overall accuracy of bone scan in the evaluation of the painful prosthetic joint is "…too low to be clinically useful, except perhaps as a screening test or in conjunction with other radionuclide studies like gallium or labeled leukocyte imaging."

Although some authors suggest that periprosthetic uptake patterns allow differentiation of infection from aseptic loosening, others suggest this is not reliable [28]. Furthermore, performing a 3-phase bone scan apparently does not improve the accuracy of the test [28,74,75,77,78].

Gallium scan: False-negative gallium scans can occur in patients treated with antibiotics. A positive gallium scan is very likely to indicate infection, but a normal scan does not exclude infection. Overall, the sensitivity of bone/gallium scans ranges from 37% to 83% and the specificity from 59% to 100% [28,74,75,79-81]. Love et al [28], in summary, commented that for prosthetic infection, "Combined bone/gallium imaging offers only a modest improvement over bone scintigraphy alone." Similarly, Aliabadi et al [75] concluded that because of its low sensitivity, gallium scanning is generally not useful in evaluation of the painful hip replacement.

WBC scanning: A range of results have been reported using labeled WBCs alone for evaluation of infection following THA. Sensitivities range from 50% to 100% and specificities from 23% to 100% [79,81-84]. Limited sensitivity (false-negative examination) has been attributed to the chronicity of infection (although Love et al note that neutrophils are present even in chronic infections), and poor specificity (false-positive examination) has been ascribed to the presence of nonspecific inflammation (although this explanation also has been disputed) [28]. Love et al [28] attribute imperfect results to an inability to develop a satisfactory method for image interpretation and to marrow expansion that makes it difficult to differentiate normal marrow from infection. A semiquantitative approach, delayed scanning, and combining the WBC scan with a 3-phase bone scan have been suggested to improve test accuracy [73,84].

WBC/marrow scan: Four studies evaluating the results of WBC/marrow scans for infection in hip prostheses have found a sensitivity of 46%, specificity of 100%, and accuracy of 88% [30]; sensitivity of 100%, specificity of 97%, and accuracy of 98% [83]; sensitivity of 92%, specificity of 100%, and accuracy of 97% [85]; and sensitivity of 100%, specificity of 88%, and accuracy of 95% [86].

FDG-PET: FDG-PET images are high-resolution tomographic images and can be performed within a few hours after radiopharmaceutical injection [28,37,72,78,87]. Encouraging results have been reported by some investigators for differentiating infection from aseptic loosening of THAs. For example, Zhuang et al [88] found a sensitivity, specificity, and accuracy of 90%, 89.3%, and 89.5%, respectively, for prosthetic hip infections. Mumme et al [89] found a sensitivity of 91%, specificity of 92%, and accuracy of 91% for diagnosing infection, an improvement in both sensitivity and specificity over 3-phase bone scan. Pill et al [90] found FDG-PET to be more sensitive than WBC/marrow scan (95.2% compared to 50%) and nearly as specific (93% compared to 95.1%).

The results of other investigations, however, have been less satisfactory. Stumpe et al [78] examined 35 patients with painful total hip arthroplasties using FDG-PET, radiography, and 3-phase bone scan. They reported that FDG-PET was less accurate than the 3-phase bone scan and was more specific but less sensitive than conventional radiography for the diagnosis of infection. Love et al [72] noted that regardless of the criteria used for interpretation, FDG-PET does not differentiate infection from aseptic loosening and is not a suitable replacement for WBC/marrow imaging for diagnosing prosthetic joint infection. Delank et al [31] found that although a negative FDG scan excludes infection, a positive scan could not accurately differentiate infection from aseptic loosening. García-Barrecheguren et al [91] studied 24 hip replacements and reported that FDG-PET was neither sensitive (64%) nor specific (67%) for infection.

Various techniques have been used to analyze and interpret FDG-PET scans following THA. Patterns of uptake and intensity of uptake have been studied. Some authors find that localization of uptake at the prosthesis-bone interface of the femoral component is an important indicator of infection [77,88,92]. A review of 5 selected studies by Zoccali et al [93] found the weighted sensitivity of FDG-PET scanning for total hip prosthesis infection to be 82.8% and the weighted specificity to be 87.3%. It was concluded that FDG-PET scanning could be a valid option if research is able to find an uptake pattern specific for septic versus aseptic loosening.

Issues related to the use of FDG-PET/CT for evaluation of hip prostheses are being evaluated and its role has not been fully assessed.

^{18}F-fluoride PET: Kobayashi et al [37] studied ^{18}F-fluoride PET scans in asymptomatic controls and in patients with septic and aseptic loosening. In 27 surgically proven cases, ^{18}F-fluoride PET scanning was 95% sensitive and 88% specific for infection. In the septic loosening group, periprosthetic uptake was more diffuse and the maximum SUV (SUV_{max}) significantly higher than in the control and aseptically loosened groups. Nonspecific

uptake on ^{18}F-fluoride PET scans was observed during the first postoperative year even in uncomplicated cases.

Choe et al [94] analyzed periprosthetic uptake patterns on ^{18}F-fluoride PET and found that major uptake (defined as uptake involving >50% of at least 1 component with an SUV_{max} >5) was present in 23 of 24 infected components. They concluded that ^{18}F-fluoride PET may be helpful for selecting an area for tissue sampling and for identifying components that can be preserved at surgery.

US: One study found that a 3.2-mm bone capsule distance (indicating increased joint fluid) was 100% sensitive for the diagnosis of infection but not entirely specific (74%) [95]. The combination of intra-articular effusion with extra-articular extension was indicative of infection. Unlike arthrography, both communicating and noncommunicating abscesses can be detected with US [96]. Sinus tracts can also be identified [39].

Joint aspiration and aspiration/arthrography: Joint aspiration, although not perfect, is probably the most useful test for confirming of the presence or absence of infection. The sensitivity of preoperative aspiration ranges from 40% to 93% and the specificity from 82% to 100% [97-99]. Thus, both false-positive and false-negative studies occur. Debate remains regarding the indications for aspiration. In 2010, the American Academy of Orthopaedic Surgeons recommended a selective approach to aspiration of the hip based on the patient's probability of periprosthetic joint infection and the results of the erythrocyte sedimentation rate and C-reactive protein [86]. It was recommended that aspirated fluid be sent for microbiologic culture and white blood cell count and differential [86]. In cases where there is a discrepancy between the probability of periprosthetic joint infection and the initial aspiration culture result, repeat aspiration was suggested. They recommend that patients be off antibiotics for a minimum of 2 weeks prior to obtaining intra-articular culture. Their meta-analysis indicated that hip aspiration for culture is a good test to "rule in" infection but is not as good to "rule out" infection (positive likelihood ratio, 9.8; negative likelihood ratio, 0.33).

Arthrography can be performed at the time of joint aspiration and can show signs suggesting infection such as abscesses or sinus tracts.

Variant 4: Evaluating patients with a painful primary total hip arthroplasty: suspect aseptic loosening (infection excluded).

Radiographs: Loosening (complete failure of fixation of an implant at surgery) is usually evaluated on radiographs [7]. However, there may be difficulty in the identification and quantification of lucent zones, which are important radiographic indicators of loosening. Smith et al [100] compared the use of various radiological methods to evaluate femoral and acetabular loosening. They found these exhibited limited inter- and intraobserver reliability on an electronic picture archiving and communications system.

Evaluation of radiographs for femoral component aseptic loosening has revealed a sensitivity of 81% and a specificity of 74% compared to surgical findings or subsequent clinical course [101]. A meta-analysis of 32 English-language articles published between January 1975 and June 2004 on the diagnostic performance of radiography revealed a sensitivity of 82% and a specificity of 81% for femoral component loosening [102].

A sensitivity of 85% and a specificity of 85% have been found for radiographic assessment of acetabular loosening [103]. Radiography had the highest diagnostic accuracy in the evaluation of aseptic loosening of the acetabular component in comparison to subtraction arthrography, nuclear arthrography, and bone scan [103].

CT: CT (with metal artifact reduction protocols) can be used to evaluate component fixation [10].

MRI: The role of MRI in detecting component loosening is not yet established. In 1 series, MRI documented femoral component loosening as low-signal fluid collections parallel to the component on fast-spin-echo T1-weighted images [104].

Bone scan: One study found that the combination of bone scan and radiography was about 84% sensitive and 92% specific for loosening, infection, or both in patients without obvious radiographic findings of loosening. However, it was not possible to distinguish between aseptic loosening and infection [75]. Temmerman et al [101] found bone scanning to have a sensitivity of 88% and a specificity of 50% for the diagnosis of aseptic femoral component loosening. This series did not include patients with infection. A meta-analysis of 32 English-language articles revealed a pooled sensitivity of 85% (95% confidence interval [CI], 79–89) and a specificity of 72% (95% CI, 64–79) for the diagnosis of aseptic femoral component loosening [102].

For acetabular aseptic loosening, a sensitivity of 83% and a specificity of 67% have been reported [103]. Meta-

analysis of 28 studies yielded a pooled sensitivity of 67% (95% CI, 57–97) and a specificity of 75% (95% CI, 64–83) for acetabular loosening [105].

Nuclear arthrography: In 1 series of *uncemented* components, this procedure, which was 70% sensitive and 100% specific for femoral loosening, was more sensitive than contrast arthrography [106]. In another study, the nuclear arthrogram performed better than or equal to the contrast arthrogram for evaluation of cemented and uncemented components [107]. The combination of nuclear and radiographic arthrographic procedures is advantageous. In a small investigation of *uncemented* femoral stems, the sensitivity of the combined examinations was 90%, and the specificity was 100% for loosening [106]. For acetabular loosening, a meta-analysis of 28 studies revealed a sensitivity of 87% and a specificity of 64% for nuclear arthrography [105].

FDG-PET: Reinartz et al [77] studied 92 hip prostheses and reported that by analyzing periprosthetic uptake patterns, aseptic loosening could be differentiated from infection. SUV analysis was not useful for this purpose. Chacko et al [92] observed that FDG uptake around the neck and head of the prosthesis, even when intense, is associated with aseptic loosening. Manthey et al [108] reported that by analyzing both the pattern and intensity of periprosthetic uptake, FDG-PET could differentiate among synovitis, aseptic loosening, and infection.

^{18}F-fluoride-PET: Choe et al [94] found that aseptic loosening of hip replacements was characterized by increased periprosthetic activity around <50% of a component with an SUV_{max} <5. Kobayashi et al [37] reported similar results.

Arthrography: The role of arthrography in documenting loosening of *cemented* components has been extensively studied. One group of investigators used refined criteria, high injection pressure, and subtraction technique and found a sensitivity of 96% and a specificity of 92% for demonstrating femoral component loosening and a sensitivity of 97% and a specificity of 68% for acetabular component loosening [109]. Temmerman et al [103] found subtraction arthrography for aseptic acetabular loosening to have a sensitivity of 72% and a specificity of 70%, with good interobserver variability. Optimal arthrographic technique is important to demonstrate loosening.

The efficacy of arthrography in defining loosening of *uncemented* components is less well studied and less certain. One study analyzed contrast arthrography in 12 uncemented femoral components and found a sensitivity of 50% and a specificity of 100% for loosening evaluated at surgery [106]. Contrast arthrography in 31 uncemented femoral components in another study showed a sensitivity of 59% and a specificity of 64%, lower than the results for cemented femoral components (sensitivity, 76%; specificity, 70%) [107]. Currently, arthrography for evaluation of loosening has been abandoned in many centers [110].

Anesthetic injection: Intra-articular injection of anesthetic that results in pain relief indicates an articular cause for the symptoms [111].

Variant 5: Evaluating suspected particle disease (aggressive granulomatous disease, infection excluded).

Localized areas of bone resorption around total hip arthroplasties occur as a response to the release of small particles of cement, polyethylene, or metal. Osteolysis increases as component wear increases [112]. Osteolysis has been a more frequent complication than infection, dislocation, or extensive heterotopic bone formation [113], although improvements in polyethylene are likely to decrease the rate of this complication. Loosening may or may not accompany granulomatous disease. With continued particle shedding, the lesions progress over time. The condition may be clinically silent, emphasizing the need for imaging.

Radiographs: Radiographs are typically the first method of identifying these areas of bone resorption. Oblique Judet views can be used to supplement the AP radiograph for this assessment. However, particularly in the acetabulum, considerable bone loss is necessary before lesions are identified with certainty on radiographs. Puri et al [9] found the sensitivity of radiographs for identifying acetabular osteolytic lesions to be 62% and the specificity 100% in comparison to a CT standard.

CT: Focal osteolysis is seen on CT as multiple expansile oval or round radiolucencies that form a multilobular shape [114]. Improved CT scanning techniques enable better demonstration of bone adjacent to prostheses and provide a more sensitive method than radiography for determining the extent and location of areas of osteolysis [10]. Stulberg et al [48] found the prevalence of osteolysis without clinical or radiographic findings (silent osteolysis) to be 48% on CT scans and 24% on radiographs in 80 young, active patients who had undergone bone-ingrowth total hip replacement at least 7 years before. Identification of periacetabular lytic lesions on CT is location dependent, with better detection for ilial and rim lesions [115]. Segmentation for quantification of lesions

in a series of cadavers with created defects, however, showed lesion volume to be underestimated using CT when a metal component was in place and even more so when metal reduction was used [116].

MRI: On MRI, focal periprosthetic intraosseous masses of intermediate to slightly increased signal with a low signal rim have been described in cases of aggressive granulomatous disease [21]. Peripheral and some internal enhancement of these granulomas have been noted after intravenous gadolinium injection [23]. MRI has been said to be the most accurate method for detecting and quantifying osteolysis and wear-induced synovitis after hip arthroplasty [21,117]. In 1 study, use of a cadaver model showed that MRI was the most sensitive test (95.4%) for detecting periacetabular lesions, although CT was the most accurate for determining lesion volume. For larger (more clinically concerning) lesions (>3 cm^3), both methods were effective in finding lesions and demonstrated detection rates >80% [118].

FDG-PET: There are few data on the role of FDG-PET in the evaluation of particle disease. Increased FDG uptake in a mass due to aggressive granulomatous disease has been described [119].

Variant 6: Evaluating patients with a painful primary metal-on-metal total hip arthroplasty or surface replacement: evaluate for aseptic lymphocyte-dominated vasculitis-associated lesion.

Newer metal-on-metal prostheses have been reintroduced in an effort to reduce wear and osteolysis associated with metal-on-polyethylene articulations [120]. Metal-on-metal prostheses can be conventional total hip replacements or resurfacing prostheses. An overview of imaging of these prostheses is provided by Bestic and Berquist [121].

Adverse local tissue reactions seen in patients with metal-on-metal prostheses include wear-induced metallosis (macroscopic staining of soft tissues) [2] and a metal-induced hypersensitivity reaction variously termed "metal hypersensitivity reaction," "pseudotumor," or "aseptic lymphocyte-dominated vasculitis-associated lesion (ALVAL)" [122-125]. Although ALVAL is thought to be due to a local hypersensitivity response to the metal component alloys, the cause remains uncertain [126]. Macnair et al [127] found no relation to metal ion levels or component wear rates [123], and metal ion levels can be unreliable for screening.

The characteristic histologic feature of ALVAL is the presence of a dense perivascular infiltrate [124]. Masses are formed that can contain areas of necrosis [128]. Anterior lesions tend to be solid, whereas posterior and lateral lesions can be more cystic [121]. Anterior lesions often involve or are near the psoas muscle, and lateral lesions typically involve the trochanteric bursa and can extend to the gluteal muscles [121].

Radiographs: Thinning of the femoral neck is a common finding after surface replacement arthroplasty, although its cause is not known and it usually stabilizes by 3 years [121]. Radiographs in cases of ALVAL are often normal [129], although early osteolysis may be present [130].

MRI: Findings including fluid collections, synovitis, periprosthetic soft tissue masses, proximal femoral bone marrow edema, surrounding muscular and soft-tissue edema, tendon avulsions, bone loss, periosteal stripping, neurovascular involvement, and periprosthetic fractures have been described after metal-on-metal hip replacement [123,124,128,129,131-134]. Using metal artifact reduction techniques [129], MRI can demonstrate ALVAL pseudotumors after metal-on-metal prostheses even in asymptomatic individuals [50,122,123,125,128,135], and the relation of the soft-tissue masses to symptoms is variable. Hauptfleisch et al [136] found that solid anterior pseudotumors were more likely to be associated with severe symptoms. Chang et al [131] found that clinical symptoms did not correlate with presence or size of pseudotumor formation; other findings (bone marrow edema and high-grade abductor tendon tears) at MR imaging did correlate with pain.

Grading systems have been developed for these lesions [123,137]. Synovial volumes can be quantified [138]. Greater synovial thickness and synovial volumes have been highly predictive of ALVAL [138,139]. Gadolinium contrast is not needed for evaluation but can define areas of necrosis [121]. CT is thought to be less useful than MRI [129].

US: US has been helpful in detecting reactive masses as this technique is not compromised by the presence of metal components [128]. It can be used in patients who cannot have MRI or when MRI is not available. Although US has been noted to be limited in its ability to detect deep fluid collections and osseous abnormalities [117], Douis [39] found that this is not usually the case, especially if newer US imaging equipment is used. Williams et al [125] used US to evaluate the prevalence of pseudotumor formation in asymptomatic patients with a metal-on-metal total hip replacement after a minimum follow-up of 2 years. They found solid or cystic masses in 32% (10

of 31) of patients with metal-on-metal hip replacements, as compared to 25% (5 of 20) of patients with metal-on-metal hip resurfacing arthroplasties and 4% (1 of 24) of metal-on-polyethylene total hip arthroplasties. It was recommended that high-resolution US surveillance be performed in all asymptomatic patients with a metal-on-metal implant that is known to result in high serum metal ion levels. Nishii et al [140] found US to be 74% sensitive and 92% specific in detecting adverse local tissue reaction, as compared to the gold standard of MRI of metal-on-metal prostheses. In 3 cases, US detected lesions not detected by MRI.

Variant 7: Total hip arthroplasty, trochanteric pain; suspect abductor injury or trochanteric bursitis.

Radiographs: Radiographic examination is usually the first test in patients presenting with trochanteric pain after hip arthroplasty to help identify trochanter fractures or heterotopic bone formation. Surface irregularities of the trochanter may suggest abductor tendon abnormality; 90% of patients in 1 series (with no prior surgery) with trochanteric surface irregularities >2 mm on radiographs had abductor tendon abnormalities on MRI [141].

MRI: MRI has been shown to be an effective method for evaluating postoperative gluteal muscle atrophy and tendon tears [142-144]. Pfirrmann et al [143] found that abductor tendon defects and fatty atrophy of the gluteus medius muscle and the posterior part of the gluteus minimus muscle were uncommon findings in asymptomatic patients after THA.

US: Sonography can identify and characterize hip abductor tendon abnormalities even in postoperative THA patients [145]. US findings are best correlated with the clinical site of pain [39]. This technique can be used to separate patients with abductor tendon avulsion from those with other causes of postoperative insufficiency of the abductor muscles (such as decreased femoral offset or denervation) [146].

Arthrography: Arthrography in cases of tendon disruption can demonstrate a capsular defect with contrast extending to the region of the trochanteric bursa [147]. Development of a fibrous capsule can lead to false-negative studies, however. Thus, a positive arthrographic study is helpful but a negative study does not exclude tendon avulsion.

Trochanteric bursitis can be identified on US [39], MRI, or CT.

Variant 8: Total hip arthroplasty; suspect iliopsoas bursitis or tendinitis.

Anterior iliopsoas impingement may lead to postoperative groin pain and functional disability [148]. Impingement can occur as a result of protrusion of the acetabular cup past the anteromedial edge of the acetabulum, protruding bone graft, acetabular fixation screws, anterior cement [149], an acetabular cage or reinforcement ring [148], prominence of the femoral head-neck junction, or osteophytes of the femoral neck [150].

Radiographs, CT, MRI, US, or diagnostic injection can be used to confirm the diagnosis [148]. A true lateral radiograph or CT can demonstrate acetabular component undercoverage [148]. In 1 series, all patients with iliopsoas impingement had an acetabular cup overhang of >12 mm, although overhang was <8 mm in control patients and those with other causes for symptoms [151].

MRI can be used to evaluate the iliopsoas tendon. Abnormal findings include deviation of the tendon from an oversized acetabular component, tendinopathy, tear, or bursitis [149]. Snapping of the tendon over the anterior acetabular component can be demonstrated on US [149].

Injection of the tendon with anesthetic, with or without corticosteroid, can be confirmatory and alleviate symptoms [148,150,152,153].

Iliopsoas bursitis can be demonstrated by MRI, US, or CT. Although there are some advantages for MRI of this bursa in nonarthroplasty patients [154], this may not be true when metal components are in place [39].

Variant 9: Total hip arthroplasty, suspect nerve damage.

The overall prevalence of nerve palsy following THA is 1% [155]. The sciatic nerve or the peroneal division of the sciatic nerve is involved in nearly 80% of cases [155]. The inferior division of the superior gluteal nerve is the main nerve supplying the abductor muscles and can be damaged during a direct lateral approach to hip replacement [156]. Poorly positioned acetabular screws, extravasated cement, heterotopic ossification, scar tissue, synovial expansion, and osteolytic lesions, as well as hematomas and fluid collections, can compress nerves [157].

MRI has been used successfully to evaluate nerves around the hip, including the sciatic nerve [157-159]. US is

less satisfactory than MRI for detecting subtle nerve lesions in this region, especially in obese patients or when evaluating lesions at the level of the piriformis [39].

Variant 10: Total hip arthroplasty, evaluate heterotopic bone.

Radiographs: Radiographs are the standard method for evaluating and grading heterotopic bone [160,161]. A lateral view can be helpful [162]. Heterotopic bone is usually visible within 6 weeks postoperatively and generally does not increase after 6 months [163].

CT and MRI: CT can be used to identify and determine the volume of heterotopic bone and its relationship to neurovascular structures. Some authors find it preferable to MRI for this [164]. However, MRI can also be used to evaluate the relation of heterotopic bone to vessels, nerves, and the joint [21].

Bone scan: Three-phase bone scanning is reported to be the most sensitive test for detecting heterotopic ossification [165]. Flow studies and blood-pool images can detect heterotopic bone approximately 2.5 weeks after injury, and delayed bone scans become positive approximately 1 week after that [165]. Serial bone scans can be used to determine the maturity of the heterotopic bone and aid in the timing of surgical resection [166]. However, in practice, performance of bone scanning for determination of the maturity of heterotopic ossification for surgical resection after THA is not often done.

US: US can detect heterotopic ossification earlier than radiography. In the series of Popken et al [167], early diagnosis of heterotopic bone was possible 1 week after surgery. Mature ossified lesions are more confidently recognized. Serial examinations have demonstrated a specific zonal pattern (matching the pathological process) that can be seen prior to radiologic abnormalities [168].

Variant 11: Total hip arthroplasty, suspect periprosthetic fracture.

Most cases of suspected fracture are diagnosed on radiographs. CT is thought by some authors to be more helpful than MRI in evaluating fractures of the acetabular bone [164]. Fritz et al [7], however, note that optimized MRI is the "most accurate modality" in indeterminate cases because of its ability to demonstrate stress reactions and subtle and nondisplaced fractures.

Summary of Recommendations

- A large number of techniques are available for evaluating total hip arthroplasties.
- Radiographs remain the standard imaging modality.
- Bone scan is a useful screening modality.
- Joint aspiration is the best available test for evaluation of joint infection.
- WBC/marrow scan is overall the best imaging test for diagnosing infection.
- CT and MRI are useful for assessing granulomatous disease. Radiography underestimates bone loss.
- MRI appears to be the best technique for evaluating complications of metal-on-metal prostheses such as ALVAL. US has been used for screening but appears to be less sensitive than MRI.
- MRI or US is useful for assessing abductor tendon and muscle abnormalities.
- Anesthetic/corticosteroid injection can help confirm the diagnosis of iliopsoas impingement and alleviate symptoms.
- MRI is the most effective method for evaluating nerve damage after THA.
- Heterotopic ossification is usually evaluated on radiographs, although bone scan and possibly US may be more sensitive for early diagnosis.
- Most periprosthetic fractures can be diagnosed on radiographs.

Summary of Evidence

Of the 168 references cited in the *ACR Appropriateness Criteria® Imaging After Total Hip Arthroplasty* document, 166 are categorized as diagnostic references including 4 well designed studies, 16 good quality studies, and 43 quality studies that may have design limitations. Additionally, 1 reference is categorized as a well-designed therapeutic study. There are 103 references that may not be useful as primary evidence. There is 1 reference that is a meta-analysis study.

The 168 references cited in the *ACR Appropriateness Criteria® Imaging After Total Hip Arthroplasty* document were published from 1973-2015.

While there are references that report on studies with design limitations, 21 well designed or good quality studies provide good evidence.

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Relative Radiation Level Information

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

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

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

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