

American College of Radiology ACR Appropriateness Criteria®

Clinical Condition: Osteonecrosis of the Hip

Variant 1: Adult or Child. Clinically suspected osteonecrosis. First study.

Radiologic Procedure	Rating	Comments	RRL*
X-ray pelvis and hips	9	This procedure includes the frog-leg view. The RRL for the adult procedure is ☼☼☼.	☼☼☼☼
CT hips without IV contrast	1	The RRL for the adult procedure is ☼☼☼.	☼☼☼☼
CT hips with IV contrast	1	The RRL for the adult procedure is ☼☼☼.	☼☼☼☼
CT hips without and with IV contrast	1	The RRL for the adult procedure is ☼☼☼☼.	☼☼☼☼☼
Tc-99m bone scan with SPECT hips	1	The RRL for the adult procedure is ☼☼☼.	☼☼☼☼
MRI hips without IV contrast	1		O
MRI hips 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

Variant 2: Adult. Clinically suspected osteonecrosis. Normal radiographs or radiographs that show femoral head lucencies suspicious for osteonecrosis.

Radiologic Procedure	Rating	Comments	RRL*
MRI hips without IV contrast	9		O
CT hips without IV contrast	5		☼☼☼
MRI hips without and with IV contrast	5		O
Tc-99m bone scan with SPECT hips	4		☼☼☼
CT hips with IV contrast	1		☼☼☼
CT hips 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 3: Child. Clinically suspected osteonecrosis. Normal radiographs or radiographs suspicious for osteonecrosis.

Radiologic Procedure	Rating	Comments	RRL*
MRI hips without IV contrast	8		O
MRI hips without and with IV contrast	8		O
CT hips without IV contrast	1		☼☼☼☼
CT hips with IV contrast	1		☼☼☼☼
CT hips without and with IV contrast	1		☼☼☼☼☼
Tc-99m bone scan with SPECT hips	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: Osteonecrosis of the Hip

Variant 4: Adult. Osteonecrosis with femoral head collapse by radiographs in the painful hip(s). Surgery contemplated.

Radiologic Procedure	Rating	Comments	RRL*
MRI hips without IV contrast	8	This procedure is recommended for affected hip preoperative planning and status of contralateral hip.	O
CT hips without IV contrast	7	This procedure is recommended for affected hip preoperative planning.	☼☼☼
Tc-99m bone scan with SPECT hips	3		☼☼☼
MRI hips without and with IV contrast	1		O
CT hips with IV contrast	1		☼☼☼
CT hips without and with IV contrast	1		☼☼☼☼
<u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 5: Child. Osteonecrosis with femoral head collapse by radiographs in the painful hip(s). Surgery contemplated.

Radiologic Procedure	Rating	Comments	RRL*
MRI hips without IV contrast	8		O
MRI hips without and with IV contrast	7		O
CT hips 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.	☼☼☼☼
Tc-99m bone scan with SPECT hips	3		☼☼☼☼
CT hips with IV contrast	1		☼☼☼☼
CT hips without and with IV contrast	1		☼☼☼☼☼
<u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: Osteonecrosis of the Hip

Variant 6: Adult or child. Osteonecrosis clinically suspected. Radiographs normal or abnormal but MRI contraindicated. Further evaluation is needed.

Radiologic Procedure	Rating	Comments	RRL*
CT hips without IV contrast	9	This procedure is more specific than bone scintigraphy and allows anatomic assessment, particularly with abnormal radiographs. The RRL for the adult procedure is ☼☼☼.	☼☼☼☼
Tc-99m bone scan with SPECT hips	8	This procedure is more sensitive than CT (SPECT/CT should be performed if possible), particularly with normal radiographs. The RRL for the adult procedure is ☼☼☼.	☼☼☼☼
CT hips with IV contrast	1	The RRL for the adult procedure is ☼☼☼.	☼☼☼☼
CT hips without and with IV contrast	1	The RRL for the adult procedure is ☼☼☼☼.	☼☼☼☼☼
<u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

OSTEONECROSIS OF THE HIP

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Summary of Literature Review

Introduction/Background

Osteonecrosis (often termed avascular necrosis with involvement of the epiphyseal regions) is a relatively common disease in which there is ischemic death of the cellular elements of bone and marrow. The femoral heads are the most commonly affected sites, with estimates of symptomatic femoral head osteonecrosis of 2 to 4.5 per patient year, resulting in 10,000–20,000 new cases annually in the United States [1]. Because the majority of patients are asymptomatic, this incidence likely significantly underestimates the true prevalence of osteonecrosis. Osteonecrosis affects both children and adults and there are numerous predisposing causes, including dislocation of the hip, femoral neck fracture, corticosteroid usage, alcoholism, collagen vascular disease, hemoglobinopathies, Gaucher disease, caisson disease, and some skeletal dysplasias [2].

In adults with collapse of the femoral head, disabling hip pain may result in the need for a hemiarthroplasty, hip resurfacing arthroplasty, or total joint replacement in early adulthood. Nontraumatic osteonecrosis is bilateral in 70%–80% of cases, which further increases the extent of disability in the setting of femoral head collapse. The high incidence of bilateral involvement of osteonecrosis in systemic disease with the use of corticosteroids and in children often requires imaging of the contralateral hip. Unlike adults, in the skeletally immature patient there is the potential for remodeling of the deformed femoral head. Thus, in the pediatric population the prognosis depends on the age of onset of the disease and the extent of femoral head deformity [3].

There are no specific physical findings or laboratory examinations that can reliably establish the diagnosis of osteonecrosis. Clinically suspected osteonecrosis can be confirmed only by diagnostic imaging or biopsy. Imaging methods that can assist in establishing the diagnosis include radiography, computed tomography (CT), radionuclide bone scintigraphy, and magnetic resonance imaging (MRI), with or without contrast enhancement. These methods vary considerably in their cost, diagnostic accuracy, and the information provided.

Although the optimal treatment for femoral head osteonecrosis is debated, early diagnosis is important. First, establishing that osteonecrosis is the cause for a patient's hip pain allows exclusion of conditions such as infection, neoplasm, fracture, arthritis, femoroacetabular impingement syndrome, labral tear, adjacent tendon injury, or other soft-tissue abnormality [4,5]. Second, accurate diagnosis and staging of osteonecrosis are needed to assess the efficacy of treatment.

Overview of Imaging Modalities

Radiography

Radiographs are the least expensive and most widely available imaging technology. Radiographs should be obtained as the initial study in every patient suspected to have osteonecrosis. In the presence of osteonecrosis, the radiographic findings may be normal, abnormal, or equivocal. Both anteroposterior of the pelvis and frog-leg lateral views of the hip should be obtained because articular collapse or cortical depression may be seen on only 1 of the 2 projections. In children, the earliest radiographic findings of osteonecrosis include a smaller ossific

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nucleus, increased radiodensity, subchondral fracture, and metaphyseal radiolucencies [1]. Subsequently, fragmentation, resorption, reossification, and remodeling of the affected femoral head and neck are seen.

Computed Tomography

In adults, CT with multiplanar reconstruction has been reported to be less sensitive than bone scintigraphy and MRI [6]. However, there have been few studies comparing MRI to current-generation multidetector CT (MDCT) scanners. One study using MDCT showed it was superior to MRI and radiography for detecting articular collapse of the femoral head in adult osteonecrosis [7]. Major roles for CT are in determining the severity of articular collapse and its location and evidence of early secondary degenerative joint disease [8]. This information is useful in surgical planning for rotational osteotomy, arthroplasty, resurfacing procedures, or joint replacement [9-12]. In the pediatric population, CT is not commonly used for assessment of osteonecrosis.

Bone Scintigraphy

More recently, MRI has largely replaced radionuclide bone scintigraphy because of its greater sensitivity (up to 100%, compared to 90% for radionuclide bone scanning) [13]. The addition of single-photon emission CT (SPECT) may improve the accuracy of radionuclide imaging for diagnosing osteonecrosis. In 1 study, SPECT was found to be more accurate than noncontrast MRI for detecting early osteonecrosis after renal transplant [14]. If bone scintigraphy is to be undertaken, it is suggested that the study be done using pinhole collimation and SPECT with scatter correction and iterative reconstruction algorithms. More recently, SPECT/CT has been advocated compared to SPECT alone for the diagnosis of osteonecrosis [15,16]. In the pediatric population, it is now less common to use nuclear imaging owing to concerns of radiation exposure.

Magnetic Resonance Imaging

MRI is the most sensitive and specific radiologic modality in the detection of osteonecrosis [1,13]. Recent studies report an improved specificity for MRI in detecting osteonecrosis [17,18]. In the adult population, 2 potential causes for incorrect diagnosis of osteonecrosis by MRI are transient osteoporosis and subchondral insufficiency fracture [19-21]. Attention to the specific MRI findings usually allows differentiation of these 2 entities [22-24]. Transient osteoporosis of the hip demonstrates osteopenia of the femoral head on radiography, diffuse intense increased radionuclide uptake in the femoral head (without central photopenia, as with osteonecrosis) on all bone scintigraphy phases, and marrow replacement of the femoral head on T1-weighted MRI that reveals marked diffuse increased signal intensity on water-sensitive sequences (without areas of low signal intensity in the superolateral femoral head, as with osteonecrosis) [25]. In subchondral insufficiency fracture the low-signal-intensity band in the superolateral femoral head is convex to the articular surface, as opposed to concave in osteonecrosis [20], and contrast enhancement is seen commonly (90%) proximal to this area [26]. Although MRI costs more than radionuclide bone scintigraphy, a limited MRI examination may permit the diagnosis of osteonecrosis at a lower cost [27,28].

Osteonecrosis of the hip in childhood is typically idiopathic and referred to as Legg-Calvé-Perthes disease. In the pediatric population, several studies have suggested a role for contrast-enhanced MRI. In 1 study using contrast-enhanced MRI with subtraction technique, the region of hypoperfusion was more clearly delineated in the early stages of Legg-Calvé-Perthes disease [29]. This technique has also been shown to predict the femoral head deformity in a small cohort at 2-year follow-up [30]. Other studies using dynamic technique have detected disease at an earlier stage prior to other MRI manifestations, particularly with Legg-Calvé-Perthes disease, with increased peak enhancement and delayed time to peak enhancement [31-33]. This technique has also been used to identify femoral heads at risk for development of osteonecrosis subsequent to femoral neck fracture [32].

MRI can also be useful in both adults and children to detect asymptomatic osteonecrosis in the contralateral hip.

MRI with diffusion sequences, T2 mapping, and apparent diffusion coefficient mapping has also been advocated more recently, although the usefulness of these techniques for evaluation of osteonecrosis remains investigative [34-37].

Disease Progression

In the adult population, the long-term clinical importance of osteonecrosis is largely predicated on its likelihood of subchondral and subsequent articular collapse [38]. Imaging identification of factors that increase this possibility is therefore important to guide potential therapy. Osteonecrosis that involves >30% of the femoral head progresses to collapse in 46%–83% of hips, in contrast to osteonecrosis that involves <30% of the femoral head, which progresses in <5% of cases [39]. Additionally, lesions involving <30% of the femoral head are unlikely to

become symptomatic or require treatment. The sagittal plane has been emphasized as optimal in evaluating articular collapse on MRI [40]. Various staging systems include the Association Research Circulation Osseous, Ficat and Arlet, and Steinberg [41], although their interobserver and intraobserver reliability has been questioned [42]. All of these staging systems have in common progression from radiologically occult disease to positive imaging manifestations of osteonecrosis, followed by femoral head collapse and subsequent development of secondary osteoarthritis. The volume of joint effusion, presence of prominent edema about the focus of osteonecrosis, patient age (>40 years), and body mass index (≥ 24 kg/m) have been associated with increased stage and likelihood of femoral head collapse [40,41,43]. As described above, in the pediatric population disease progression and outcome are determined by the age of onset of the disease, the extent of femoral head involvement, and subsequent development of femoral head deformity.

Treatment

Treatment of osteonecrosis in the adult population with significant potential for articular collapse or symptomatic lesions includes core decompression, injection of autologous bone marrow mononuclear cells with core decompression, fibular grafting, bisphosphonates, extracorporeal shock wave therapy, and hyperbaric oxygen [44-51]. Additional literature suggests that core decompression should be performed only when the area of involvement as measured by MRI is small [52,53], although the natural history of these lesions suggests that progression even without treatment is unlikely. In the pediatric population the treatment is based on the age of disease onset, associated symptoms, and extent of femoral head involvement. Treatment options range from nonoperative symptomatic treatment to weight relief and casting to surgical procedures such as femoral or pelvic osteotomies. Early intervention has been shown to improve outcome [54]. Although most osteonecrosis is discovered during imaging for pain, asymptomatic osteonecrosis is commonly found in individuals who are imaged for a symptomatic contralateral hip or unrelated reasons [17,18,55,56]. In children, bilateral involvement of idiopathic osteonecrosis occurs in 15%–20% and is most often asynchronous in disease onset.

Discussion of Imaging Modalities by Variant

Variant 1: Adult or Child. Clinically suspected osteonecrosis. First study.

The initial imaging study in either an adult or child with clinically suspected osteonecrosis should be radiography. These images must include a frog-leg lateral view. The important features of osteonecrosis can be seen only on this projection. Although radiography is not sensitive for early changes of osteonecrosis, it is the least expensive and most widely available imaging modality. Identification of characteristic features and detection of articular collapse at radiography may obviate the need for additional imaging. Additionally, radiographs may demonstrate an alternative diagnosis such as hip arthritis, fracture, or tumor involvement as a cause of symptoms in cases where osteonecrosis is not present.

Variant 2: Adult. Clinically suspected osteonecrosis. Normal radiographs or radiographs that show femoral head lucencies suspicious for osteonecrosis.

In the adult patient with suspected osteonecrosis of the hip and normal or suspicious radiographs but clinically requiring further radiologic assessment, MRI is the modality of choice. MRI is generally considered the most sensitive and specific radiologic method of assessment for identification of osteonecrosis, with accuracy of 97%–100% in several series [4,17,28,48]. In an animal study by Brody et al, MRI findings of osteonecrosis were apparent as early as 1 week following induced vascular imaging [3].

Intravenous contrast is typically not used or necessary for the diagnosis or evaluation of femoral head osteonecrosis. However, several researchers have described the identification of the lack of contrast enhancement on dynamic contrast-enhanced MRI as the most sensitive to detect osteonecrosis in animal studies [31,57]. This technique may be useful to suggest foci of osteonecrosis subsequent to femoral neck fracture, which has been reported in up to 75% of cases [32,58,59].

Variant 3: Child. Clinically suspected osteonecrosis. Normal radiographs or radiographs suspicious for osteonecrosis.

In a child with suspected femoral head osteonecrosis with normal radiographs or radiographic evidence of osteonecrosis but in whom further evaluation is needed, MRI is the radiologic modality of choice. Similar to the adult patient, MRI is both sensitive and specific for the identification of osteonecrosis in the pediatric population. However, in contradistinction to the adult patient, the use of contrast-enhanced MRI is often advocated. In early stages of femoral head osteonecrosis, absence of enhancement or hypoperfusion on postcontrast MRI including dynamic subtraction techniques has been described as superior to noncontrast MRI assessment [3,29,30,60,61].

Dynamic subtraction MRI techniques demonstrate increased peak enhancement in early stages of Legg-Calvé-Perthes disease [3,29,30,60,61]. In addition, prognostic features can be assessed by MRI, as discussed previously (see Variants 3 and 4). Bone scintigraphy and CT are not commonly used in radiologic assessment of osteonecrosis of the femoral head in the pediatric population owing to the increased radiation exposure.

Variants 4 and 5: Adult or child. Osteonecrosis with femoral head collapse by radiographs in the painful hip(s). Surgery contemplated.

In the adult or child patient with pain and radiographic evidence of articular collapse resulting from femoral head osteonecrosis and with surgical intervention contemplated for treatment, further imaging assessment is typically required. MRI features that are associated with articular collapse include involvement of >25%–50% of femoral head volume, older patient age (>40 years), increasing joint effusion volume, prominent surrounding marrow edema, and large body mass index (≥ 24 kg/m) [39-41,43,62,63]. MRI may also be useful to determine the degree and location of articular collapse, which is optimally evaluated in the sagittal imaging plane, and the status of the contralateral hip. However, MDCT was superior to radiography and MRI to detect articular collapse location and extent in several studies [7,8] and can be used if not adequately assessed by MRI for further assessment of preoperative planning. This assessment of the extent and location of articular collapse is often important to guide treatment options, including rotational osteotomy or core decompression.

The use of contrast-enhanced MRI including dynamic subtraction techniques has been advocated for evaluation of osteonecrosis in the pediatric population and may have prognostic implications. Contrast-enhanced MRI features associated with a worsened outcome include lack of revascularization of the lateral pillar, transphyseal neovascularization pattern, physeal disruption, and enhancing synovial hypertrophy [3,30,60,61,64].

Additional imaging features associated with a poorer outcome in the pediatric population include larger volume of femoral head involvement, lateral subluxation of the femoral head, loss of femoral head containment, and increased fragmentation [65,66]. Diffusion-weighted MRI has also been studied in the pediatric population, with increased diffusivity reflecting cell damage compared to a normal femoral head. Increased diffusivity in the metaphyseal region has been associated with a worsened outcome in the pediatric population [64,67].

Variant 6: Adult or child. Osteonecrosis clinically suspected. Radiographs normal or abnormal but MRI contraindicated. Further evaluation is needed.

The imaging assessment of a patient, adult or child, who cannot undergo MRI but requires further radiologic evaluation can be performed with either bone scintigraphy or CT. Bone scintigraphy should be performed with high-resolution pinhole collimation and is particularly useful in patients with normal radiographs. More recently, SPECT has been shown to improve the diagnostic accuracy of this technique [15,16]. In the study by Ryu et al [14], SPECT was found to be more sensitive than MRI in identifying early femoral head osteonecrosis in renal transplantation patients (100% versus 66%). The disadvantage of bone scintigraphy in assessment of osteonecrosis is the lack of anatomic evaluation and specificity.

CT, although less sensitive than MRI and bone scintigraphy for detection of early femoral head osteonecrosis, is more specific and has the advantage of allowing anatomic assessment (particularly in patients with abnormal radiographs) [1,11]. Osteonecrosis of the femoral head that is more chronic is well seen on CT evaluation. In addition, similar to MRI, sagittal and coronal MDCT allows assessment of the volume of femoral head involvement, the presence of articular collapse, and early secondary degenerative disease [7,8]. The use of intravenous contrast is not needed for CT evaluation of femoral head osteonecrosis. The CT assessment of femoral head osteonecrosis in this clinical scenario is important to guide the need and types of further treatment that may be required.

Summary of Recommendations

- When a patient who is at risk for osteonecrosis develops hip pain, the initial examination should consist of an anteroposterior pelvis and frog-leg lateral hip radiographs of the symptomatic hip or both hips.
- If the radiographic findings are definitive for osteonecrosis, an MRI might be indicated if identification of asymptomatic osteonecrosis in the contralateral hip is clinically important.
- If the radiographic findings are equivocal for osteonecrosis or are normal on the symptomatic side, then MRI is indicated to establish the diagnosis of osteonecrosis and to exclude other potential causes for the patient's hip pain.

- In adult patients with radiographically proven, occult, or equivocal osteonecrosis, MRI may be indicated for diagnosis, evaluation of extent or volume of disease, and evidence of articular collapse, if clinically important to guide optimal treatment. CT (MDCT) can be useful for preoperative assessment if not adequately evaluated by MRI.
- In adult patients in whom MRI cannot be performed, bone scintigraphy with SPECT, or preferably SPECT/CT, imaging is a reasonable alternative for diagnosing radiographically occult osteonecrosis. In these patients, CT can also be useful to identify the extent or volume of disease and evidence of articular collapse, if clinically important.
- In children, if the diagnosis is equivocal or occult at radiography, perfusion MRI can be helpful to establish the diagnosis and to assess the extent of abnormal perfusion.
- In children, CT and bone scintigraphy are infrequently used given the concern of radiation exposure. Less commonly, bone scintigraphy can be used if MRI is contraindicated and early definitive diagnosis is required.
- Screening of a patient who is at high risk for osteonecrosis may be of value if prophylactic treatment of asymptomatic osteonecrosis is proven useful.

Summary of Evidence

Of the 67 references cited in the *ACR Appropriateness Criteria® Osteonecrosis of the Hip* document, 59 are categorized as diagnostic references including 2 well designed studies, 12 good quality studies, and 17 quality studies that may have design limitations. Additionally, 8 references are categorized as therapeutic references including 7 well designed studies. There are 29 references that may not be useful as primary evidence.

The 67 references cited in the *ACR Appropriateness Criteria® Osteonecrosis of the Hip* document were published from 1965-2014.

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

Relative Radiation Level Information

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

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
○	0 mSv	0 mSv
⊕	<0.1 mSv	<0.03 mSv
⊕⊕	0.1-1 mSv	0.03-0.3 mSv
⊕⊕⊕	1-10 mSv	0.3-3 mSv
⊕⊕⊕⊕	10-30 mSv	3-10 mSv
⊕⊕⊕⊕⊕	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as “Varies”.

Supporting Documents

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

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The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.