

**American College of Radiology
ACR Appropriateness Criteria®
Osteonecrosis**

Variant 1: Clinically suspected osteonecrosis. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography area of interest	Usually Appropriate	Varies
MRI area of interest without and with IV contrast	Usually Not Appropriate	○
MRI area of interest without IV contrast	Usually Not Appropriate	○
Bone scan area of interest	Usually Not Appropriate	☼☼☼
CT area of interest with IV contrast	Usually Not Appropriate	Varies
CT area of interest without and with IV contrast	Usually Not Appropriate	Varies
CT area of interest without IV contrast	Usually Not Appropriate	Varies

Variant 2: Clinically suspected osteonecrosis. Normal radiographs or radiographs that show findings suspicious for osteonecrosis. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
MRI area of interest without IV contrast	Usually Appropriate	○
MRI area of interest without and with IV contrast	May Be Appropriate	○
CT area of interest without IV contrast	May Be Appropriate (Disagreement)	Varies
Bone scan area of interest	Usually Not Appropriate	☼☼☼
CT area of interest with IV contrast	Usually Not Appropriate	Varies
CT area of interest without and with IV contrast	Usually Not Appropriate	Varies

Variant 3: Known osteonecrosis with articular collapse by radiographs. Surgery planned. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
MRI area of interest without IV contrast	Usually Appropriate	○
CT area of interest without IV contrast	Usually Appropriate	Varies
MR arthrography area of interest	Usually Not Appropriate	○
MRI area of interest without and with IV contrast	Usually Not Appropriate	○
Bone scan area of interest	Usually Not Appropriate	☼☼☼
CT area of interest with IV contrast	Usually Not Appropriate	Varies
CT area of interest without and with IV contrast	Usually Not Appropriate	Varies

OSTEONECROSIS

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Summary of Literature Review

Introduction/Background

Osteonecrosis is defined as bone death due to inadequate vascular supply. Although exact pathophysiology is unknown, 3 possible mechanisms have been proposed: 1) vascular interruption, 2) vascular occlusion, or 3) extravascular intraosseous compression, most likely caused by lipid hypertrophy [1]. It is sometimes also called “avascular necrosis” and “aseptic necrosis” when involving epiphysis or “bone infarct” when involving metadiaphysis and will be addressed in this document as “osteonecrosis.” Common sites include the femoral head, humeral head, tibial metadiaphysis, femoral metadiaphysis, scaphoid, lunate, and talus [2,3].

Osteonecrosis is thought to be a common condition most commonly affecting adults in third to fifth decades of life, with femoral head osteonecrosis incidence reported to be 10,000 to 20,000 new symptomatic cases per year in the United States [4,5]. True prevalence of osteonecrosis is likely quite underestimated because many patients are asymptomatic, especially the metadiaphyseal cases. Recent studies have shown that MR-proven cases of femoral osteonecrosis can be retrospectively visualized on CT abdomen/pelvis with intravenous (IV) contrast performed for other clinical purposes and were originally vastly underreported [6,7]. Risk factors for osteonecrosis are numerous and include trauma, corticosteroid therapy, alcohol use, HIV, lymphoma/leukemia, blood dyscrasias, chemotherapy, radiation therapy, Gaucher disease, and Caisson disease [8-10]. In nontraumatic cases, femoral head osteonecrosis is often bilateral (70%-80%) [5]. Other locations of osteonecrosis (eg, talus, humeral head) are often involved in cases of multifocal osteonecrosis [11,12]. In a long-term follow-up of patients on steroids, Nawata et al [12] found osteonecrosis in the hip (68%), knee (44%), ankle (17%), and shoulder (15%).

Epiphyseal osteonecrosis can lead to subchondral fracture and secondary osteoarthritis, whereas metadiaphyseal cases do not, likely explaining their lack of long-term sequelae [5,10]. The necrotic volume of epiphyseal osteonecrosis has been shown to be predictive of future articular collapse. Femoral heads with necrotic volume >30% progressed to collapse in 46% to 83% of cases, in contrast to femoral heads with <30% in necrotic volume, which progressed to collapse in <5% of cases [13]. Similarly, the necrotic volume in the humeral head can be measured via necrotic angle (mid-coronal plane measurement of the extent of osteonecrosis spanning the humeral head, typically involving the superomedial aspect). Humeral heads with a necrotic angle <90° did not collapse in the subsequent 24 months follow-up [14]. In addition, the increased risk for femoral head collapse has been associated with increased joint effusion, increased bone marrow edema about the focus of osteonecrosis, patient age >40 years, and increased body mass index (≥24 kg/m) [5].

Early diagnosis of osteonecrosis is important 1) to exclude other causes of patient’s pain and 2) to allow for possible early surgical prevention to prevent articular collapse and the need for joint replacements. Imaging is also important for preoperative planning.

Many staging systems have been developed for femoral osteonecrosis and often adapted for the humeral head. Ficat and Arlet, developed in the 1960s, does not account for size or location of the necrotic lesion but remains the most commonly used system. Other systems, University of Pennsylvania (Steinberg), Association Research Circulation Osseous (ARCO), and Japanese Orthopedic Association systems, may also be used [15].

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Noninvasive therapy for osteonecrosis has so far gained limited supporting data. They include statins, bisphosphonates, anticoagulants, extracorporeal shock wave therapy, and hyperbaric oxygen [16-18].

Invasive therapies for early osteonecrosis aim at preventing articular collapse and delaying/preventing the need for joint replacement. Core decompression can be performed in various locations including femoral head, humeral head, and talus. Core decompression can be supplemented with injection of autologous bone marrow cells, vascular fibular grafting, or electric stimulation. However, overall efficacy of core decompression at preventing eventual articular collapse remains controversial [11,19-22]. For late-stage femoral or humeral head osteonecrosis with articular collapse, resurfacing hemiarthroplasty may be needed, whereas total joint arthroplasty is performed in cases of severe secondary osteoarthritis [23]. Femoral head osteonecrosis accounts for 10% of indications for total hip replacements in the United States [24]. For late-stage talar osteonecrosis, talar resection/replacement with arthroplasty or tibiotalar joint fusion may be performed [11].

The following body regions are covered in this document: chest, pelvis, hip, femur, knee, tibia/fibula, ankle, foot, shoulder, humerus, elbow, forearm, wrist, and hand. Osteonecrosis of the lunate and scaphoid are both covered in the ACR Appropriateness Criteria® topic on “[Chronic Wrist Pain](#)” [25]. Osteonecrosis of the metatarsal head, also known as “Freiberg’s infraction,” is covered in the ACR Appropriateness Criteria® topic on “[Chronic Foot Pain](#)” [26]. Spontaneous Osteonecrosis of the Knee has been shown to represent fracture in osteopenic bone and not osteonecrosis. Subsequently, this entity has been renamed Subchondral Insufficiency Fracture the Knee and will not be included in this document.

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 in which each procedure provides unique clinical information to effectively manage the patient’s care).

Discussion of Procedures by Variant

Variant 1: Clinically suspected osteonecrosis. Initial imaging.

The body regions covered in this clinical scenario are chest, pelvis, hip, femur, knee, tibia/fibula, ankle, foot, shoulder, humerus, elbow, forearm, wrist, and hand.

Radiography Area of Interest

Radiography is beneficial as the initial imaging study for clinically suspected osteonecrosis. Although radiographs are less sensitive for detection of early osteonecrosis, they help to exclude other causes of extremity pain such as fracture, primary arthritis, or tumor. Anteroposterior, lateral (frog-leg lateral for hip), and oblique (eg, ankle/knee) views are recommended to exclude subchondral collapse in cases of epiphyseal osteonecrosis [27,28]. In late-stage osteonecrosis, radiography will also show findings of secondary osteoarthritis.

Bone Scan Area of Interest

In recent years, bone scintigraphy has been replaced by MRI for detection of osteonecrosis because of poor spatial resolution, low specificity, and the inability to quantify size of the necrotic lesion [29]. Single-photon emission CT (SPECT) was shown to improve accuracy of bone scintigraphy in a small group of posttransplant patients [30], but radionuclide scintigraphy is not commonly performed for detection of osteonecrosis. Early limited data for PET/CT have not been shown to be useful in diagnosis of early osteonecrosis [31]. More studies are needed to see if PET/CT may be useful in the detection of multifocal osteonecrosis.

CT Area of Interest With IV Contrast

There is limited evidence to support the use of CT with IV contrast as the initial imaging study for clinically suspected osteonecrosis.

CT Area of Interest Without and With IV Contrast

There is limited evidence to support the use of CT without and with IV contrast as the initial imaging study for clinically suspected osteonecrosis.

CT Area of Interest Without IV Contrast

There is limited evidence to support the use of CT without IV contrast as the initial imaging study for clinically suspected osteonecrosis.

MRI Area of Interest Without and With IV Contrast

There is limited evidence to support the use of MRI without and with IV contrast as the initial imaging study for clinically suspected osteonecrosis.

MRI Area of Interest Without IV Contrast

There is limited evidence to support the use of MRI without IV contrast as the initial imaging study for clinically suspected osteonecrosis.

Variant 2: Clinically suspected osteonecrosis. Normal radiographs or radiographs that show findings suspicious for osteonecrosis. Next imaging study.

The body regions covered in this clinical scenario are chest, pelvis, hip, femur, knee, tibia/fibula, ankle, foot, shoulder, humerus, elbow, forearm, wrist, and hand.

Bone Scan Area of Interest

Because of poor spatial resolution, low specificity, and the inability to quantify the size of the necrotic lesion, bone scintigraphy is not beneficial for characterization of osteonecrosis. SPECT may improve the accuracy of bone scintigraphy [30,32,33] for detection of osteonecrosis, but its use has not been widely accepted. In addition, few studies suggest that bone scan may be used to screen for multifocal osteonecrosis [34,35].

CT Area of Interest With IV Contrast

There is limited evidence to support the use of CT with IV contrast as the next imaging study for clinically suspected osteonecrosis following radiographs.

CT Area of Interest Without and With IV Contrast

There is limited evidence to support the use of CT without and with IV contrast as the next imaging study for clinically suspected osteonecrosis following radiographs.

CT Area of Interest Without IV Contrast

CT is less sensitive than bone scintigraphy and MRI for the detection of early osteonecrosis [36]. Once an insufficiency fracture occurs, CT is superior to MRI in showing location and extent of articular collapse [37,38]. CT also shows osseous details of secondary osteoarthritis well.

MRI Area of Interest Without and With IV Contrast

MRI with dynamic contrast enhancement has been shown to be useful to differentiate osteonecrosis from transient bone marrow edema syndrome and subchondral insufficiency fracture [39]. Transient bone marrow edema shows subchondral spot of marked hyperperfusion (plasma flow), whereas osteonecrosis shows a rim of high plasma flow surrounding a subchondral area without flow [40]. This rim is thought to represent granulation tissue. Higher slope of enhancement and maximum enhancement in epiphysis was seen in transient bone marrow edema than in subchondral fracture. Osteonecrosis showed overall decreased maximal enhancement [41].

MRI Area of Interest Without IV Contrast

MRI is the most sensitive and specific imaging modality for the diagnosis of osteonecrosis, with a sensitivity and specificity nearing 100% [24,28,42]. A meta-analysis of 43 studies for early detection of femoral head osteonecrosis reported a sensitivity of 93% and specificity of 91% [43]. MRI allows for characterization of the osteonecrosis including location, volume, and presence of associated bone marrow edema or joint effusion [13,14]. MRI is also important for detecting asymptomatic osteonecrosis in the contralateral hip.

MRI helps to differentiate femoral osteonecrosis from its main differential diagnosis of transient osteoporosis of the hip (also called, “transient bone marrow edema syndrome”), seen in middle-aged patients, originally described in pregnant women during the third trimester. Bone marrow edema is seen throughout the femoral head and neck. Condition is idiopathic, self-limiting (lasting 3-9 months), and treated conservatively [5,40]. Subchondral insufficiency fracture is another differential diagnosis to consider, whereas epiphyseal tumors are rare (clear cell

chondrosarcoma in older adults or chondroblastoma in adolescents). Infarct-associated sarcomas (most commonly malignant fibrous histiocytomas and osteosarcomas) are extremely rare and total up to less than 80 cases in the literature [44,45].

Recent developments in whole-body MRI protocols for various conditions (eg, multiple myeloma, polymyositis, lymphoma) have led to detection of multifocal osteonecrosis [46-48]. Of note, Zhen-Guo's study used a rapid MR protocol lasting only 12 to 15 minute consisting only of a coronal short-tau inversion recovery sequence with 11.6% of rate of osteonecrosis in patients with polymyositis/dermatomyositis.

Variants 3: Known osteonecrosis with articular collapse by radiographs. Surgery planned. Next imaging study.

The body regions covered in this clinical scenario are ankle, elbow, hip, knee, shoulder, and wrist.

Bone Scan Area of Interest

There is limited evidence to support the use of bone scan for preoperative planning of osteonecrosis.

CT Area of Interest With IV Contrast

There is limited evidence to support the use of CT with IV contrast for preoperative planning of osteonecrosis.

CT Area of Interest Without and With IV Contrast

There is limited evidence to support the use of CT without and with IV contrast for preoperative planning of osteonecrosis.

CT Area of Interest Without IV Contrast

CT is superior to MRI in showing the location and extent of articular collapse [37,38] and, therefore, plays a critical role in surgical planning. Preoperative CT, before total hip arthroplasty, showed that 21% of femoral head osteonecrosis staged as ARCO stage I or II on radiographs to actually be stage III on CT [49]. With developing technologies in 3-D printing, CT also plays an important role. Li et al [50] reported that a 3-D guide plate in core decompression led to decreased surgery time and blood loss.

MR Arthrography Area of Interest

There is limited evidence to support the use of MR arthrography for preoperative planning of osteonecrosis.

MRI Area of Interest Without and With IV Contrast

Not surprisingly, the volume of hip synovitis seen on contrast-enhanced MRI was found to be increased after femoral head collapse compared to precollapse [51]. There is limited evidence to support the use of MRI without and with IV contrast for preoperative planning of osteonecrosis.

MRI Area of Interest Without IV Contrast

For epiphyseal osteonecrosis, necrotic volume has been shown to be predictive of future articular collapse. When femoral head necrotic volume is >30%, femoral head progressed to collapse in 46% to 83% of cases, whereas femoral heads with <30% necrotic volume progressed to collapse in <5% of cases [13]. Sagittal view has been shown to be important in detection of articular collapse on MRI [52]. Similarly, the volume of necrotic volume in the humeral head (most often found in the superior medial aspect) was measured as the necrotic angle on the mid-coronal plane. Humeral heads with a necrotic angle <90° did not collapse in the subsequent 24 months follow-up [14].

Summary of Recommendations

- **Variants 1:** Radiography is usually appropriate for the initial imaging of clinically suspected osteonecrosis.
- **Variants 2:** MRI without IV contrast is usually appropriate as the next imaging study for clinically suspected osteonecrosis following normal or suspicious radiographs. Although the panel did not agree on recommending CT without IV contrast because there is insufficient medical literature to conclude whether these patients would benefit from the procedure, its use may be appropriate.
- **Variants 3:** In the setting of known osteonecrosis with articular collapse by radiographs, MRI without IV contrast or CT without IV contrast is usually appropriate as the next imaging study for preoperative planning. MRI without IV contrast can predict necrotic volume well, whereas CT without IV contrast can show the location and extent of articular collapse well.

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 go to www.acr.org/ac.

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 [53].

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.”

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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.