

**American College of Radiology  
ACR Appropriateness Criteria®  
Osteomyelitis or Septic Arthritis-Child (Excluding Axial Skeleton)**

**Variant 1: Child. Younger than 5 years of age. Concern for osteomyelitis or septic arthritis involving an extremity. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US area of interest	Usually Appropriate	○
Radiography area of interest	Usually Appropriate	Varies
MRI area of interest without and with IV contrast	Usually Appropriate	○
MRI extremity area of interest without and with IV contrast	Usually Appropriate	○
MRI area of interest without IV contrast	May Be Appropriate	○
MRI extremity area of interest without IV contrast	May Be Appropriate	○
MRI whole body without and with IV contrast	May Be Appropriate (Disagreement)	○
MRI whole body without IV contrast	May Be 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
Bone scan whole body and 3-phase bone scan area of interest	Usually Not Appropriate	☼☼☼☼
3-phase bone scan area of interest	Usually Not Appropriate	☼☼☼☼
Bone scan whole body	Usually Not Appropriate	☼☼☼☼

**Variant 2:**

**Child. Younger than 5 years of age. Concern for osteomyelitis or septic arthritis involving an extremity. Initial radiographs normal, or with findings suggestive of osteomyelitis. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
US area of interest	Usually Appropriate	○
Image-guided aspiration area of interest	Usually Appropriate	Varies
MRI area of interest without and with IV contrast	Usually Appropriate	○
MRI extremity area of interest without and with IV contrast	Usually Appropriate	○
MRI extremity area of interest without IV contrast	Usually Appropriate	○
Bone scan whole body and 3-phase bone scan area of interest	May Be Appropriate	⊛⊛⊛⊛
MRI area of interest without IV contrast	May Be Appropriate	○
MRI whole body without and with IV contrast	May Be Appropriate	○
MRI whole body without IV contrast	May Be 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 3:****Child. 5 years of age or older. Concern for osteomyelitis or septic arthritis involving an extremity. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US area of interest	Usually Appropriate	○
Radiography area of interest	Usually Appropriate	Varies
MRI area of interest without and with IV contrast	Usually Appropriate	○
MRI area of interest without IV contrast	Usually Appropriate	○
MRI extremity area of interest without and with IV contrast	Usually Appropriate	○
MRI extremity area of interest without IV contrast	May Be 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
Bone scan whole body and 3-phase bone scan area of interest	Usually Not Appropriate	☼☼☼☼
MRI whole body without and with IV contrast	Usually Not Appropriate	○
MRI whole body without IV contrast	Usually Not Appropriate	○
3-phase bone scan area of interest	Usually Not Appropriate	☼☼☼☼
Bone scan whole body	Usually Not Appropriate	☼☼☼☼

**Variant 4:**

**Child. 5 years of age or older. Concern for osteomyelitis or septic arthritis involving an extremity. Initial radiographs normal, or with findings suggestive of osteomyelitis. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
Image-guided aspiration area of interest	Usually Appropriate	Varies
MRI area of interest without and with IV contrast	Usually Appropriate	○
MRI area of interest without IV contrast	Usually Appropriate	○
MRI extremity area of interest without and with IV contrast	Usually Appropriate	○
MRI extremity area of interest without IV contrast	Usually Appropriate	○
US area of interest	May Be Appropriate	○
Bone scan whole body and 3-phase bone scan area of interest	May Be Appropriate	⊕⊕⊕⊕
3-phase bone scan area of interest	May Be Appropriate	⊕⊕⊕⊕
Bone scan whole body	May Be 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
MRI whole body without and with IV contrast	Usually Not Appropriate	○
MRI whole body without IV contrast	Usually Not Appropriate	○

**Variant 5:****Child. With one or more clinical signs concerning for septic arthritis. Initial radiographs normal or demonstrating possible joint effusion. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
US area of interest	Usually Appropriate	○
Image-guided aspiration area of interest	Usually Appropriate	Varies
MRI area of interest without and with IV contrast	Usually Appropriate	○
MRI area of interest without IV contrast	May Be Appropriate	○
MRI extremity area of interest without and with IV contrast	May Be Appropriate	○
MRI extremity area of interest without IV contrast	May Be 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
Bone scan whole body and 3-phase bone scan area of interest	Usually Not Appropriate	☢☢☢☢
MRI whole body without and with IV contrast	Usually Not Appropriate	○
MRI whole body without IV contrast	Usually Not Appropriate	○
3-phase bone scan area of interest	Usually Not Appropriate	☢☢☢☢
Bone scan whole body	Usually Not Appropriate	☢☢☢☢

## OSTEOMYELITIS OR SEPTIC ARTHRITIS-CHILD (EXCLUDING AXIAL SKELETON)

Expert Panel on Pediatric Imaging: Narendra S. Shet, MD<sup>a</sup>; Ramesh S. Iyer, MD, MBA<sup>b</sup>; Sherwin S. Chan, MD, PhD<sup>c</sup>; Keith Baldwin, MD<sup>d</sup>; Tushar Chandra, MD, MBBS<sup>e</sup>; Jimmy Chen, MD<sup>f</sup>; Matthew L. Cooper, MD<sup>g</sup>; C. Buddy Creech, MD, MPH<sup>h</sup>; Anne E. Gill, MD<sup>i</sup>; Terry L. Levin, MD<sup>j</sup>; Michael M. Moore, MD<sup>k</sup>; Helen R. Nadel, MD<sup>l</sup>; Mohsen Saidinejad, MD, MBA<sup>m</sup>; Gary R. Schooler, MD<sup>n</sup>; Judy H. Squires, MD<sup>o</sup>; David W. Swenson, MD<sup>p</sup>; Cynthia K. Rigsby, MD.<sup>q</sup>

### Summary of Literature Review

#### **Introduction/Background**

Pediatric musculoskeletal infections can result in significant morbidity, particularly given ongoing skeletal maturation, and delayed diagnosis may result in premature physal arrest or joint damage. Among osteoarticular infections, osteomyelitis occurs twice as frequently as septic arthritis [1]. Estimates of the incidence of pediatric osteomyelitis vary widely but have been cited between 2 to 20 per 100,000 [1-4]. Concomitant joint and bone or other extra-articular infections are common in children and may occur in >50% of cases [5-7].

Both osteomyelitis and septic arthritis most commonly arise from hematogenous spread of bacteria. For pediatric osteomyelitis, the metaphysis is the most frequent site of involvement within an individual long bone due to looping nutrient vessels, which do not traverse the physis. However, because of the presence of transphyseal vessels in children ≤18 months of age, infection can spread to the epiphysis in this subset of patients [3,8,9]. Furthermore, the presence of transphyseal infection in older pediatric patients may be underestimated [10]. The most commonly implicated pathogen is *Staphylococcus aureus* among all pediatric patients, but other organisms should be considered in select populations, such as group B streptococcus in neonates, *Kingella kingae* in children <4 years of age, and *Salmonella* spp. in patients with sickle cell disease [3,11,12]. Diagnosis of skeletal infection can be particularly challenging in children; the typical triad of fever, pain, and diminished mobility is reportedly just above 50% of cases of acute hematogenous osteomyelitis [8]. In neonates and infants, septic arthritis may occur secondary to spread of osteomyelitis into the adjacent joint. Osteomyelitis can spread to the subperiosteal space directly from the metaphysis and through seeding from a hematogenous infection and can lead to a subperiosteal abscess, which can lead to bone ischemia and necrosis [13], making prompt diagnosis critical.

Septic arthritis, which most commonly occurs in the knee and hip joints, is considered an orthopedic emergency because bacterial proliferation and metabolites can rapidly result in cartilage damage [11]. The Kocher criteria, first described in 1999, are widely applied in evaluation of the hip joint as a means to distinguish septic arthritis (surgical emergency) from transient synovitis (expectant management) [14]. The criteria include fever >101.3°F, erythrocyte sedimentation rate of at least 40 mm/hour, white blood cell (WBC) count of at least 12,000 cells/mm<sup>3</sup>, and an inability to bear weight on the affected side. Satisfying more of these criteria results in higher likelihood of septic arthritis, with near 100% likelihood in patients who meet all four criteria. More recently, elevated C-reactive protein >2.0 mg/dL has been described as an accurate predictor of septic arthritis [15]. Clinical suspicion of septic arthritis is of paramount importance in management because diagnosis is made by arthrocentesis.

The distribution of septic arthritis and osteomyelitis varies by age. Children <2 years of age have been reported to be more likely to have septic arthritis than osteomyelitis ( $P = .0003$ ). In children between 2 and 10 years old, osteomyelitis is slightly more common than septic arthritis, and in children from 10 to 18 years old, septic arthritis is slightly more common [6].

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Typical management of uncomplicated osteomyelitis in the pediatric population consists initially of intravenous (IV) antibiotic therapy followed by a prolonged course of outpatient antibiotics, either oral or IV. However, surgical debridement may be indicated in certain scenarios, such as in the setting of subperiosteal collections, necrosis, or failure to respond to initial management. Typical management of septic arthritis consists of antibiotics, arthrotomy, irrigation, and debridement [16]. Imaging plays a critical role in characterizing and differentiating septic arthritis from osteomyelitis.

In this discussion, imaging of pediatric osteomyelitis and septic arthritis involving only the appendicular skeleton will be reviewed; the axial skeleton will not be covered. For additional information regarding osteoarticular infection of the spine, please refer to the separate ACR Appropriateness Criteria® topic on “[Back Pain-Child](#)” [17].

Please note that chronic recurrent multifocal osteomyelitis, which affects the pediatric population and typically manifests with multiple sites of involvement, is a nonbacterial autoinflammatory disorder and as such will not be discussed in this document, which will focus on acute musculoskeletal infection.

### **Special Imaging Considerations**

Evaluation for pediatric musculoskeletal infection in the setting of existing orthopedic hardware can be impacted by artifact. On CT, beam hardening artifact occurs, which can be reduced on conventional CT by corrective software, as well as filtration and calibration connection [18,19]. With the advent of dual-energy CT, metal artifact reduction can be performed to reduce beam hardening by acquisition of data at two distinct energy spectra in order to create a virtual monochromatic image to optimize visualization of bone or soft tissue [19]. On MRI, susceptibility artifact limits regional visualization and directly correlates with magnetic field strength. Basic metal artifact reduction can be performed by increasing bandwidth, decreasing slice thickness, increasing echo train length, and increasing matrix size [20]. Advanced MR software packages and sequences have been developed for more robust through-section and in-plane artifact reduction.

### **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: Child. Younger than 5 years of age. Concern for osteomyelitis or septic arthritis involving an extremity. Initial imaging.**

In this discussion, the literature regarding imaging of pediatric osteomyelitis and septic arthritis will be broadly applied to the appendicular skeleton. In the narrative below, “area of interest” can refer to the following: foot, ankle, tibia/fibula, knee, femur, hip, hand, wrist, forearm, elbow, humerus, or shoulder. Where it is noted that the entire extremity is imaged, for the upper extremity, this is assumed to cover from the shoulder through the hand, and for the lower extremity, this is assumed to cover from the hip through the foot.

Osteomyelitis commonly occurs in young children, with half of cases reportedly in children <5 years of age [13,21]. Although hematogenous bacterial seeding is the most common underlying cause for osteomyelitis, a history of trauma, often minor, is frequently elicited [11,13]. Infants and toddlers with septic arthritis or osteomyelitis often present with a limp, though it is often difficult in this population to localize a site of involvement on physical examination. In these cases, imaging is often utilized to help identify the affected site [22]. Concurrent osteomyelitis and septic arthritis are common.

### **3-Phase Bone Scan Area of Interest**

There is no relevant literature regarding the use of 3-phase bone scan of the area of interest in the initial evaluation of osteomyelitis or septic arthritis in children <5 years of age.

### **Bone Scan Whole Body**

There is no relevant literature regarding the use of whole-body bone scan in the initial evaluation of osteomyelitis or septic arthritis in children <5 years of age.

### **Bone Scan Whole Body and 3-Phase Bone Scan Area of Interest**

There is no relevant literature regarding the use of whole-body bone scan with 3-phase bone scan of the area of interest in the initial evaluation of osteomyelitis or septic arthritis in children <5 years of age.

### **CT Area of Interest**

There is no relevant literature regarding the use of CT in the initial evaluation of osteomyelitis or septic arthritis in children <5 years of age.

### **MRI Area of Interest**

MRI is widely regarded as sensitive and specific in diagnosis of acute osteomyelitis, with sensitivity reportedly 82% to 100% and specificity 75% to 96% [23-26]. Fluid sensitive sequences alone may be sufficient for diagnosis; one study noted 100% identification of cases of septic arthritis and osteomyelitis in children  $\geq 2$  years of age with review of only these sequences [27]. Children with sickle cell disease pose a diagnostic dilemma because marrow infarction and osteomyelitis may present similarly. Fat-suppressed T1-weighted imaging has been theorized as a useful differentiator, but this has not been substantiated [28]. Subperiosteal fluid has been described as a distinguishing feature of osteomyelitis [29]. Another challenging scenario is differentiation of osteomyelitis from Ewing sarcoma. Several distinguishing MRI features of neoplasia include sharply demarcated margins on T1, presence of a soft-tissue mass, and cortical breach [30,31]. In addition, imaging features of Langerhans cell histiocytosis may overlap with those of acute osteomyelitis, and differentiation in some instances can be difficult.

Although some studies have shown no significant difference in sensitivity and specificity in diagnosis of osteomyelitis or septic arthritis with or without the use of gadolinium-based contrast agents, IV contrast has been shown to improve detection of abscesses [32,33]. Decreased femoral head enhancement on early postcontrast imaging has been noted as a reliable feature of septic arthritis not seen in transient synovitis, and diminished femoral head enhancement on MRI in the setting of septic arthritis in children <12 months of age correlated with development of secondary osteomyelitis [34,35]. Contrast has been shown to markedly improve detection of infection of unossified growth cartilage (chondritis) in children <6 years of age, in which the cartilage most commonly appeared normal on unenhanced sequences; hypoenhancement was more commonly noted with infection [36,37]. In one study of children <18 months of age with community acquired *S aureus* infection of the unossified epiphyseal cartilage, 7 of 9 cases demonstrated normal cartilage signal on noncontrast sequences; hypoenhancement or nonenhancement of involved foci was used for diagnosis [36]. In another study of children <6 years of age, focal or global cartilage nonenhancement was demonstrated in 71% of 14 patients with surgically confirmed epiphyseal osteomyelitis, compared with 21% of controls [37]. Global enhancement defects were more sensitive, noted in 43% of cases but not seen in any control cases.

### **MRI Extremity Area of Interest**

In one study, a large field-of-view MRI was performed to encompass both lower extremities rather than the area of concern [38]. In patients who were later found to have osteomyelitis, 11% had contralateral extremity findings, including contralateral osteomyelitis, and 20% had ipsilateral septic arthritis. Among patients who did not have osteomyelitis, 20% had contralateral abnormalities; most common diagnoses included stress reaction, soft-tissue edema, myositis, sterile joint effusion, and leukemia.

### **MRI Whole Body**

In a study of children  $\leq 5$  years of age with suspected osteomyelitis, of which 39% were confirmed to have osteomyelitis, large field-of-view MRI with coverage from neck to toes provided additional pertinent information for management in 22% of cases, including contralateral infection or alternative diagnoses [39]. Given the small size of young children, whole-body imaging can be achieved in one to two MRI stations [13].

### **Radiography Area of Interest**

Features of acute osteomyelitis on radiographs include periosteal reaction, a well-circumscribed focal bone lucency, and frank bone destruction. Radiographs are not sensitive in assessment of early osteomyelitis because bone destruction does not typically occur until 7 to 10 days into the disease course, and radiographs are normal until >30% osseous matrix destruction has occurred [24,40]. Radiographs, however, do have initial utility in all populations in excluding other entities that may mimic acute osteomyelitis, such as fracture or neoplasm and can be used to direct subsequent imaging evaluation [3,25,31,40]. A particularly challenging subset of patients to



evaluate is those with sickle cell disease. One study found that 63% of patients with known hand or wrist osteomyelitis and underlying sickle cell disease had lytic radiographic changes or periosteal reaction, compared with 23% of patients without sickle cell disease, with the greater frequency in the sickle cell population attributed to either marrow infarction or osteomyelitis as the underlying cause for radiographic changes [41]. Radiographs are highly variable in identifying hip joint effusions, with sensitivity ranging from 20% to 73% [40,42,43]. Radiographs are also variable for identifying fluid in joints other than the hip.

### **US Area of Interest**

Ultrasonography (US) is a highly sensitive method of diagnosing joint effusions, with the bulk of literature addressing the hip joint. US can reportedly detect hip effusions as small as 1 mL [44]. The absence of hip joint effusion virtually excludes septic arthritis; a false negative rate of 5% has been described, noted in patients with a shorter duration of symptoms (<1 day) [40,43,45-47]. Hip US for the purpose of identifying joint effusion can be performed with high sensitivity and specificity [48]. In one study, nearly 80% of pediatric patients with septic arthritis of the hip required US imaging alone to guide their management [45]. US can also be used to identify joint fluid in extremity joints other than the hip. US in evaluation of osteomyelitis is limited in its ability to assess the osseous structures but can identify abutting inflammatory changes such as periosteal elevation, subperiosteal collections, and soft-tissue edema [40,49,50].

### **Variant 2: Child. Younger than 5 years of age. Concern for osteomyelitis or septic arthritis involving an extremity. Initial radiographs normal, or with findings suggestive of osteomyelitis. Next imaging study.**

In this discussion, the literature regarding imaging of pediatric osteomyelitis and septic arthritis will be broadly applied to the appendicular skeleton. In the narrative below, “area of interest” can refer to the following: foot, ankle, tibia/fibula, knee, femur, hip, hand, wrist, forearm, elbow, humerus, or shoulder. Where it is noted that the entire extremity is imaged, for the upper extremity, this is assumed to cover from the shoulder through the hand, and for the lower extremity, this is assumed to cover from the hip through the foot.

### **Bone Scan Whole Body and 3-Phase Bone Scan Area of Interest**

Skeletal scintigraphy has been traditionally used to accurately detect disease in cases of suspected acute osteomyelitis with normal radiographs because scintigraphic changes are present within the first 1 to 2 days of symptoms [8]. Although multiple studies have documented the success of scintigraphy in identifying acute osteomyelitis in children, there is limited data with studies in which only the area of interest was imaged. In one study in which blood pool and delayed imaging of only the area of interest were performed, 70 of 71 cases of osteomyelitis were identified [51]. However, multifocal osteomyelitis is common in the pediatric population, particularly among young children, and as a result, whole-body bone scan is typically advocated [52]. One study, in which a 3-phase bone scan was performed followed by a whole-body scan, delayed imaging noted 19% of cases of acute osteomyelitis were noted to be multifocal osteomyelitis, with over half of those cases noted in patients <6 years of age, the majority of which were neonates [52]. Single-photon emission computed tomography (SPECT)/CT offers improved characterization of osseous pathology compared to planar imaging [53]. MRI is generally considered preferable in detection of early manifestations of osteomyelitis, as well as infection of the surrounding soft tissues, because of the rapid progression of disease [53]. Whole-body bone scan is typically helpful when scintigraphy is used for suspected osteomyelitis, particularly if there is a fever of unknown origin or bacteremia [54]. One study assessed the accuracy of bone scan for the diagnosis of suspected acute hematogenous osteomyelitis and septic arthritis in 86 children, using whole-body and selected static images, without blood flow or blood pool views [55]. Bone scan findings were correlated with the final diagnosis in 34 sites of septic arthritis and in 62 sites of osteomyelitis. Bone scan accuracy was 81%. Positive predictive value was 82% for those sites with increased activity and 100% for those sites with decreased activity. Negative predictive value was 63%. In another smaller study, 9 patients who underwent whole-body scan, 100% (7 of 7) patients with osteomyelitis had increased uptake corresponding to the site of involvement [56]. In one study of 213 children referred for skeletal scintigraphy because of suspicion for acute hematogenous osteomyelitis who underwent a 3-phase bone scan of the area of interest along with whole-body delayed images, accurate diagnosis was made in 84% of cases without the need for MRI, including 92% of those diagnosed with osteomyelitis, although it should be noted that bone scan was limited regarding soft-tissue and articular pathology [57]. In another study of 65 children who underwent whole-body scan with focused evaluations of the area of interest and the contralateral side, 23 patients who were classified as having osteomyelitis all had abnormal bone scans [58]. SPECT/CT offers improved characterization of osseous pathology compared with planar imaging [59]. MRI is generally considered preferable in detection of early manifestations of osteomyelitis, as well as infection of the surrounding soft tissues, because of the rapid progression of the disease [53].

### **CT Area of Interest**

There is no relevant literature regarding the use of CT as the next imaging study in evaluation of osteomyelitis or septic arthritis in children under 5 years of age.

### **Image-Guided Aspiration Area of Interest**

Primary differential considerations when a joint effusion is present in the absence of trauma are transient synovitis and septic arthritis. Although the most common locations of septic arthritis are the knee and hip joints, this can affect any joint [60]. Although most nontraumatic hip joint effusions are secondary to transient synovitis, early diagnosis of septic arthritis is extremely important in preventing complications, and US-guided hip aspiration is considered highly accurate for diagnosis [43,61]. In one study, 100% of children were confirmed to have septic hip arthritis via bedside joint aspiration and were able to avoid arthrotomy. However, it should be noted that US guidance for aspiration was only provided in one case, and the remainder were performed using anatomic landmarks without imaging guidance [62]. In the setting of confirmed transient synovitis, children who underwent US-guided joint aspiration experienced shorter duration of stay and shorter duration of a limp compared with those who did not undergo joint aspiration [61]. In patients with suspected or confirmed septic arthritis, femoral neck aspiration performed at the time of incision and drainage was noted to improve diagnosis of concurrent osteomyelitis compared with preoperative MRI alone [63].

### **MRI Area of Interest**

MRI is widely regarded as sensitive and specific in the diagnosis of acute osteomyelitis, with sensitivity reportedly 82% to 100% and specificity 75% to 96% [23-26]. Fluid sensitive sequences alone may be sufficient for diagnosis; one study noted 100% identification of cases of septic arthritis and osteomyelitis in children  $\geq 2$  years of age, with the review of only these sequences [27]. Children with sickle cell disease pose a diagnostic dilemma because marrow infarction and osteomyelitis may present similarly. Fat-suppressed T1-weighted imaging has been theorized as a useful differentiator but this has not been substantiated [28]. Subperiosteal fluid has been described as a distinguishing feature of osteomyelitis [29]. Another challenging scenario is the differentiation of osteomyelitis from Ewing sarcoma. Several distinguishing MRI features of neoplasia include sharply demarcated margins on T1, presence of a soft-tissue mass, and cortical breach [30,31].

Although some studies have shown no significant difference in sensitivity and specificity in the diagnosis of osteomyelitis or septic arthritis with or without the use of gadolinium-based contrast agents, IV contrast has been shown to improve detection of abscesses [32,33]. Decreased femoral head enhancement on early postcontrast imaging has been noted as a reliable feature of septic arthritis not seen in transient synovitis, and diminished femoral head enhancement on MRI has been noted in the setting of septic arthritis in children under 12 months of age correlated with development of secondary osteomyelitis [34,35]. Contrast has been shown to markedly improve detection of infection of unossified growth cartilage (chondritis) in children  $< 6$  years of age, in which the cartilage most commonly appeared normal on unenhanced sequences; hypoenhancement was more commonly noted with infection [36,37]. In one study of children  $< 18$  months of age with community acquired *S aureus* infection of the unossified epiphyseal cartilage, 7 of 9 cases demonstrated normal cartilage signal on noncontrast sequences; hypoenhancement or nonenhancement of involved foci was used for diagnosis [36]. In another study of children  $< 6$  years of age, focal or global cartilage nonenhancement was demonstrated in 71% of 14 patients with surgically confirmed epiphyseal osteomyelitis, compared with 21% of controls [37]. Global enhancement defects were more sensitive, noted in 43% of cases but not seen in any control cases.

Repeat MRI of the area of interest performed for worsening or persistent symptoms resulted in clinical management changes in 21% of patients [64]. In one study on septic elbow arthritis, 40% of patients did not respond to antibiotic therapy and were noted on subsequent elbow MRI to have concurrent osteomyelitis [60].

### **MRI Extremity Area of Interest**

In one study, a large field-of-view MRI was performed to encompass both lower extremities rather than the area of concern [38]. In patients who were later found to have osteomyelitis, 11% had contralateral extremity findings, including contralateral osteomyelitis, and 20% had ipsilateral septic arthritis. Among patients who did not have osteomyelitis, 20% had contralateral abnormalities; most common diagnoses included stress reaction, soft-tissue edema, myositis, sterile joint effusion, and leukemia.

## **MRI Whole Body**

In a study of children  $\leq 5$  years of age with suspected osteomyelitis, of which 39% were confirmed to have osteomyelitis, large field-of-view MRI with coverage from neck to toes provided additional pertinent information for management in 22% of cases, including contralateral infection or alternative diagnoses [39].

## **US Area of Interest**

US is a highly sensitive method of diagnosing hip joint effusion, and the absence of hip joint effusion virtually excludes septic arthritis; a false negative rate of 5% has been described, noted in patients with a shorter duration of symptoms ( $< 1$  day) [40,43,45-47]. US can reportedly detect hip effusions as small as 1 mL [44]. Hip US for the purpose of identifying joint effusion can be performed with high sensitivity and specificity [48]. In one study, nearly 80% of pediatric patients with hip septic arthritis required US imaging alone to guide their management [45]. US in evaluation of osteomyelitis is limited in its ability to assess the osseous structures but can identify abutting inflammatory changes affecting the soft tissues such as periosteal elevation and subperiosteal collections [40,49,50].

## **Variant 3: Child. 5 years of age or older. Concern for osteomyelitis or septic arthritis involving an extremity. Initial imaging.**

In this discussion, the literature regarding imaging of pediatric osteomyelitis and septic arthritis will be broadly applied to the appendicular skeleton. In the narrative below, “area of interest” can refer to the following: foot, ankle, tibia/fibula, knee, femur, hip, hand, wrist, forearm, elbow, humerus, or shoulder. Where it is noted that the entire extremity is imaged, for the upper extremity, this is assumed to cover from the shoulder through the hand, and for the lower extremity, this is assumed to cover from the hip through the foot.

## **3-Phase Bone Scan Area of Interest**

There is no relevant literature regarding the use of 3-phase bone scan in the initial evaluation of osteomyelitis or septic arthritis in children  $\geq 5$  years of age.

## **Bone Scan Whole Body**

There is no relevant literature regarding the use of whole-body bone scan in the initial evaluation of osteomyelitis or septic arthritis in children  $\geq 5$  years of age.

## **Bone Scan Whole Body and 3-Phase Bone Scan Area of Interest**

There is no relevant literature regarding the use of whole-body bone scan with 3-phase bone scan of the area of interest in the initial evaluation of osteomyelitis or septic arthritis in children  $\geq 5$  years of age.

## **CT Area of Interest**

There is no relevant literature regarding the use of CT in the initial evaluation of osteomyelitis or septic arthritis in children  $\geq 5$  years of age.

## **MRI Area of Interest**

MRI is widely regarded as sensitive and specific in the diagnosis of acute osteomyelitis, with sensitivity reportedly 82% to 100% and specificity 75% to 96% [23-26]. Fluid sensitive sequences alone may be sufficient for diagnosis; one study noted 100% identification of cases of septic arthritis and osteomyelitis in children  $\geq 2$  years of with review of only these sequences [27]. Children with sickle cell disease pose a diagnostic dilemma because marrow infarction and osteomyelitis may present similarly. Fat-suppressed T1-weighted imaging had been theorized as a useful differentiator but this has not been substantiated [28]. Subperiosteal fluid has been described as a distinguishing feature of osteomyelitis [29]. Another challenging scenario is differentiation of osteomyelitis from Ewing sarcoma. Several distinguishing MRI features include sharply demarcated margins on T1, presence of a soft-tissue mass, and cortical breach [30,31].

Although some studies have shown no significant difference in sensitivity and specificity in diagnosis of osteomyelitis or septic arthritis with or without the use of gadolinium-based contrast agents, contrast has been shown to improve detection of abscesses [32,33]. Decreased femoral head enhancement on early postcontrast imaging has been noted as a reliable feature of septic arthritis not seen in transient synovitis [34].

In addition, MRI has been shown to be useful in evaluating for concurrent musculoskeletal infection. In assessment of septic arthritis, the majority of pediatric patients with septic arthritis were noted on MRI to have infection beyond the joint space, though this may vary based on population factors such as geography [7,46,60,65,66]. Conversely, in metaphyseal osteomyelitis,  $> 50\%$  in one study were noted on MRI to have concomitant joint effusions, 75% of which were confirmed to be septic arthritis [67].

### **MRI Extremity Area of Interest**

In one study, a large field-of-view MRI was performed to encompass both lower extremities rather than the area of concern [38]. In patients who were later found to have osteomyelitis, 11% had contralateral extremity findings, including contralateral osteomyelitis, and 20% had ipsilateral septic arthritis. Among patients who did not have osteomyelitis, 20% had contralateral abnormalities, most commonly stress reaction, soft-tissue edema, myositis, joint effusion (not septic), and leukemia.

### **MRI Whole Body**

There is no relevant literature regarding the use of MRI whole body in the initial imaging study in evaluation of osteomyelitis or septic arthritis in children  $\geq 5$  years of age.

### **Radiography Area of Interest**

Radiographs are not sensitive in assessment of early osteomyelitis because bone destruction does not typically occur until 7 to 10 days into the disease course, and radiographs are normal until  $>30\%$  osseous matrix destruction has occurred [24,40]. Radiographs, however, do have utility in all populations in excluding other entities that may mimic acute osteomyelitis, such as fracture or neoplasm [3,25,31,40]. Radiographs are highly variable in identifying hip joint effusions, with sensitivity ranging from 20% to 73% [40,42,43].

### **US Area of Interest**

US is a highly sensitive method of diagnosing hip joint effusion, and the absence of hip joint effusion virtually excludes septic arthritis; a false negative rate of 5% has been described, noted in patients with a shorter duration of symptoms ( $<1$  day) [40,43,45-47]. US can reportedly detect hip effusions as small as 1 mL [44]. Hip US for the purpose of identifying joint effusion can be performed with high sensitivity and specificity [48]. In one study, nearly 80% of pediatric patients with hip septic arthritis required US imaging alone to guide their management [45]. US in evaluation of osteomyelitis is limited in its ability to assess the osseous structures but can identify abutting inflammatory changes affecting the soft tissues such as periosteal elevation and subperiosteal collections [40,49,50].

### **Variant 4: Child. 5 years of age or older. Concern for osteomyelitis or septic arthritis involving an extremity. Initial radiographs normal, or with findings suggestive of osteomyelitis. Next imaging study.**

In this discussion, the literature regarding imaging of pediatric osteomyelitis and septic arthritis will be broadly applied to the appendicular skeleton. In the narrative below, “area of interest” can refer to the following: foot, ankle, tibia/fibula, knee, femur, hip, hand, wrist, forearm, elbow, humerus, or shoulder. Where it is noted that the entire extremity is imaged, for the upper extremity, this is assumed to cover from the shoulder through the hand, and for the lower extremity, this is assumed to cover from the hip through the foot.

### **3-Phase Bone Scan Area of Interest**

Skeletal scintigraphy has been traditionally used to accurately detect disease in cases of suspected acute osteomyelitis with normal radiographs because scintigraphic changes are present within the first 1 to 2 days of symptoms [8]. Although multiple studies have documented the success of scintigraphy in identifying acute osteomyelitis in children, there is limited data with studies in which only the area of interest was imaged. In one study in which blood pool and delayed imaging of only the area of interest were performed, 70 of 71 cases of osteomyelitis were identified [51]. However, multifocal osteomyelitis is common in the pediatric population, particularly among young children, and as a result, whole-body bone scan is typically advocated [52]. One study, in which a 3-phase bone scan was performed followed by a whole-body scan, delayed imaging noted 19% of cases of acute osteomyelitis were noted to be multifocal osteomyelitis, with over half of those cases noted in patients  $<6$  years of age, the majority of which were neonates [52]. SPECT/CT offers improved characterization of osseous pathology compared with planar imaging [59]. MRI is generally considered preferable in detection of early manifestations of osteomyelitis, as well as infection of the surrounding soft tissues, because of the rapid progression of the disease [53].

### **Bone Scan Whole Body**

Whole-body bone scan is typically recommended when scintigraphy is used for suspected osteomyelitis, particularly if there is a fever of unknown origin or bacteremia [54]. One study assessed the accuracy of bone scan for the diagnosis of suspected acute hematogenous osteomyelitis and septic arthritis in 86 children, using whole-body and selected static images, without blood flow or blood pool views [55]. Bone scan findings were correlated with the final diagnosis in 34 sites of septic arthritis and in 62 sites of osteomyelitis. Bone scan accuracy was 81%. Positive predictive value was 82% for those sites with increased activity and 100% for those sites with decreased activity. Negative predictive value was 63%. In another smaller study, 9 patients who underwent whole-body scan,

100% (7 of 7) patients with osteomyelitis had increased uptake corresponding to the site of involvement [56]. SPECT/CT offers improved characterization of osseous pathology compared to planar imaging [59]. MRI is generally considered preferable in detection of early manifestations of osteomyelitis, as well as infection of the surrounding soft tissues, because of the rapid progression of the disease [53].

### **Bone Scan Whole Body and 3-Phase Bone Scan Area of Interest**

Whole-body bone scan is typically recommended when scintigraphy is used for suspected osteomyelitis, particularly if there is a fever of unknown origin or bacteremia [54]. In one study of 213 children referred for skeletal scintigraphy because of a suspicion for acute hematogenous osteomyelitis who underwent a 3-phase bone scan of the area of interest along with whole-body delayed images, accurate diagnosis was made in 84% of cases without the need for MRI, including 92% of those diagnosed with osteomyelitis [57]. In another study of 65 children who underwent whole-body scan with focused evaluations of the area of interest and the contralateral side, 23 patients who were classified as having osteomyelitis all had abnormal bone scans [58]. SPECT/CT offers improved characterization of osseous pathology compared with planar imaging [59]. MRI is generally considered preferable in detection of early manifestations of osteomyelitis, as well as infection of the surrounding soft tissues, because of the rapid progression of the disease, but SPECT/CT offers improved characterization of osseous pathology compared with planar imaging [53,59].

### **CT Area of Interest**

There is no relevant literature regarding the use of CT as the next imaging study in evaluation of osteomyelitis or septic arthritis in children  $\geq 5$  years of age.

### **Image-Guided Aspiration Area of Interest**

Primary differential considerations when a joint effusion is present in the absence of trauma are transient synovitis and septic arthritis. Though most nontraumatic hip joint effusions are secondary to transient synovitis, early diagnosis of septic arthritis is extremely important in preventing complications, and US-guided hip aspiration is considered highly accurate for diagnosis [43,61]. In one study, 100% of children were confirmed to have septic hip arthritis via bedside joint aspiration and were able to avoid arthrotomy. However, it should be noted that US guidance for aspiration was only provided in one case, and the remainder were performed using anatomic landmarks and without imaging guidance [62]. In the setting of confirmed transient synovitis, children who underwent US-guided joint aspiration experienced shorter duration of stay and shorter duration of a limp compared with those who did not undergo joint aspiration [61]. In patients with suspected or confirmed septic arthritis, femoral neck aspiration performed at the time of incision and drainage was noted to improve diagnosis of concurrent osteomyelitis compared with preoperative MRI alone [63]. Although the bulk of literature on image-guided joint aspiration in the pediatric population refers to the hip joint, aspiration could also be considered in other joints.

### **MRI Area of Interest**

MRI is widely regarded as sensitive and specific in diagnosis of acute osteomyelitis, with sensitivity reportedly 82% to 100% and specificity 75% to 96% [23-26]. Fluid sensitive sequences alone may be sufficient for diagnosis; one study noted 100% identification of cases of septic arthritis and osteomyelitis in children  $\geq 2$  years of with review of only these sequences [27]. Children with sickle cell disease pose a diagnostic dilemma because marrow infarction and osteomyelitis may present similarly. Fat-suppressed T1-weighted imaging had been theorized as a useful differentiator but this has not been substantiated [28]. Subperiosteal fluid has been described as a distinguishing feature of osteomyelitis [29]. Another challenging scenario is differentiation of osteomyelitis from Ewing sarcoma. Several distinguishing MRI features include sharply demarcated margins on T1, presence of a soft-tissue mass, and cortical involvement [30,31].

Although some studies have shown no significant difference in sensitivity and specificity in the diagnosis of osteomyelitis or septic arthritis with or without the use of gadolinium-based contrast agents, contrast has been shown to improve detection of abscesses [32,33]. Decreased femoral head enhancement on early postcontrast imaging has been noted as a reliable feature of septic arthritis not seen in transient synovitis [34].

In addition, MRI has been shown to be useful in evaluating for concurrent musculoskeletal infection. In assessment of septic arthritis, the majority of pediatric patients with septic arthritis were noted on MRI to have infection beyond the joint space, although this may vary based on population factors such as geography [7,46,60,65,66]. Conversely, in metaphyseal osteomyelitis, over 50% in one study were noted on MRI to have concomitant joint effusions, 75% of which were confirmed to be septic arthritis [67].

Repeat MRI of the area of interest performed for worsening or persistent symptoms resulted in clinical management changes in 21% of patients [64]. In one study on septic elbow arthritis, 40% of patients did not respond to antibiotic therapy and were noted on subsequent elbow MRI to have concurrent osteomyelitis [60].

### **MRI Extremity Area of Interest**

In one study, a large field-of-view MRI was performed to encompass both lower extremities rather than the area of concern [38]. In patients who were later found to have osteomyelitis, 11% had contralateral extremity findings, including contralateral osteomyelitis, and 20% had ipsilateral septic arthritis. Among patients who did not have osteomyelitis, 20% had contralateral abnormalities, most commonly stress reaction, soft-tissue edema, myositis, joint effusion (not septic), and leukemia.

### **MRI Whole Body**

There is no relevant literature regarding the use of MRI of the whole body as the next imaging study in evaluation of osteomyelitis or septic arthritis in children  $\geq 5$  years of age.

### **US Area of Interest**

US is a highly sensitive method of diagnosing hip joint effusion, and the absence of hip joint effusion virtually excludes septic arthritis; a false negative rate of 5% has been described, noted in patients with a shorter duration of symptoms (<1 day) [40,43,45-47]. US can reportedly detect hip effusions as small as 1 mL [44]. Hip US for the purpose of identifying joint effusion can be performed with high sensitivity and specificity [48]. In one study, nearly 80% of pediatric patients with hip septic arthritis required US imaging alone to guide their management [45]. US in evaluation of osteomyelitis is limited in its ability to assess the osseous structures but can identify abutting inflammatory changes affecting the soft tissues such as periosteal elevation and subperiosteal collections [40,49,50].

### **Variant 5: Child. With one or more clinical signs concerning for septic arthritis. Initial radiographs normal or demonstrating possible joint effusion. Next imaging study.**

In this discussion, the literature regarding imaging of septic arthritis will be broadly applied to the appendicular skeleton. In the narrative below, “area of interest” can refer to the following: foot, ankle, tibia/fibula, knee, femur, hip, hand, wrist, forearm, elbow, humerus, or shoulder. Where it is noted that the entire extremity is imaged, for the upper extremity, this is assumed to cover from the shoulder through the hand, and for the lower extremity, this is assumed to cover from the hip through the foot. The data regarding imaging of septic arthritis in the pediatric population are focused on the hip joint, with little literature about other appendicular joints. The available literature on the hip joint will be presented with extrapolation to other appendicular joints.

### **3-Phase Bone Scan Area of Interest**

There is limited data regarding the use of 3-phase bone scan of area of interest as the next imaging study in evaluation of septic arthritis. In one study in which blood pool and delayed imaging of only the area of interest were performed, 8 of 9 cases of septic arthritis were identified [51].

### **Bone Scan Whole Body**

There is limited data regarding the use of whole-body bone scan as the next imaging study in the evaluation of septic arthritis. One study assessed the accuracy of bone scan for the diagnosis of suspected acute hematogenous osteomyelitis and septic arthritis in 86 children, using whole-body and selected static images, without blood flow or blood pool views [55]. Bone scan findings were correlated with the final diagnosis in 34 sites of septic arthritis and in 62 sites of osteomyelitis. Bone scan accuracy was 81%. Positive predictive value was 82% for those sites with increased activity and 100% for those sites with decreased activity. Negative predictive value was 63%.

### **Bone Scan Whole Body and 3-Phase Bone Scan Area of Interest**

There is no relevant recent regarding the use of whole-body bone scan and 3-phase bone scan of area of interest as the next imaging study in the evaluation of suspected septic arthritis.

### **CT Area of Interest**

There is no relevant literature regarding the use of CT as the next imaging study in the evaluation of suspected septic arthritis.

### **Image-Guided Aspiration Area of Interest**

Early diagnosis of septic arthritis is extremely important in preventing complications, and US-guided hip aspiration is considered highly accurate [43,61]. In one study, 100% of children were confirmed to have septic hip arthritis via bedside joint aspiration and were able to avoid arthrotomy. However, it should be noted that US guidance for

aspiration was only provided in one case, and the remainder performed using anatomic landmarks without imaging guidance [62]. In the setting of confirmed transient synovitis, children who underwent US-guided joint aspiration experienced shorter duration of stay and shorter duration of limp compared with those who did not undergo joint aspiration [61]. In patients with suspected or confirmed septic arthritis, femoral neck aspiration performed at the time of incision and drainage was noted to improve diagnosis of concurrent osteomyelitis compared with preoperative MRI alone [63].

### **MRI Area of Interest**

Although differentiation of etiology of hip effusion can be challenging on MRI, decreased femoral head enhancement on early postcontrast imaging has been noted as a reliable feature of septic arthritis not seen in transient synovitis [34]. In addition, the majority of pediatric patients with confirmed septic arthritis were noted on MRI to have infection beyond the joint space, although this may vary based on epidemiologic factors such as geography [7,46,60,65,66]. The presence of concurrent infections was notably more frequent about the shoulder joint [65,68]. However, preoperative MRI may not be indicated in all patients because it can potentially delay treatment. In a recent study, five variables were noted to be predictive of adjacent infection: C-reactive protein above cutoff 13.8 mg/L, absolute neutrophil count above cutoff  $8.6 \times 10^3$  cells/ $\mu$ L, platelet level below cutoff 314 cells/ $\mu$ L, duration of symptoms >3 days, and age >3.6 years [7]. Presence of at least three risk factors was classified as high risk for adjacent infection, with a sensitivity of 90% and a positive predictive value of 80% on the initial study, and was validated in a subsequent study with a sensitivity of 86% and a positive predictive value of 91% [7,69].

### **MRI Extremity Area of Interest**

There is some literature on the use of MRI in the evaluation of septic arthritis, particularly as part of the workup for coexisting osteomyelitis, with one study recommending the field of view always include the adjacent joint to assess articular disease [6,67].

### **MRI Whole Body**

There is no relevant literature regarding the use of MRI of the whole body as the next imaging study in the evaluation of suspected septic arthritis.

### **US Area of Interest**

US is a highly sensitive method of diagnosing hip joint effusion, and the absence of hip joint effusion virtually excludes septic arthritis; a false negative rate of 5% has been described, noted in patients with shorter duration of symptoms (<1 day) [40,43,45,47]. US can reportedly detect hip effusions as small as 1 mL [44]. Hip US for the purpose of identifying joint effusion can be performed with high sensitivity and specificity [48]. In one study, nearly 80% of pediatric patients with hip septic arthritis required US imaging alone to guide their management [45].

### **Summary of Recommendations**

- **Variation 1:** US area of interest or radiography area of interest or MRI area of interest without and with IV contrast or MRI extremity area of interest without and with IV contrast is usually appropriate for the initial imaging of a child, younger than 5 years of age with a concern for osteomyelitis or septic arthritis involving an extremity. Although all of these studies can be performed as part of initial imaging of a child, the use of radiography as an initial imaging study often necessitates a next imaging study as part of the workup if clinical suspicion for osteomyelitis or septic arthritis remains following completion of this study. The panel did not agree on recommending MRI whole body without and with IV contrast for the initial imaging of a child, younger than 5 years of age with a concern for osteomyelitis or septic arthritis involving an extremity. There is insufficient medical literature to conclude whether or not these patients would benefit from MRI whole body without and with IV contrast for this clinical scenario. MRI whole body without and with IV contrast in this patient population is controversial but may be appropriate.
- **Variation 2:** US area of interest or image-guided aspiration area of interest or MRI area of interest without and with IV contrast or MRI extremity area of interest without and with IV contrast or MRI extremity area of interest without IV contrast is usually appropriate for the next imaging study of a child, younger than 5 years of age with normal initial radiographs, or with findings suggestive of osteomyelitis with a concern for osteomyelitis or septic arthritis involving an extremity. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variation 3:** US area of interest or radiography area of interest or MRI area of interest without and with IV contrast or MRI area of interest without IV contrast or MRI extremity area of interest without and with IV

contrast is usually appropriate for the initial imaging of children, 5 years of age or older with a concern for osteomyelitis or septic arthritis involving an extremity. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care). Although all of these studies can be performed as part of initial imaging of a child, the use of radiography as an initial imaging study often necessitates a next imaging study as part of the workup if clinical suspicion for osteomyelitis or septic arthritis remains following completion of this study.

- **Variation 4:** Image-guided aspiration area of interest or MRI area of interest without and with IV contrast or MRI area of interest without IV contrast or MRI extremity area of interest without and with IV contrast or MRI extremity area of interest without IV contrast is usually appropriate for the next imaging study of a child, 5 years of age or older with normal initial radiographs, or with findings suggestive of osteomyelitis with a concern for osteomyelitis or septic arthritis involving an extremity. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care).
- **Variation 5:** US area of interest or image-guided aspiration area of interest or MRI area of interest without and with IV contrast is usually appropriate for the next imaging study of a child with normal initial radiographs or demonstrating possible joint effusion with one or more clinical signs concerning for septic arthritis. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care).

### Supporting Documents

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to [www.acr.org/ac](http://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 [70].

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.”

## References

1. Dodwell ER. Osteomyelitis and septic arthritis in children: current concepts. *Curr Opin Pediatr* 2013;25:58-63.
2. Gafur OA, Copley LA, Hollmig ST, Browne RH, Thornton LA, Crawford SE. The impact of the current epidemiology of pediatric musculoskeletal infection on evaluation and treatment guidelines. *J Pediatr Orthop* 2008;28:777-85.
3. Jaramillo D. Infection: musculoskeletal. *Pediatr Radiol* 2011;41 Suppl 1:S127-34.
4. Riise OR, Kirkhus E, Handeland KS, et al. Childhood osteomyelitis-incidence and differentiation from other acute onset musculoskeletal features in a population-based study. *BMC Pediatr* 2008;8:45.
5. Chen WL, Chang WN, Chen YS, et al. Acute community-acquired osteoarticular infections in children: high incidence of concomitant bone and joint involvement. *J Microbiol Immunol Infect* 2010;43:332-8.
6. Monsalve J, Kan JH, Schallert EK, Bisset GS, Zhang W, Rosenfeld SB. Septic arthritis in children: frequency of coexisting unsuspected osteomyelitis and implications on imaging work-up and management. *AJR Am J Roentgenol* 2015;204:1289-95.
7. Rosenfeld S, Bernstein DT, Daram S, Dawson J, Zhang W. Predicting the Presence of Adjacent Infections in Septic Arthritis in Children. *J Pediatr Orthop* 2016;36:70-4.
8. Guillerman RP. Osteomyelitis and beyond. *Pediatr Radiol* 2013;43 Suppl 1:S193-203.
9. Jaimes C, Chauvin NA, Delgado J, Jaramillo D. MR imaging of normal epiphyseal development and common epiphyseal disorders. *Radiographics* 2014;34:449-71.
10. Gilbertson-Dahdal D, Wright JE, Krupinski E, McCurdy WE, Taljanovic MS. Transphyseal involvement of pyogenic osteomyelitis is considerably more common than classically taught. *AJR Am J Roentgenol* 2014;203:190-5.
11. Dolitsky R, DePaola K, Fericola J, Collins C. Pediatric Musculoskeletal Infections. *Pediatr Clin North Am* 2020;67:59-69.
12. Sadat-Ali M. The status of acute osteomyelitis in sickle cell disease. A 15-year review. *Int Surg* 1998;83:84-7.
13. Jaramillo D, Dormans JP, Delgado J, Laor T, St Geme JW, 3rd. Hematogenous Osteomyelitis in Infants and Children: Imaging of a Changing Disease. *Radiology* 2017;283:629-43.
14. Kocher MS, Zurakowski D, Kasser JR. Differentiating between septic arthritis and transient synovitis of the hip in children: an evidence-based clinical prediction algorithm. *J Bone Joint Surg Am* 1999;81:1662-70.
15. Caird MS, Flynn JM, Leung YL, Millman JE, D'Italia JG, Dormans JP. Factors distinguishing septic arthritis from transient synovitis of the hip in children. A prospective study. *J Bone Joint Surg Am* 2006;88:1251-7.
16. Montgomery NI, Epps HR. Pediatric Septic Arthritis. *Orthop Clin North Am* 2017;48:209-16.

17. Booth TN, Iyer RS, Falcone RA, Jr., et al. ACR Appropriateness Criteria® Back Pain-Child. *J Am Coll Radiol* 2017;14:S13-S24.
18. Barrett JF, Keat N. Artifacts in CT: recognition and avoidance. *Radiographics* 2004;24:1679-91.
19. Katsura M, Sato J, Akahane M, Kunimatsu A, Abe O. Current and Novel Techniques for Metal Artifact Reduction at CT: Practical Guide for Radiologists. *Radiographics* 2018;38:450-61.
20. Talbot BS, Weinberg EP. MR Imaging with Metal-suppression Sequences for Evaluation of Total Joint Arthroplasty. *Radiographics* 2016;36:209-25.
21. Frank G, Mahoney HM, Eppes SC. Musculoskeletal infections in children. *Pediatr Clin North Am* 2005;52:1083-106, ix.
22. Safdar NM, Rigsby CK, Iyer RS, et al. ACR Appropriateness Criteria® Acutely Limping Child Up To Age 5. *J Am Coll Radiol* 2018;15:S252-S62.
23. Erdman WA, Tamburro F, Jayson HT, Weatherall PT, Ferry KB, Peshock RM. Osteomyelitis: characteristics and pitfalls of diagnosis with MR imaging. *Radiology* 1991;180:533-9.
24. Jaramillo D, Treves ST, Kasser JR, Harper M, Sundel R, Laor T. Osteomyelitis and septic arthritis in children: appropriate use of imaging to guide treatment. *AJR Am J Roentgenol* 1995;165:399-403.
25. Karmazyn B. Imaging approach to acute hematogenous osteomyelitis in children: an update. *Semin Ultrasound CT MR* 2010;31:100-6.
26. Pineda C, Vargas A, Rodriguez AV. Imaging of osteomyelitis: current concepts. *Infect Dis Clin North Am* 2006;20:789-825.
27. Markhardt BK, Woo K, Nguyen JC. Evaluation of suspected musculoskeletal infection in children over 2 years of age using only fluid-sensitive sequences at MRI. *Eur Radiol* 2019;29:5682-90.
28. Delgado J, Bedoya MA, Green AM, Jaramillo D, Ho-Fung V. Utility of unenhanced fat-suppressed T1-weighted MRI in children with sickle cell disease -- can it differentiate bone infarcts from acute osteomyelitis? *Pediatr Radiol* 2015;45:1981-7.
29. Ahmad S, Khan ZA, Rehmani R, Sheikh MY. Diagnostic dilemma in sicklers with acute bone crisis: role of subperiosteal fluid collection on MRI in resolving this issue. *J Pak Med Assoc* 2010;60:819-22.
30. Henninger B, Glodny B, Rudisch A, et al. Ewing sarcoma versus osteomyelitis: differential diagnosis with magnetic resonance imaging. *Skeletal Radiol* 2013;42:1097-104.
31. McCarville MB, Chen JY, Coleman JL, et al. Distinguishing Osteomyelitis From Ewing Sarcoma on Radiography and MRI. *AJR Am J Roentgenol* 2015;205:640-50; quiz 51.
32. Averill LW, Hernandez A, Gonzalez L, Pena AH, Jaramillo D. Diagnosis of osteomyelitis in children: utility of fat-suppressed contrast-enhanced MRI. *AJR Am J Roentgenol* 2009;192:1232-8.
33. Kan JH, Young RS, Yu C, Hernanz-Schulman M. Clinical impact of gadolinium in the MRI diagnosis of musculoskeletal infection in children. *Pediatr Radiol* 2010;40:1197-205.
34. Kim EY, Kwack KS, Cho JH, Lee DH, Yoon SH. Usefulness of dynamic contrast-enhanced MRI in differentiating between septic arthritis and transient synovitis in the hip joint. *AJR Am J Roentgenol* 2012;198:428-33.
35. Merlini L, Anooshiravani M, Ceroni D. Concomitant septic arthritis and osteomyelitis of the hip in young children; a new pathophysiological hypothesis suggested by MRI enhancement pattern. *BMC Med Imaging* 2015;15:17.
36. Browne LP, Guillerman RP, Orth RC, Patel J, Mason EO, Kaplan SL. Community-acquired staphylococcal musculoskeletal infection in infants and young children: necessity of contrast-enhanced MRI for the diagnosis of growth cartilage involvement. *AJR Am J Roentgenol* 2012;198:194-9.
37. Johnson DP, Hernanz-Schulman M, Martus JE, Lovejoy SA, Yu C, Kan JH. Significance of epiphyseal cartilage enhancement defects in pediatric osteomyelitis identified by MRI with surgical correlation. *Pediatr Radiol* 2011;41:355-61.
38. Metwalli ZA, Kan JH, Munjal KA, Orth RC, Zhang W, Guillerman RP. MRI of suspected lower extremity musculoskeletal infection in the pediatric patient: how useful is bilateral imaging? *AJR Am J Roentgenol* 2013;201:427-32.
39. Lindsay AJ, Delgado J, Jaramillo D, Chauvin NA. Extended field of view magnetic resonance imaging for suspected osteomyelitis in very young children: is it useful? *Pediatr Radiol* 2019;49:379-86.
40. Nguyen JC, Lee KS, Thapa MM, Rosas HG. US Evaluation of Juvenile Idiopathic Arthritis and Osteoarticular Infection. *Radiographics* 2017;37:1181-201.
41. Tordjman D, Holvoet L, Benkerrou M, et al. Hematogenous osteoarticular infections of the hand and the wrist in children with sickle cell anemia: preliminary report. *J Pediatr Orthop* 2014;34:123-8.

42. Volberg FM, Sumner TE, Abramson JS, Winchester PH. Unreliability of radiographic diagnosis of septic hip in children. *Pediatrics* 1984;74:118-20.
43. Zawin JK, Hoffer FA, Rand FF, Teele RL. Joint effusion in children with an irritable hip: US diagnosis and aspiration. *Radiology* 1993;187:459-63.
44. Zieger MM, Dorr U, Schulz RD. Ultrasonography of hip joint effusions. *Skeletal Radiol* 1987;16:607-11.
45. Laine JC, Denning JR, Riccio AI, Jo C, Joglar JM, Wimberly RL. The use of ultrasound in the management of septic arthritis of the hip. *J Pediatr Orthop B* 2015;24:95-8.
46. Manz N, Krieg AH, Heininger U, Ritz N. Evaluation of the current use of imaging modalities and pathogen detection in children with acute osteomyelitis and septic arthritis. *Eur J Pediatr* 2018;177:1071-80.
47. Gordon JE, Huang M, Dobbs M, Luhmann SJ, Szymanski DA, Schoenecker PL. Causes of false-negative ultrasound scans in the diagnosis of septic arthritis of the hip in children. *J Pediatr Orthop* 2002;22:312-6.
48. Vieira RL, Levy JA. Bedside ultrasonography to identify hip effusions in pediatric patients. *Ann Emerg Med* 2010;55:284-9.
49. Inusa BP, Oyewo A, Brokke F, Santhikumar G, Jogeessvaran KH. Dilemma in differentiating between acute osteomyelitis and bone infarction in children with sickle cell disease: the role of ultrasound. *PLoS One* 2013;8:e65001.
50. Mah ET, LeQuesne GW, Gent RJ, Paterson DC. Ultrasonic features of acute osteomyelitis in children. *J Bone Joint Surg Br* 1994;76:969-74.
51. Gilday DL, Paul DJ, Paterson J. Diagnosis of osteomyelitis in children by combined blood pool and bone imaging. *Radiology* 1975;117:331-5.
52. Howman-Giles R, Uren R. Multifocal osteomyelitis in childhood. Review by radionuclide bone scan. *Clin Nucl Med* 1992;17:274-8.
53. Andersen JB, Mortensen J, Bech BH, Hojgaard L, Borgwardt L. First experiences from Copenhagen with paediatric single photon emission computed tomography/computed tomography. *Nucl Med Commun* 2011;32:356-62.
54. DiPoce J, Jbara ME, Brenner AI. Pediatric osteomyelitis: a scintigraphic case-based review. *Radiographics* 2012;32:865-78.
55. Tuson CE, Hoffman EB, Mann MD. Isotope bone scanning for acute osteomyelitis and septic arthritis in children. *J Bone Joint Surg Br* 1994;76:306-10.
56. Treves S, Khettry J, Broker FH, Wilkinson RH, Watts H. Osteomyelitis: early scintigraphic detection in children. *Pediatrics* 1976;57:173-86.
57. Connolly LP, Connolly SA, Drubach LA, Jaramillo D, Treves ST. Acute hematogenous osteomyelitis of children: assessment of skeletal scintigraphy-based diagnosis in the era of MRI. *J Nucl Med* 2002;43:1310-6.
58. Majd M, Frankel RS. Radionuclide imaging in skeletal inflammatory and ischemic disease in children. *AJR Am J Roentgenol* 1976;126:832-41.
59. Linke R, Kuwert T, Uder M, Forst R, Wuest W. Skeletal SPECT/CT of the peripheral extremities. *AJR Am J Roentgenol* 2010;194:W329-35.
60. Nduaguba AM, Flynn JM, Sankar WN. Septic Arthritis of the Elbow in Children: Clinical Presentation and Microbiological Profile. *J Pediatr Orthop* 2016;36:75-9.
61. Liberman B, Herman A, Schindler A, Sherr-Lurie N, Ganel A, Givon U. The value of hip aspiration in pediatric transient synovitis. *J Pediatr Orthop* 2013;33:124-7.
62. Kotlarsky P, Shavit I, Kassis I, Eidelman M. Treatment of septic hip in a pediatric ED: a retrospective case series analysis. *Am J Emerg Med* 2016;34:602-5.
63. Schlung JE, Bastrom TP, Roocroft JH, Newton PO, Mubarak SJ, Upasani VV. Femoral Neck Aspiration Aids in the Diagnosis of Osteomyelitis In Children With Septic Hip. *J Pediatr Orthop* 2018;38:532-36.
64. Courtney PM, Flynn JM, Jaramillo D, Horn BD, Calabro K, Spiegel DA. Clinical indications for repeat MRI in children with acute hematogenous osteomyelitis. *J Pediatr Orthop* 2010;30:883-7.
65. Ernat J, Riccio AI, Fitzpatrick K, Jo C, Wimberly RL. Osteomyelitis is Commonly Associated With Septic Arthritis of the Shoulder in Children. *J Pediatr Orthop* 2017;37:547-52.
66. Refakis CA, Arkader A, Baldwin KD, Spiegel DA, Sankar WN. Predicting Periarticular Infection in Children With Septic Arthritis of the Hip: Regionally Derived Criteria May Not Apply to All Populations. *J Pediatr Orthop* 2019;39:268-74.
67. Schallert EK, Kan JH, Monsalve J, Zhang W, Bisset GS, 3rd, Rosenfeld S. Metaphyseal osteomyelitis in children: how often does MRI-documented joint effusion or epiphyseal extension of edema indicate coexisting septic arthritis? *Pediatr Radiol* 2015;45:1174-81.

68. Montgomery CO, Siegel E, Blasier RD, Suva LJ. Concurrent septic arthritis and osteomyelitis in children. *J Pediatr Orthop* 2013;33:464-7.
69. Welling BD, Haruno LS, Rosenfeld SB. Validating an Algorithm to Predict Adjacent Musculoskeletal Infections in Pediatric Patients With Septic Arthritis. *Clin Orthop Relat Res* 2018;476:153-59.
70. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf>. Accessed September 30, 2021.

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.