

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

**Suspected Osteomyelitis, Septic Arthritis, or Soft Tissue Infection (Excluding Spine and Diabetic Foot)**

**Variant 1:** Suspected osteomyelitis or septic arthritis or soft tissue infection (excluding spine and diabetic foot). Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography area of interest	Usually Appropriate	Varies
US area of interest	Usually Not Appropriate	○
MRI area of interest without and with IV contrast	Usually Not Appropriate	○
MRI area of interest without IV contrast	Usually Not Appropriate	○
3-phase 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:** Suspected septic arthritis or soft tissue infection. Initial radiographs normal or with findings suggestive of joint effusion or soft tissue swelling. 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	Usually Appropriate	○
CT area of interest with IV contrast	Usually Appropriate	Varies
CT area of interest without IV contrast	May Be Appropriate	Varies
3-phase bone scan area of interest	Usually Not Appropriate	⊕⊕⊕
CT area of interest without and with IV contrast	Usually Not Appropriate	Varies

**Variant 3:** Suspected osteomyelitis. Initial radiographs normal or with findings suggestive of osteomyelitis. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
MRI area of interest without and with IV contrast	Usually Appropriate	○
MRI area of interest without IV contrast	Usually Appropriate	○
3-phase bone scan area of interest	May Be Appropriate	⊕⊕⊕
3-phase bone scan and WBC scan and sulfur colloid scan area of interest	May Be Appropriate	⊕⊕⊕⊕
3-phase bone scan and WBC scan area of interest	May Be Appropriate	⊕⊕⊕⊕
FDG-PET/CT area of interest	May Be Appropriate	⊕⊕⊕⊕
WBC scan and sulfur colloid scan area of interest	May Be Appropriate	⊕⊕⊕⊕
CT area of interest with IV contrast	May Be Appropriate	Varies
CT area of interest without IV contrast	May Be Appropriate	Varies
US area of interest	Usually Not Appropriate	○
WBC scan area of interest	Usually Not Appropriate	⊕⊕⊕⊕
CT area of interest without and with IV contrast	Usually Not Appropriate	Varies

**Variant 4:** Suspected osteomyelitis or soft tissue infection with implanted extra-articular surgical hardware. Initial radiographs normal or with findings suggestive of osteomyelitis or soft tissue infection with implanted extra-articular surgical hardware. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
MRI area of interest without and with IV contrast	Usually Appropriate	○
MRI area of interest without IV contrast	Usually Appropriate	○
US area of interest	May Be Appropriate	○
3-phase bone scan and WBC scan area of interest	May Be Appropriate	⊕⊕⊕⊕
FDG-PET/CT area of interest	May Be Appropriate	⊕⊕⊕⊕
WBC scan and sulfur colloid scan area of interest	May Be Appropriate	⊕⊕⊕⊕
WBC scan area of interest	May Be Appropriate	⊕⊕⊕⊕
CT area of interest with IV contrast	May Be Appropriate	Varies
CT area of interest without IV contrast	May Be Appropriate	Varies
Image-guided aspiration area of interest	Usually Not Appropriate	Varies
3-phase bone scan area of interest	Usually Not Appropriate	⊕⊕⊕
3-phase bone scan and WBC scan and sulfur colloid scan area of interest	Usually Not Appropriate	⊕⊕⊕⊕
CT area of interest without and with IV contrast	Usually Not Appropriate	Varies

**Variant 5:** Suspected septic arthritis with arthroplasty or other implanted intra-articular surgical hardware. Initial radiographs normal or with findings suggestive of septic arthritis with arthroplasty or other implanted intra-articular surgical hardware. 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	○
CT area of interest with IV contrast	Usually Appropriate	Varies
US area of interest	May Be Appropriate	○
3-phase bone scan and WBC scan area of interest	May Be Appropriate	⊕⊕⊕⊕
FDG-PET/CT area of interest	May Be Appropriate	⊕⊕⊕⊕
WBC scan and sulfur colloid scan area of interest	May Be Appropriate	⊕⊕⊕⊕
WBC scan area of interest	May Be Appropriate	⊕⊕⊕⊕
CT area of interest without IV contrast	May Be Appropriate	Varies
3-phase bone scan area of interest	Usually Not Appropriate	⊕⊕⊕
3-phase bone scan and WBC scan and sulfur colloid scan area of interest	Usually Not Appropriate	⊕⊕⊕⊕
CT area of interest without and with IV contrast	Usually Not Appropriate	Varies

**Variant 6:** Suspected soft tissue infection. History of puncture wound with possible retained foreign body. Radiographs normal. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
US area of interest	Usually Appropriate	○
MRI area of interest without and with IV contrast	Usually Appropriate	○
MRI area of interest without IV contrast	Usually Appropriate	○
CT area of interest with IV contrast	Usually Appropriate	Varies
CT area of interest without and with IV contrast	Usually Appropriate	Varies
CT area of interest without IV contrast	Usually Appropriate	Varies

**Variant 7:** Suspected soft tissue infection. Initial radiographs show soft tissue gas (without puncture wound) or are normal with high clinical suspicion of necrotizing fasciitis. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
MRI area of interest without and with IV contrast	Usually Appropriate	○
MRI area of interest without IV contrast	Usually Appropriate	○
CT area of interest with IV contrast	Usually Appropriate	Varies
CT area of interest without IV contrast	Usually Appropriate	Varies
US area of interest	May Be Appropriate	○
CT area of interest without and with IV contrast	Usually Not Appropriate	Varies

## **SUSPECTED OSTEOMYELITIS, SEPTIC ARTHRITIS, OR SOFT TISSUE INFECTION (EXCLUDING SPINE AND DIABETIC FOOT)**

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### **Summary of Literature Review**

#### **Introduction/Background**

Infections of the musculoskeletal system are a leading cause of pain, disability, and health care encounters. Because of the rise of an aging population, diabetes and obesity, and orthopedic surgeries, the incidence of musculoskeletal infections are also increasing. The overall infection rate following orthopedic hardware placement is estimated to be approximately 5%, and the overall mortality rate associated with necrotizing fasciitis (NF) is >10% [1].

Musculoskeletal infections may have bone and soft tissue involvement and often need imaging using a multimodality approach [2]. The nonspecific signs and symptoms of musculoskeletal infections can make their diagnosis particularly challenging. Predisposing conditions including inflammatory arthritis, diabetes, immunosuppression, drug and alcohol abuse, surgery, burns, extremes of body habitus, and poor socioeconomic status can further add to the difficulty of diagnosing musculoskeletal infections both clinically and with imaging [3]. Placement of orthopedic hardware can make imaging diagnosis challenging because of metal artifact, especially on CT and MRI.

Imaging plays a critical role in the diagnosis and treatment of musculoskeletal infections. When imaging is appropriately used, proper characterization of bone and soft tissue infections often guides clinical management. Even when infection is clinically apparent, imaging often provides additional information including the extent of infection into deeper tissues, presence of abscesses, joint involvement, and vascular complications. These assessments are central to medical, surgical, and image-guided treatments [4].

#### **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: Suspected osteomyelitis or septic arthritis or soft tissue infection (excluding spine and diabetic foot). Initial imaging.**

For osteomyelitis, the body regions covered are ankle, chest, elbow, femur, foot, forearm, hand, hip, humerus, knee, pelvis, shoulder, tibia/fibula, wrist.

For septic arthritis, the body regions covered are ankle, elbow, hip, knee, shoulder, wrist.

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For soft tissue infection, the body regions covered are abdomen, neck, ankle, chest, elbow, thigh, foot, forearm, hand, hip, arm, knee, pelvis, shoulder, leg, wrist.

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

There is insufficient evidence to support the use of a 3-phase bone scan area of interest for the initial evaluation of osteomyelitis, septic arthritis, or soft tissue infections.

### **CT Area of Interest**

There is insufficient evidence to support the use of CT area of interest for the initial evaluation of osteomyelitis, septic arthritis, or soft tissue infections.

### **MRI Area of Interest**

There is insufficient evidence to support the use of MRI area of interest for the initial evaluation of osteomyelitis, septic arthritis, or soft tissue infections.

### **Radiography Area of Interest**

The literature indicates that radiographs should be used for the initial evaluation of musculoskeletal infections, including osteomyelitis, septic arthritis, and soft tissue infection. Erosions and periosteal reaction are common findings in acute osteomyelitis, whereas bone sclerosis is commonly associated with chronic osteomyelitis. In early acute osteomyelitis (<14 days), radiographs may be normal or show only mild soft tissue swelling [5]. Soft tissue swelling, joint effusion, ulcers, effacement of fat planes, gas, and foreign bodies may indicate soft tissue infections or septic arthritis [2].

Many radiographic findings are not specific for infection, and a differential diagnosis may include tumors, trauma, arthritides, metabolic conditions, cardiovascular etiologies, and venous insufficiency or thrombosis. However, obtaining the initial radiograph provides an excellent overview of the anatomic area of interest and can exclude fractures and tumors as the cause of swelling or pain. Radiographs also help with the interpretation of future imaging studies such as CT, MRI, ultrasound (US), and nuclear medicine scans [6].

### **US Area of Interest**

There is insufficient evidence to support the use of US area of interest for the initial evaluation of osteomyelitis, septic arthritis, or soft tissue infections.

### **Variant 2: Suspected septic arthritis or soft tissue infection. Initial radiographs normal or with findings suggestive of joint effusion or soft tissue swelling. Next imaging study.**

For septic arthritis, the body regions covered are ankle, elbow, hip, knee, shoulder, wrist.

For soft tissue infection, the body regions covered are abdomen, neck, ankle, chest, elbow, thigh, foot, forearm, hand, hip, arm, knee, pelvis, shoulder, leg, wrist.

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

Radionuclide imaging, which includes 3-phase bone scan, is of limited use for the diagnosis of septic arthritis and soft tissue infection [7]. On 3-phase bone scans, early images may show increased activity with hyperperfusion and hyperemia on flow and blood pool phases. Delayed images may be normal or have increased activity limited to the articular surfaces, in the case of a septic joint [7]. Compared with US, CT, and MRI, bone scan has poor spatial resolution and lacks specificity [4]. However, bone scan can be useful for the evaluation of multifocal infections.

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

In many cases, imaging cannot distinguish infected from noninfected joints or fluid collections, and aspiration and culture are needed for diagnosis [8,9]. Culture allows for identification of the infectious organism, which directly affects treatment. Although imaging may delay performing the aspiration, preaspiration imaging with US, CT, or MRI can be essential for planning for a safe aspiration [8]. Image-guided aspiration is ideal because proper, accurate needle placement is confirmed with fluoroscopy, US, CT, and rarely MRI. Also, image guidance significantly reduces vascular complications and injury to nerves. Using image guidance, needle trajectory and placement can be planned to reduce the risk of contaminating normal adjacent tissues [10].

### **CT Area of Interest**

CT allows for the evaluation of various soft tissue compartments and may help differentiate cellulitis, myositis, tenosynovitis, abscess, and septic arthritis [11]. CT with intravenous (IV) contrast can assess soft tissue and the extent of infection, which can guide aspiration or surgical debridement. Contrast-enhanced CT can also improve

the detection of synovitis, inflammation, fistulas, abscesses, and vascular complications [4]. CT is also the most sensitive modality for detecting soft tissue gas. Although CT is not sensitive at detecting early bone marrow changes, it can show early periosteal reaction and bone erosions, adjacent soft tissue infection, or septic arthritis.

### **MRI Area of Interest**

MRI allows for the evaluation of musculoskeletal soft tissue infections because of its high sensitivity to fluid and inflammation in bones, joints, muscles, tendons, and other soft tissues [2,6,12]. Because of its excellent spatial and contrast resolution, MRI is excellent at detecting and evaluating the extent of both superficial and deep soft tissue infections [13]. MRI can also exclude soft tissue infection, if edema or fluid signal representing inflammation, joint effusion, or abscess are not present [2,6]. Contrast-enhanced MRI further increases the diagnostic sensitivity for abscesses, fistulas, and vascular complications. Detection of inflammation of joints, bursa, tendons, and muscles is also improved with contrast-enhanced MRI.

Compared to CT, soft tissue gas is not as well visualized on MRI. Although MRI often provides imaging for preoperative planning, MRI is not commonly used for image-guided aspiration or drainage.

### **US Area of Interest**

US is useful for detecting fluid, including joint effusions, abscesses, and infected tendon sheaths. US-guided aspirations of soft tissue fluid collections and joint effusions is becoming increasingly common [14]. With the use of color Doppler, vascularity and hyperemia can be assessed without the administration of IV contrast. If needed, US can examine the contralateral side for comparison or extend the area of imaging of suspected infection. Absence of a fluid essentially excludes the diagnosis of septic arthritis, tenosynovitis, and abscess.

Gaspari et al [14] reported that US correctly diagnosed an abscess in 29 out of 30 patients and no abscess in 30 of 35 patients with an alternative diagnosis. In comparison, CT correctly diagnosed 23 out of the same 30 patients with abscess and correctly diagnosed 32 of the 35 patients without an abscess. They reported the overall sensitivity and specificity of US for the diagnosis of an abscess as 96.7% and 85.7%, respectively, whereas CT had 76.7% sensitivity and 91.4% for specificity. They concluded that both CT and US are accurate for diagnosing superficial abscesses. US can evaluate the internal characteristics of the abscess cavity, such as necrosis or debris, and associated pathology like foreign bodies, fistulas, and vascular injury.

For deeper soft tissue structures and the evaluation of adjacent bone involvement, US is limited compared with MRI and CT.

### **Variant 3: Suspected osteomyelitis. Initial radiographs normal or with findings suggestive of osteomyelitis. Next imaging study.**

For osteomyelitis, the body regions covered are ankle, chest, elbow, femur, foot, forearm, hand, hip, humerus, knee, pelvis, shoulder, tibia/fibula, wrist.

### **3-Phase Bone Scan and WBC Scan and Sulfur Colloid Scan Area of Interest**

These 3 scans are ordered in progression to increase the accuracy of diagnosing osteomyelitis. If the 3-phase bone scan is positive with increased activity, also obtaining a white blood cell (WBC) scan and Tc-99m sulfur colloid scan may increase specificity for the evaluation of acute osteomyelitis. Addition of sulfur colloid scan may be considered if results remain equivocal following a WBC and 3-phase bone scans. In cases in which radiotracer uptake is increased on WBC scan and 3-phase bone scans, sulfur colloid imaging will show no corresponding radiotracer uptake in cases of osteomyelitis [15,16].

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

In patients with low pretest probability of infection who have a positive 3-phase bone scan, the addition of WBC scan may increase specificity for infection, particularly in the setting of recent surgery or fracture at the suspected site of infection [17].

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

A 3-phase bone scan can be used to rule out osteomyelitis. However, a positive 3-phase bone scan is nonspecific. A meta-analysis performed by Wang et al [17] showed specificity of only 45% for diagnosis of osteomyelitis, whereas sensitivity was 83%. A 3-phase bone scan is most accurate in the diagnosis of osteomyelitis when bone is not affected by other underlying condition such as osteoarthritis, recent fracture, or recent hardware implantation [18]. Addition of single-photon emission CT (SPECT)/CT may be helpful in localization of acute osteomyelitis [19].

### **CT Area of Interest**

CT is insensitive in evaluation of acute osteomyelitis. IV contrast administration is helpful for assessing soft tissue involvement. CT may be most useful in characterizing osseous changes from chronic osteomyelitis including detection of sequestrum. Although the use of IV contrast does not improve diagnostic sensitivity for acute osteomyelitis, it may be helpful in the identification of soft tissue infection such as abscess formation [11]. There is no added benefit in performing multiphase CT imaging before and after IV contrast administration in the evaluation of infection.

### **FDG-PET/CT Area of Interest**

Using the tracer fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT has high sensitivity (81%–100%) and high specificity (87%–100%) for the detection of osteomyelitis [17]. PET imaging's higher resolution allows for more precise localization when compared with other single-photon techniques. Additionally, PET/CT may offer advantages in the evaluation of multifocal infection as a whole-body imaging technique when hematogenous spread is suspected [15,18,20]. Recent fracture or orthopedic implant may lower accuracy of FDG-PET as FDG-uptake can be seen in inflammation, including aseptic hardware loosening [15,21,22].

### **MRI Area of Interest**

MRI is highly accurate for detection of acute osteomyelitis. Noncontrast MRI has high sensitivity and specificity in the diagnosis of osteomyelitis. MRI is sensitive at depicting marrow signal changes of acute osteomyelitis. Additionally MRI provides excellent evaluation of the adjacent soft tissues including abscess or fistulas [13,23-26]. The use of IV contrast does not improve diagnosis of peripheral osteomyelitis; however, its use may improve the evaluation of soft tissue infections [27].

### **US Area of Interest**

US is of limited benefit in the diagnosis of osteomyelitis. Although findings such as juxtacortical fluid collections and fistulous tracts may be seen, these findings are not specific for osteomyelitis [28].

### **WBC Scan and Sulfur Colloid Scan Area of Interest**

A sulfur colloid scan is often performed when WBC scan results are equivocal. If osteomyelitis is present, a sulfur colloid scan will show no radiotracer activity in areas of WBC scan activity. WBC scan combined with marrow imaging has been reported up to 90% accurate in diagnosing osteomyelitis [18]. Disadvantages include low spatial resolution [15,16].

### **WBC Scan Area of Interest**

A WBC scan has been reported to have variable sensitivity and specificity when performed alone in the evaluation of osteomyelitis [17]. The addition of SPECT/CT has been suggested to increase the accuracy of WBC scan for the diagnosis of osteomyelitis. When a WBC scan is positive on planar images, SPECT/CT can be performed for more accurate localization of infection [15,21].

**Variant 4: Suspected osteomyelitis or soft tissue infection with implanted extra-articular surgical hardware. Initial radiographs normal or with findings suggestive of osteomyelitis or soft tissue infection with implanted extra-articular surgical hardware. Next imaging study.**

For osteomyelitis and soft tissue infection, the body regions covered are ankle, elbow, hip, knee, shoulder, wrist.

### **3-Phase Bone Scan and WBC Scan and Sulfur Colloid Scan Area of Interest**

There is insufficient evidence to support the use of 3-phase bone scan, WBC scan, and sulfur colloid scan for the evaluation of infection of extra-articular surgical hardware in the absence of known fluid collection or abscess.

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

A 3-phase bone scan has low specificity for infection in the setting of trauma or recent surgery. A WBC scan should be considered in patients with a low suspicion of infection who have positive findings on 3-phase bone scan [21].

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

A meta-analysis by Wang et al [17] found that a 3-phase bone scan had sensitivity of 83% but specificity of <50%. In the setting of prior surgery or trauma, the specificity of 3-phase bone scan is likely even lower because osseous remodeling will result in radiotracer uptake [21]. Although studies have shown that SPECT/CT aids in anatomic localization of infection, findings often remain equivocal [19].

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

There is insufficient evidence to support the use of image-guided aspiration for evaluation of infection of extra-articular surgical hardware in the absence of known fluid collection or abscess.

### **CT Area of Interest**

CT is useful in the evaluation of postsurgical complications including hardware fracture, periprosthetic osteolysis, and fracture nonunion [29]. Osseous changes of osteomyelitis can be visualized with CT, although these findings are often nonspecific, particularly if there has been recent trauma or surgery. CT can be helpful in identifying fluid collections adjacent to bone or surgical hardware that can be targeted for further investigation with percutaneous or surgical drainage. CT may also be useful in the detection of necrotic osseous fragments or sequestra that supply a nidus for chronic infection [21]. IV contrast should be considered because this may allow for better definition of fluid collections or fistulous communication to orthopedic implants [22].

### **FDG-PET/CT Area of Interest**

A systematic review by Govaert et al [21] found that FDG-PET/CT has specificity for posttraumatic osteomyelitis ranging from 76% to 100% and sensitivity ranging from 83% to 100%. However, in the acute setting, inflammation due to fracture or recent surgery may decrease accuracy. A retrospective review by Hartmann et al [30] demonstrated sensitivity of 100% and specificity ranging from 88% to 93%. This study included patients with orthopedic implants and joint replacements. This small study of 33 patients also suggested that FDG-PET was most specific when evaluating infection in the axial skeleton. Wenter et al [22] retrospectively reviewed PET imaging performed in 215 patients for suspected osteomyelitis or implant associated infection and reported sensitivity of 88% and specificity of 76%. Their results also showed no significant decrease in accuracy in patients with orthopedic implants.

### **MRI Area of Interest**

MRI is useful for the evaluation of osteomyelitis or soft tissue infection in the setting of extra-articular surgical hardware. MRI allows for characterization of both bone marrow signal and adjacent soft tissues. Recent advances in metal artifact reduction techniques have improved orthopedic hardware imaging, particularly in the appendicular skeleton [31]. In the setting of posttraumatic osteomyelitis, MRI can be used to determine the degree of osseous and soft tissue involvement. However, caution must be used in the recent postoperative or posttrauma period because bone marrow and soft tissue edema may persist and mimic infection [21]. IV contrast administration is preferred to help evaluate the soft tissues [27,32].

### **US Area of Interest**

US may be used in detection of soft tissue abnormalities such as abscess or fistulous tracts. However, assessment of the underlying bone is typically limited with US findings of osteomyelitis either not visualized or nonspecific [28,33].

### **WBC Scan and Sulfur Colloid Scan Area of Interest**

Combining a sulfur colloid scan with a WBC scan may reduce false positive results from normal WBC accumulation in bone marrow adjacent to orthopedic hardware. No studies were found that specifically investigated accuracy of combined WBC scan and sulfur colloid scan in diagnosing osteomyelitis associated with extra-articular hardware. Because sulfur colloid is a bone marrow imaging technique, there is no added benefit for assessment of soft tissue infection associated with orthopedic hardware. The addition of SPECT/CT hybrid imaging may increase ability to localize infection in cases with orthopedic hardware.

### **WBC Scan Area of Interest**

A systematic review by Govaert et al [21] found that a WBC scan for posttraumatic osteomyelitis had sensitivity ranging from 50% to 100% and specificity ranging from 40% to 97%. The addition of SPECT/CT hybrid imaging may increase ability to localize infection in cases with orthopedic hardware.

**Variant 5: Suspected septic arthritis with arthroplasty or other implanted intra-articular surgical hardware. Initial radiographs normal or with findings suggestive of septic arthritis with arthroplasty or other implanted intra-articular surgical hardware. Next imaging study.**

For septic arthritis, the body regions covered are ankle, elbow, hip, knee, shoulder, wrist.

### **3-Phase Bone Scan and WBC Scan and Sulfur Colloid Scan Area of Interest**

There is insufficient evidence to support the use of 3-phase bone scan, WBC scan, and sulfur colloid scan for evaluation of suspected septic arthritis.



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

While the literature does not support routine use of 3-phase bone scan and WBC scan for suspected periprosthetic infection, WBC may be performed following a positive bone scan to assess for infection. A 3-phase bone scan can be positive for multiple reasons in the post arthroplasty setting. Trevail et al [34] suggested the addition of WBC scan following a positive arthroplasty is up to 99% specific for infection and 80% sensitive.

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

Bone scintigraphy alone has high sensitivity and low specificity in the evaluation of suspected periprosthetic joint infection [35,36]. A negative 3-phase bone scan suggests low probability of periprosthetic infection [34,37].

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

The use of image-guided joint aspiration is supported to evaluate suspected septic arthritis. Depending on the joint, image guidance may be used to access the joint and confirm intra-articular needle positioning in the event of dry tap. Joint aspiration may be performed under fluoroscopy, US, or, less commonly, CT. The decision of imaging modality should be based on operator expertise and comfort because no modality has been proven superior to others. Laboratory analysis should include cultures, Gram stain, and cell count with differential [31,38,39].

### **CT Area of Interest**

CT can be used to evaluate hardware complications including osteolysis adjacent to implanted hardware. The use of metal artifact reduction techniques can improve the detection of joint effusion, soft tissue abscess, and periostitis. CT is also helpful in identifying necrotic bone fragments or sequestra in the setting of chronic osteomyelitis [21,31]. Although IV contrast is not helpful for assessment of osteomyelitis, the addition of IV contrast may aid in the detection of synovial thickening or soft tissue abscesses [11].

### **FDG-PET/CT Area of Interest**

A meta-analysis by Verberne et al [36] showed that there was considerable heterogeneity in the literature regarding the diagnostic criteria for prosthetic joint infection. The authors suggested that radiotracer accumulation around prosthetic head, neck, and distal tip may persist for up to 2 years following implantation, thus limiting evaluation of septic arthritis. Although there seems to be promise for FDG-PET/CT in the evaluation of prosthetic joint infection, the specificity of PET/CT in the diagnosis of septic arthritis remains uncertain because of a lack of clearly defined diagnostic criteria [40].

### **MRI Area of Interest**

Although MRI is susceptible to metallic artifact as a result of indwelling hardware, metal reduction sequences have mitigated this as a limitation. MRI is useful at detection of osseous changes of osteomyelitis with high sensitivity and specificity. MRI findings of synovial enhancement, joint effusion, and T1 hypointense bone marrow signal changes have a high correlation with infection [41]. MRI also provides evaluation of adjacent soft tissues including tendons and muscles that may offer an alternative diagnosis to infection in patients with pain following arthroplasty [42]. MRI is accurate for localization of soft tissue fluid collections that may be targeted for aspiration or surgical drainage. One disadvantage of MRI is that bone marrow signal abnormalities may persist for months following injury or surgery. [21]. IV contrast administration should be considered because this can assist in differentiating abscess from phlegmon [32,43].

### **US Area of Interest**

US may be useful for the detection of synovial thickening or joint effusion. However these are not specific to septic arthritis. US limitations include difficulty imaging deeper structures, deep larger joints (such as the shoulder or hip), an inability to evaluate metal implants, and a lack of sensitivity and specificity to findings such as fistulous tracts, subperiosteal fluid collections, and periosteal thickening [28,33].

### **WBC Scan and Sulfur Colloid Scan Area of Interest**

The addition of a sulfur colloid scan is useful in cases in which results are equivocal for septic loosening or osteomyelitis because leukocytes may accumulate in marrow adjacent to orthopedic implants [36,44]. However, the addition of a sulfur colloid bone marrow scan to a WBC scan does not increase the accuracy for detection of septic arthritis. The addition of SPECT/CT is recommended in positive studies to aid in the differentiation of soft tissue infection from osteomyelitis.

### **WBC Scan Area of Interest**

Systematic reviews by Verberne et al [36] and Van der Bruggen et al [45] both describe significant variability in specificity and sensitivity of WBC scan ability to diagnosis infection of orthopedic implants. This is likely due to

variability in scanning technique and criteria used for diagnosis of prosthetic related infection. In a study of 215 patients, Trevail et al [34] reported that a WBC scan had a sensitivity of 80% and a specificity >99%. The addition of SPECT/CT is recommended in positive studies to aid in the differentiation of soft tissue infection from osteomyelitis.

**Variant 6: Suspected soft tissue infection. History of puncture wound with possible retained foreign body. Radiographs normal. Next imaging study.**

For soft tissue infection, the body regions covered are abdomen, neck, ankle, chest, elbow, thigh, foot, forearm, hand, hip, arm, knee, pelvis, shoulder, leg, wrist.

In patients with puncture wounds, one of the main goals of imaging is to determine the presence or absence of a retained foreign body. Around the foreign body and puncture wound, soft tissue granulomatous reaction occurs and a superimposed soft tissue infection can develop including cellulitis, abscess, myositis, septic arthritis, or sinus tract.

Foreign bodies are either radiodense or radiolucent. Metal, stone, and graphite are radiodense and are detected on radiographs. However, plastic, rubber, and wood are not visible or radiolucent. Glass and ceramic are not always seen on radiographs.

**CT Area of Interest**

CT has been reported as 5 to 15 times more sensitive than radiography in detecting foreign bodies [46]. Precise localization of foreign bodies can often be made with CT. CT can visualize soft tissue gas, which can be seen in puncture wounds and in wood foreign bodies. Carneiro et al [46] suggested using thin (1 mm) slice thickness because foreign bodies may be very small and missed on CT if thicker slices are obtained. Although radiolucent on radiographs, glass and wood are moderately hyperdense on CT. CT can identify certain foreign body material composition based on attenuation and Hounsfield unit (HU) values [47]. The utility of foreign body visualization with CT is based on the object's density, such as foreign bodies with metal will have high attenuation density/HU values and foreign bodies that are more porous will have lower values because of air content.

CT can evaluate for the complications of foreign body infections such as cellulitis, muscle/fascial edema, abscesses, sinus tracts, and vascular or tendon injuries. Vascular injuries or pseudoaneurysms are best evaluated with the administration of IV contrast. However, soft tissue changes associated with foreign bodies, such as peripheral edema, hyperemia, and inflammation, may require a more sensitive modality such as MRI or US. CT can detect bone changes related to foreign bodies including osseous destruction, sclerosis, periosteal reaction, or intraosseous abscess [46,47]. Although CT can detect foreign bodies embedded in bone, CT is not as sensitive as MRI for detecting bone marrow edema.

**MRI Area of Interest**

On MRI, foreign bodies are usually low signal on all sequences and demonstrate morphology that is not anatomic (ie, linear or polygonal shape). MRI is the most sensitive modality for evaluating the soft tissue and osseous changes of infection; however, it is not sensitive or specific for detecting foreign bodies. Especially if the foreign bodies are small, many may be missed. Because of the granulomatous, inflammatory response to foreign bodies within soft tissues, surrounding fluid signal, edema, peripheral enhancement is a dominant pattern on MRI, which can be used to help localize foreign bodies. MRI with IV contrast can also assess complications of foreign bodies in soft tissues and bone, including cellulitis, fasciitis, abscesses, sinus tracts, osteomyelitis, and vascular or tendon injuries. Compared with US and CT, MRI has a lower sensitivity and inferior spatial resolution for detection of foreign bodies. Radiodense foreign bodies are better visualized on radiography [46].

Metallic foreign bodies and air produce susceptibility artifact, which can limit MRI quality. With metallic objects and MRI, there is a potential for severe soft tissue heating and motion of the foreign body because of the magnetic field. The severity of this risk is dependent on the ferromagnetic properties and location of the metallic foreign body, how long the foreign body has been in place, and the strength of the MRI unit [47]. Therefore, radiographic screening for metallic foreign bodies is recommended before MRI.

**US Area of Interest**

If a foreign body is not visualized on radiographs, US can be used for further evaluation especially in the acute, emergency setting [46,47]. US has a reported sensitivity of 95% for the detection of foreign bodies [48]. Tantray et al [48] reported out of 120 patients that went to surgery for foreign body exploration, US visualized foreign bodies in 114 patients. Among the 6 patients with negative US, only 1 patient had a foreign body on surgery. In addition, US can further characterize foreign body morphology, depth, and location in relation to adjacent structures like

vessels, bone, joints, tendons, or nerves. Furthermore, US can provide image guidance for removal of the foreign bodies. US can show the complications of foreign body infections such as cellulitis, myositis, abscesses, sinus tracts, and vascular or tendon injuries [47].

All foreign bodies are hyperechoic on US with some degree of posterior acoustic shadowing. A rim of hyperechogenicity may surround the foreign body with increased inflammation and vascularity on color Doppler. This can develop within 24 hours, and it is thought to represent soft tissue granulomatous reaction [47]. Although most superficial foreign bodies are visible on US, deeper locations (>4 cm from the skin) are more difficult to detect on US [46]. It is also difficult to visualize foreign bodies if there is air in the adjacent soft tissues, especially deeper and smaller foreign bodies. US cannot detect foreign bodies within bone.

**Variant 7: Suspected soft tissue infection. Initial radiographs show soft tissue gas (without puncture wound) or are normal with high clinical suspicion of necrotizing fasciitis. Next imaging study.**

For soft tissue infection, the body regions covered are abdomen, neck, ankle, chest, elbow, thigh, foot, forearm, hand, hip, arm, knee, pelvis, shoulder, leg, wrist.

NF is a rare, rapidly progressive soft tissue infection, which is often difficult to treat and requires surgical intervention with a high mortality rate ranging from 29% to 80% [2,49]. A polymicrobial infection composed of both aerobic and anaerobic organisms is typically seen. The infection causes necrosis by microvascular occlusion along the fascial tissues beginning at the superficial fascia along the subcutaneous soft tissues and then progressing into the deeper fascial layers between muscle planes and compartments [49].

In addition to the clinical findings of NF, laboratory evaluation can be helpful. A scoring system named Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC) is often used, which takes into consideration WBC, hemoglobin, blood chemistry values, and C-reactive protein [50]. Although NF is primarily diagnosed clinically, imaging findings can be critical to support the diagnosis, to aid in surgical planning, and to map disease extent and involvement. However, obtaining imaging studies, such as MRI, should not delay appropriate surgical treatment in patients who are severely ill and unstable [49].

**CT Area of Interest**

The CT findings in NF correlate with the pathophysiology of the infection causing soft tissue inflammation and liquefactive necrosis. Skin thickening, inflammatory subcutaneous fat stranding, and fluid or gas in the superficial or deep fascial planes are the typical CT findings [49,51,52]. In a study evaluating 20 surgically proven cases of NF, Wysoki et al [53] reported that CT demonstrated subcutaneous fat stranding and fascial fluid or thickening in 80%, soft tissue gas in 55%, and abscesses in 35% of cases. Tso et al [52] concluded that although the overall sensitivity of CT in diagnosing NF is 80%, the specificity is low because similar findings may be present in non-NF, cellulitis, pyomyositis, bursitis, and other soft tissue infections.

Compared with radiography, US, and MRI, CT is the most sensitive modality for detection of soft tissue gas [51,52,54]. Fernando et al [54] reported in a meta-analysis of 23 studies that the visualization of soft tissue gas on radiographs had a sensitivity of 49% and a specificity of 94% for the diagnosis of NF. Soft tissue gas on CT was associated with a sensitivity of 89% and a specificity of 93% for diagnosing NF. Gas within fascial planes and fluid collections is an important finding and can be a CT hallmark of NF; however, the absence of soft tissue gas does not exclude NF [2,49,51,52]. Early in the disease process, especially NF infections with more aerobic organisms, and in diabetic patients, soft tissue gas may not be present or detectable by CT [52].

In the Fernando et al meta-analysis of NF studies, most CT examinations were performed without IV contrast or the type of CT examination was not specified [52,54]. The evaluation of the use of contrast-enhanced imaging in the medical literature is limited [2]. Carbonetti et al [51] performed a retrospective study investigating 36 selected patients who had contrast-enhanced CT imaging performed and concern for NF or other severe soft tissue infection, which included confirmed patients with NF (10 surgically proven patients), non-NF (2 patients), cellulitis (10 patients), soft tissue abscess (7 patients), myositis (5 patients), and gas gangrene (2 patients). This study concluded that CT findings of fascial fluid and thickening and lack of enhancement of the fascia after CT with IV contrast administration were both highly associated with NF. The Carbonetti et al study reported that more patients with surgically proven NF had absence of fascial enhancement compared with those with other musculoskeletal infections, suggesting that the absence of fascial enhancement was specific for NF [55]. Contrast-enhanced CT imaging also improves the assessment for abscess, tissue necrosis, and vascular complications [6,52].

However, noncontrast CT is highly accurate for detection of NF [2,49,52,54].

### **MRI Area of Interest**

MRI is the modality of choice for detecting superficial or deep fascial fluid or edema [2,49,50,52,56,57]. MRI can recognize small amounts of fluid or edema in the fascia, potentially allowing for earlier diagnosis [54,56]. MRI has the highest reported sensitivity of 93% for the diagnosis of NF because of this detection of fluid signal on T2 fat suppressed or short tau inversion recovery (STIR) sequences [49,52]. Furthermore, the absence of fluid signal along the fascia essentially excludes the diagnosis of NF [2,52,56,57]. However, MRI findings of superficial and deep fascial fluid or edema are not specific for NF and can be seen in other soft tissue infections, such as severe cellulitis and non-NF. If the MRI is negative or with nonspecific findings and there is high clinical suspicion of NF, appropriate surgical treatment should be planned [49]. Also, in stable yet nonimproving patients, obtaining follow-up MRI can be of benefit to assess for progression of necrosis or fascial fluid and edema [49].

Yoon et al [50] reported that thickening of the deep intermuscular fascia  $\geq 3$  mm on fluid sensitive MR sequences (T2-weighted fat suppression or STIR), significant involvement of the deep fascia with 3 or more muscular compartments involved in one extremity, and low signal intensity foci or collections on all MRI sequences representing soft tissue gas were excellent predictors of NF. Fascial thickening of  $\geq 3$  mm was seen in 86% of patients versus 30% in the non-NF group, which was statistically significant ( $P = .05$ ). Also, 100% of the NF patients had extensive deep fascial involvement whereas only 39% in the non-NF group [50].

Although CT is more sensitive for detecting soft tissue gas, it can be seen as low punctate or curvilinear signal on all MRI sequences (T1-weighted, T2-weighted, STIR) and can be detected with high sensitivity with gradient echo sequences because of blooming artifact and susceptibility artifact. The presence of soft tissue gas is highly associated with NF; however, the absence of soft tissue gas on MRI should not exclude the diagnosis of NF and may be seen in late stages of NF [50,52,56]. Although some degree of fascial thickening, indistinctness of fascial planes, and fluid accumulation can be seen on CT, the MRI high signal intensity appearance of fascial fluid and edema on T2 fat suppression/STIR sequences is far superior for the detection of NF [56]. Yoon et al [50] also compared 2 parameters for diagnosing NF: utilization of the LRINEC score only and when both MRI findings and the LRINEC scores were applied to the diagnostic scenario. When the LRINEC score was used alone, the sensitivity, specificity, positive predictive value, and negative predictive value were 57%, 84%, 77%, and 67%, respectively. Integrating both MRI findings and LRINEC scoring produced values of 77%, 84%, 82%, and 79%, respectively. They concluded that MRI findings improved the overall sensitivity of diagnosing NF.

There are varying reports regarding the amount of fascial enhancement present based on the stage of necrosis [49,52]. Similar to CT, the assessment of fascial enhancement is controversial. Based upon studies in the MRI literature from >20 years ago, NF fascial enhancement patterns following IV contrast administration are variable with nonenhancement, mixed, and enhancement patterns all reported in the medical literature [2,58]. The presence of fascial enhancement is attributed to increased capillary permeability and IV contrast extravasation. In contrast, the absence of fascial enhancement is attributed to necrosis and microvascular occlusion [2,49,52,58]. In the later stages of NF, focal or diffuse nonenhancement of the fascia may be seen because of necrosis, which can be helpful to differentiate from non-NF [50,52,57]. In general, contrast-enhanced MRI aids in the identification of abscess and areas of necrosis, extent of infection, and delineation of vascular involvement, which can be beneficial in NF [2,49,52].

However, noncontrast MRI is still an important examination with the highest reported sensitivities to detect soft tissue findings of fascial edema/fluid signal and can detect the known imaging findings of NF to include deep fascial/intermuscular edema, soft tissue gas, and fluid collections [2,49,50,52,56,57].

### **US Area of Interest**

US findings of NF include soft tissue gas, subcutaneous fat edema, and irregular thickening and fluid along superficial and deep fascial planes [52,57,59,60]. A unique benefit to US is the ability to compare the contralateral extremity or other regions of normal tissue. Also, US can evaluate for deep venous thrombosis, provide image guidance for fluid aspiration, use color Doppler, and assess for foreign bodies [52,59]. The US appearance of soft tissue gas is typically an echogenic region or foci along the superficial and/or deep fascia with some degree of incomplete posterior acoustic shadowing. The presence of gas causes the posterior acoustic shadowing, and the changes in echotexture does impede sound penetration which can limit visualization of deeper structures [57]. For NF, this may cause US to have a limited role for the evaluation of the deeper intermuscular fascia especially in larger body habitus patients [52,57]. The subcutaneous fat can be thickened and demonstrate overall increased echogenicity due to fat edema and inflammatory change. Also, the fat lobules can form a cobblestone appearance due to the thickening of subcutaneous fat septa [52,57,59,60]. Although these findings are not specific for NF and

can be seen in cellulitis or anasarca, finding irregular thickened fascia and abnormal fluid collections in deeper muscle fascia can help differentiate NF [52,60].

Consistent throughout the US literature is the importance of the detection of fluid accumulation and thickened deep intermuscular fascia for diagnosing NF [52,59-62]. The overall sensitivity of US for the diagnosis of NF varies from 42% to 88%, with a specificity of 70% to 94% [52,59,60]. These variations may be due to the amount of deep fascial thickening and fluid accumulation.

There is limited evidence regarding the role of US in the diagnosis of NF [52,57,59,60]. Because CT and MRI are more sensitive modalities for visualizing fluid and fascial thickening, a negative US should not exclude the diagnosis of NF [61]. US has been described useful in diagnosing NF in pediatric patients with thinner, soft tissues causing improved better visualization of the deeper fascial planes [57,61].

### Summary of Recommendations

- **Variation 1:** Radiography area of interest is usually appropriate for the initial imaging of suspected osteomyelitis, septic arthritis, or soft tissue infections.
- **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 area of interest without IV contrast or CT area of interest with IV contrast is usually appropriate as the next imaging study for suspected septic arthritis or soft tissue infection following normal radiographs, or with findings suggestive of joint effusion or soft tissue swelling. 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:** MRI area of interest without and with IV contrast or MRI area of interest without IV contrast is usually appropriate as the next imaging study for suspected osteomyelitis following normal radiographs, or with findings suggestive of osteomyelitis. 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 4:** MRI area of interest without and with IV contrast or MRI area of interest without IV contrast is usually appropriate as the next imaging study for suspected osteomyelitis or soft tissue infection in the setting of extra-articular surgical hardware following normal radiographs, or with findings suggestive of osteomyelitis or soft tissue infection with implanted extra-articular surgical hardware. 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:** MRI area of interest without and with IV contrast or MRI area of interest without IV contrast or Image-guided aspiration area of interest or CT area of interest with IV contrast is usually appropriate as the next imaging study for suspected septic arthritis in the setting of arthroplasty or other implanted intra-articular surgical hardware following normal radiographs, or with findings suggestive of septic arthritis with arthroplasty or other implanted intra-articular surgical hardware. 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 6:** US area of interest or MRI area of interest without and with IV contrast or MRI area of interest without IV contrast or CT area of interest with IV contrast or CT area of interest without and with IV contrast is usually appropriate as the next imaging study for suspected soft tissue infection in the setting of possible retained foreign bodies from puncture wounds following normal radiographs. These procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).
- **Variation 7:** MRI area of interest without and with IV contrast or MRI area of interest without IV contrast or CT area of interest with IV contrast or CT area of interest without IV contrast is usually appropriate as the next imaging study for suspected soft tissue infection following normal radiographs with high clinical suspicion of necrotizing fasciitis or show soft tissue gas. 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 [63].

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.