IMAGING OF MUSCULOSKELETAL INFECTION

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Learning:

1. To review the pathophysiology of primarily pyogenic musculoskeletal (MSK) infections (osteomyelitis, septic arthritis and soft tissue infections) of the axial and appendicular skeleton, excluding spinal infection, in infants, children and adults, routes of contamination and common organisms in specific age groups.
2. To review current concepts, advantages and disadvantages, of all imaging techniques that are currently utilized in diagnosis and follow-up of MSK infection including radiography, magnetic resonance imaging (MRI), computed tomography (CT), ultrasound and nuclear medicine studies.
3. To review multimodality imaging findings of osteomyelitis, septic arthritis and soft tissue infections.
4. To briefly review histopathological findings of various types of MSK infections.

Purpose:

To be comfortable with the imaging work-up and follow-up of MSK infection in everyday radiology practice.

General Content:

MSK infection is common, affects all age groups and represents a diagnostic and therapeutic challenge to clinicians, radiologists and pathologists. The patients with MSK infections frequently present to Emergency Departments. Early diagnosis allows prompt treatment which can prevent unwanted complications. MSK infection can be roughly divided into osteomyelitis, septic arthritis and soft tissue infections.

The clinical stages of osteomyelitis are acute, subacute and chronic. Soft tissue infection includes involvement of the skin, subcutaneous tissues, superficial and/or deep fascia, muscles, tendons and bursae.

Routes of contamination in osteomyelitis and septic arthritis are: hematogenous (most common), contiguous spread, direct implantation, and postoperative. Soft tissue infection is most commonly the result of direct contamination after trauma and less commonly by hematogenous seeding.

Vascular anatomy plays a significant role in the development of hematogeneous osteomyelitis in specific age groups and is different in infants, children and adults. In infants, osteomyelitis typically involves the metaphysis with extension into the epiphysis, while in children approximately 1-16 years old the disease typically involves the metaphysis. In adults osteomyelitis typically involves the epiphysis. The most common organism of pyogenic infection in all age groups is Staphylococcus aureus and the other causative organisms have predilections for certain age groups. Mycobacteria, fungi and other atypical organisms may also cause musculoskeletal infection.

Imaging of suspected osteomyelitis and septic arthritis should start with radiographs. These may be normal for up to three weeks following onset of infection, although the earliest findings are usually seen after 7-10 days. The earliest radiographic abnormality is soft tissue edema, followed by localized osteoporosis, medullary and cortical lucencies with later development of periostitis.

Brodie abscess is a subacute/chronic osteomyelitis characterized by a lucent center surrounded by peripherally ill defined sclerosis on radiographs. To be qualified as a chronic, osteomyelitis has to be present for more than six weeks. In addition to mixed areas of osteolysis and sclerosis, radiographic findings of chronic osteomyelitis comprise formation of involucra, sequestra and cloacae with characteristic radiographic appearances. Chronic recurrent multifocal osteomyelitis (CRMO) and slerosing osteomyelitis of Garre are uncommon and represent the diagnoses of exclusion.
Chronic active osteomyelitis in three different patients demonstrated on radiography, CT and MRI.

Septic arthritis (joint infection) should be considered strongly with monoarticular arthritis. In diabetic foot it is common after contiguous spread. The earliest findings on radiography are joint effusion and soft tissue swelling, followed by osteoporosis, joint space loss and marginal and central erosions. If untreated, septic arthritis leads to progressive joint space narrowing with associated erosive changes.
Radiographic imaging findings of soft tissue infections are nonspecific and usually demonstrate soft tissue edema, but can provide valuable information regarding foci of air associated with gas forming organisms and necrotizing fasciitis.

MRI with its superb contrast resolution is the study of choice to evaluate for local extent of musculoskeletal infection and for the evaluation of bone marrow. The affected areas typically demonstrate high signal intensity on fluid sensitive sequences and intermediate/decreased signal on the T1W images. Intravenous gadolinium-based contrast agents usually show diffuse contrast enhancement and depict rim enhancing intraosseous, periosteal or soft tissue abscesses and synovitis. MRI plays a significant role in the radiological evaluation of necrotizing fasciitis which is considered a surgical emergency.

Acute Osteomyelitis and subperiosteal abscess in an 11 year-old boy with negative radiographs
Nuclear medicine studies are utilized to evaluate for the presence of multifocal skeletal infection and for patients in whom MRI is contraindicated. These studies are frequently utilized in evaluation of neonatal osteomyelitis and CRMO. Several tracers are available for imaging infection: $^{99m}$Tc-diphosphonates (most commonly utilized), $^{67}$Ga-citrate, and $^{111}$In- and $^{99m}$Tc-labeled leukocytes. The role of FDG-PET without or in combination with CT in evaluation of skeletal and soft tissue infections is still evolving with promising results.

CT parallels the radiographic findings of the soft tissue and skeletal infections allowing a superb spatial resolution. Multi-slice high resolution CT imaging with coronal, sagittal and 3D reformatting allows excellent visualization of anatomical structures and the regions of abnormalities. This imaging modality is frequently employed in the evaluation of infected hardware and is the best for visualization of soft tissue gas. Like MRI, contrast enhanced CT shows enhancement of the affected soft tissues and depicts rim enhancing soft tissue and epidural abscesses. A serpiginous permeative pattern on CT images is specific for osteomyelitis.

Ultrasound is useful in detection of joint effusions and soft tissue fluid collections and may guide localization for aspiration or drainage. It has a limited role in evaluation of osteomyelitis but can show erosive bone changes and subperiosteal abscesses.

The gold standard for diagnosis of osteomyelitis is histopathologic examination of bone biopsy samples, along with blood and tissue cultures. Acute osteomyelitis reveals the presence of necrotic bone and polymorphonuclear leucocytes infiltrates while chronic osteomyelitis reveals the presence of necrotic bone, granulation tissue between bone spicules, and an aggregate of chronic inflammatory cells. Soft tissue infections are characterized by infiltration by polymorphonuclear cells. Bacteria may be present. In necrotizing fasciitis, subcutaneous fat and fascial necrosis with relative muscle sparing is typical.