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Limb infections in children and adults

J. Vial*, H. Chiavassa-Gandois

Central Radiology Department, Pavillon Putois, Purpan University Hospital, place Dr-Baylac, TSA 40031, 31059 Toulouse cedex 9, France

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Abstract Infections of the bone and soft tissue of the limbs need to be diagnosed and treated urgently regardless of the patient’s age. Clinical features are often non-specific. MRI and, in some cases, sonography investigations lead to early diagnosis and appropriate management. Computed tomography has limited value. Needle aspiration and biopsy need not be routine. In children, anatomical particularities explain the different morphological manifestations, which vary with age. It is important to both know when to propose the diagnosis of infection, so that appropriate imaging investigations are carried out, and to be aware of the symptomatology of limb infections in children and adults and understand the differential diagnoses for each age group. Clinicians should also be aware of the specific characteristics in children.

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Osteoarticular infections need to be diagnosed and treated urgently, with early diagnosis essential in order to choose the appropriate treatment and avoid the often serious and harmful complications that can arise. Imaging, making use of different techniques, plays a key role in the early diagnosis of infections as well as in monitoring during a course of treatment. The clinician needs to be aware of the characteristics of paediatric disease, as well as a number of specific forms affecting children and adults.

Definition and general points

Different types of osteoarticular infection can be distinguished according to their route of contamination and the initial site of infection [1]:

- osteomyelitis is an infection of the bone marrow of haematogenous origin (usually caused by a pyogenic bacteria); the adjacent cortical bone may also be affected;
- osteitis is defined as beginning with an infection of the cortical bone, usually due to direct introduction (trauma, surgery or puncture) or from a contiguous site; the bone marrow may also be affected;
- arthritis is a primary infection of the synovium and can arise at any age;
- osteoarthritis is an infection of the metaphysis and joints and mainly affects children under the age of 1.

Infection can be localised to the soft tissues, affecting the subcutaneous cell tissue, muscle, bursa, tendons, etc.

An infection is considered to be acute if it develops over a period of less than one month and chronic when it goes beyond one month. Between these two phases, an infection is considered to be subacute.

Osteoarticular infections can develop in patients of any age. They need to be diagnosed and treated urgently as

* Corresponding author.
E-mail address: vial.jcchu-toulouse.fr (J. Vial).

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there is a significant risk of sequelae, especially in children. Paediatric osteoarticular infections predominantly affect the lower limbs (75–80%) and mainly involve the knee (33%), the hip (25%) and the ankle (16%). These infections are very often caused by Staphylococcus aureus, irrespective of the area affected and the patient’s age. Sometimes the highly virulent Panton-Valentine strain is found [1] (the clinical picture is one of pandiaphyseal osteomyelitis). Kingella kingae has become the most common infective agent in children below the age of 5 [2], but it is also frequently seen in patients of all ages. Streptococcus and Gram-negative bacilli (E. coli) can also sometimes cause osteoarticular infections. Finally, the possibility of infection with Koch’s bacillus (KB) must always be considered.

Acute osteomyelitis and osteitis

Pathophysiology [3,4]

Acute osteomyelitis usually arises after an asymptomatic finding of bacteraemia. Less commonly, the infection can develop as contiguous infection from the soft tissue, spreading to the periostium, the cortical bone and subsequently the trabecular bone. This type of involvement is often localised to the hands and feet, and readily develops in an area weakened by diabetes or following a surgical procedure: this is then known as osteitis. Infection can also be secondary to direct introduction of a pathogenic agent during a surgical intervention, an open fracture or a penetrating trauma wound.

It is important to be aware of the specific anatomical features of the child’s skeleton, so that the topography of the lesions can be explained [5].

The metaphysis of the long bones in children, which is the region of enchondral growth, are highly vascularised, meaning that the pathogenic agent can readily establish itself. This is often the initial site of osteomyelitis. Involvement is most common in the metaphyses that grow most rapidly (distal femur, proximal tibia, proximal humerus and distal radius). Infants below the age of 1 have an anastomotic network between the metaphyseal capillaries that penetrates the epiphyseal growth plate and capillaries. This explains the frequent occurrence of osteoarthrits in newborn babies and infants. After the age of 1, the epiphyseal growth plate limits the extent to which infection in the metaphysis can propagate to the epiphysis, but this is only a relative “barrier” and infectious osteoarthitis is still possible. In children the periostium, which is involved in widthways bone growth, is looser than cortical bone. This may provide an explanation for the possibility of infection spreading into the subperiostal space and forming a subperiostal abscess.

Clinical features

Acute osteomyelitis is the most common form of osteoarticular infection in children, with incidence peaking at around the age of 6. The clinical presentation is variable, combining metaphyseal pain with loss of function, fever, and sometimes general deterioration. The onset can be sudden and accompanied by a high fever. Diagnosis is sometimes difficult due to a history of intercurrent trauma or antibiotic therapy. Clinical features in adults are often insidious.

Infection is predominantly localised to the long bones in children (femur, tibia, humerus) and to the pelvis and short bones in adults. Osteomyelitis of the long bones is rare in adults, and is usually caused by surgical interventions [6]. The infection is usually confined to one focal area, but it can be multifocal. Laboratory investigations are inconsistent in finding inflammatory signs.

Imaging [7–9]

Plain film radiography

Radiography is always routinely carried out as a first-line investigation. The earliest changes affect the soft tissue, with loss of intermuscular fat planes in the first 48–72 hours. This is followed by thickening of the subcutaneous fatty tissue, although these non-bone signs are neither sensitive nor specific. The first bone changes only appear after 7–10 days [10]. Demineralisation is often subtle at first (Fig. 1a); observers need to look carefully for subperiosteal resorption, with lucent cortical and subcortical bone. Areas of demineralisation in the metaphysis with blurred margins appear next and these merge together. The periosteal reaction is solid at first, then it becomes multilamellated, and appears as secondary to osteolysis.

MRI

Currently, due to MRI being more readily available, not emitting radiation and performing well, it is widely carried out in practice where there is clinical suspicion of acute osteomyelitis. MRI must be done routinely in children where there is suspicion that the growth plate is affected and if the patient does not respond after 48 hours of intravenous antibiotics. From the early stages, it demonstrates bone and marrow involvement and allows an evaluation to be made of the specific localisation (bone and soft tissue involvement). It can also be used to guide a fine-needle aspiration, where required. To obtain morphological information, T1-weighted sequences are used, while T2 sequences, preferably using fat saturation techniques (such as diffusion-weighted SPAIR sequences) or STIR (inversion of the signal from fat), are best for detecting fluid or inflammation. Using a gadolinium contrast medium with fat signal saturation increases the ability of this modality to sensitively detect bone oedemas and improves the enhancement of inflammatory tissue, which appears with high signal intensity. Diffusion sequences can add further weight to diagnosis and assist with differential diagnosis [11,12].

Sagittal and/or coronal and axial views of the suspected affected area must be taken, especially in children with detached periostium.

Bone signal changes appear early, from the first few days of infection. Oedema within the bone marrow appears with low signal intensity on T1-weighted images, high signal intensity on T2-weighted images, has indistinct margins and is gadolinium-enhancing (Fig. 1b–d). The bone signal is homogenous from the start of infection, subsequently becoming non-homogenous where an abscess within the bone marrow may have developed (a fluid centre with peripheral ring-enhancement). In children, clinicians should
look for a subperiosteal abscess, involvement of the growth plate or epiphysis and any disease spread to the joints.

Where the soft tissue is affected, this can also take the form of an oedema, an abscess, an effusion, bursitis or tenosynovitis in the adjacent tissues.

Scintigraphy
This investigation may be useful where there is no identifiable source of infection, in order to identify the area of pathology. Full-body MRI may be a valuable alternative [12].

Sonography
Sonography is useful for investigating whether there is an abscess affecting the subperiosteal areas (Fig. 2) or soft tissue. It may also detect joint effusion in cases of osteoarthritis. Sonography can also be used to guide the procedure if surgical or radioguided fine-needle aspiration is required.

CT
There is no indication for CT in the acute stage of osteomyelitis.

Subacute osteomyelitis
This is a more limited form of osteomyelitis caused by a less virulent pathogen or an unsuitable antibiotic regimen.

Clinical features
The patient presents bone pain or limping for several weeks with episodes of moderate fever although their general health does not deteriorate.

Imaging
On radiography, a central Brodie abscess is typically seen: round or oval central metaphyseal lesion, with well-defined margins, surrounded by a sclerotic periphery. The periosteal reaction is inconsistent. Sequestra may be visible in the cavity on plain film radiography or a CT scan. MRI is usually indicated in order to identify the extent of the lesion. It demonstrates the 'target sign' typical in abscesses: the centre of the abscess is a necrotic cavity with low signal intensity on T1-weighted images, high signal intensity on T2-weighted images, and it is non-enhancing after contrast injection. The periphery of the abscess is made up of two haloes: the inner one corresponds to highly vascularised
granulation tissue with relative high signal intensity on T1-weighted images (penumbra sign) and is contrast-enhancing; the outer halo corresponds to peripheral sclerosis with low signal intensity on all sequences. A further peripheral halo with low signal intensity on T1, high signal intensity on T2, and blurred margins may also be reported, corresponding to a bone marrow oedema [13].

**Differential diagnosis**

The differential diagnoses to explore in children or young adults presenting a Brodie abscess are eosinophilic granuloma, possibly osteoid osteoma, and osteoblastoma. In forms in which the epiphysis is affected, chondroblastoma may also be considered. Aseptic osteomyelitis and inflammatory rheumatic disorders (SPA, SAPHO syndrome) can present abnormalities on MRI that are similar to the bone signal changes in osteomyelitis, but do not entail an abscess of the soft tissue. The possibility of a tumour mimicking a picture of infection must always be considered. The finding of an intraosseous oedema must suggest to the clinician a trauma (stress fracture), an infarction, or a tumour. The hypothesis of infection should be proposed where there is periosteal reaction, a focal area of bone destruction, a fluid-filled collection in the soft tissue or fat escaping the bone marrow to form a fluid-fat level, which is rare but specific.

**Chronic osteomyelitis**

Chronic osteomyelitis has become rare [14] except after surgery or a trauma. It does not need to be treated urgently, but exhaustive investigations must be carried out to look for the signs of infection (abscesses, sequestra, fistulae) that will usually require surgical management.

Plain film radiography demonstrates bone widening and deformation, as well as bone remodelling and sclerosis taking the form of increased numbers of thicker bone trabecula, thickening of cortical bone with thick and irregular periosteal reaction attaching to the bone. It is difficult to visualise a sequestrum. Signs of acute reactivation take the form of areas of osteolysis, fine layers of periosteal reaction that are not integrated to the cortical bone, and Brodie abscesses.

The presence of bone sequestra can be confirmed on CT scanning, usually pointing to acute reactivation, materialising as dense bone fragments of varying size, (Fig. 3a), gas within the bone and possibly fistulae, and, though identified less precisely than on MRI, abscesses within the bone or soft tissue. Cortical bone thickening and sclerotic phenomena can be readily assessed on CT.

MRI, in the absence of acute reactivation, demonstrates regenerated marrow with a fat signal. Low signal intensity on T1-weighted sequences may be related to bone marrow scar tissue changes.

In cases of reactivation of infection, the bone marrow behaves the same as in the acute phase: non-homogenous high signal intensity on T2-weighted sequences or abscess within the bone (Fig. 4a—c), with peripheral oedema. The sequestrum produces low signal intensity on all sequences, surrounded by granulation tissue that has iso or high signal intensity on T1, high signal intensity on T2, and enhances with a gadolinium contrast medium (Figs. 3b, c and 5). Fistulae have linear high signal intensity on T2 (Fig. 6).

PET scanning is highly sensitive and specific for the detection of chronic infection; it is not impeded by implants or sensitive prosthetic material, even where the lesions are small [15,16].

In children, chronic osteomyelitis can be complicated by a pathological fracture.

In older patients presenting a picture of ‘inflammatory’ reactivation, clinicians must consider the possibility of malignant degeneration of chronic osteomyelitis into squamous cell carcinoma. This is a rare but classic complication that varies in the length of time the onset of secondary disease (20–30 years).

Garre’s sclerosing osteomyelitis [10] is a specific form of chronic osteomyelitis in older children and young adults that is most commonly localised to the diaphysis of the long bones. This form principally causes bone deposition, mainly multilamellated periosteal reactions and sclerosis, while osteolysis or sequestra are minimal or absent. Moderate inward curvature of the limb bones may be present. The main differential diagnosis is osteoid osteoma.
**Osteomyelitis of the epiphysis**

Less commonly, a form of osteomyelitis affecting only the epiphysis may be seen in children. Radiography can demonstrate a strip of osteolysis within the epiphysis. At the subacute or chronic stage, this area of osteolysis is surrounded by sclerosis. Local spread, especially to the joints, can be assessed on MRI. The differential diagnosis is chondroblastoma, but the infection remains the main cause by far for the finding of epiphyseal lacuna in children [10] (Fig. 7).

**Septic arthritis**

When this condition develops in children, it is usually in those aged 10 and under, with incidence peaking at around age 4, but it can be seen at any age. It is usually caused by a bacterial infection (*S. aureus, K. kingae*), seeded haematogenously. It mainly affects the knee (35%), the hip (35%) and the ankle (10%). Some cases of viral arthritis resolve spontaneously. Clinicians must not forget the possibility of tuberculous arthritis in areas with predisposing conditions and should also consider Lyme disease.

In adults, as in children, it needs to be diagnosed and treated urgently as there is an increasing risk of sequelae the longer treatment is delayed.

Routine radiography is carried out to investigate whether there is intraarticular effusion, even though it is not the most sensitive imaging modality (Fig. 8a). It is also used for differential diagnosis (osteomyelitis, fracture, tumour). In adults, abnormalities appear later and the infection must be treated before they develop: increased soft tissue density, periarticular bone rarefaction and pinching of the joint space, marginal followed by central bone erosion, bone destruction, dislocation then ankylosis and periosteal reaction.

Sonography is routinely carried out as an emergency: it is used to look for intraarticular effusion (Fig. 8b) and synovial thickening, with hyperaemia seen on Doppler sonography. Any effusion in a febrile patient must be urgently drained in the operating theatre.

MRI and bone scintigraphy are not carried out in septic arthritis when the patient responds well to treatment.

**Osteoarthritis in newborn babies and infants**

These kinds of infections are rare and becoming even more so nowadays, and are generally seen in newborn babies admitted to neonatal special care units for another pathology, and are caused iatrogenically (venous catheter). The clinical picture is often non-specific and diagnosis is delayed. The hip and shoulder are the joints most frequently affected. Involvement can be multifocal.

Joint aspiration is an emergency, as imaging investigations should not delay diagnosis: radiography can show signs of intraarticular effusion from early on and later, osteolysis or periosteal reaction.

Urgent sonography must be carried out to investigate whether there is an intraarticular effusion (the effusion may be thick, purulent and small, which can make it difficult to detect) (Fig. 9) or subperiosteal abscess.

A “full-body” type examination (bone scintigraphy or full-body MRI if it is possible, in practice, to carry out) must be done to investigate whether involvement is multifocal. Patients usually progress well. Sequelae are uncommon but severe (dislocation, limbs not of equal length).
Tuberculous infections of the bones and joints [17,18]

Tuberculous arthritis

This classically affects a single joint usually in the lower limbs. Tuberculous arthritis is generally consecutive to osteomyelitis that has spread to the epiphysis, which is rare in pyogenic infections in adults. Primary synovial involvement is rare.

The course of the disease entails the formation of paraarticular cold abscesses and fistulae. KB is rarely found in the fistulae, which may be infected by associated pyogens.

The classic signs on radiography are paraarticular osteoporosis, peripheral bone erosion, and slowly progressive joint space narrowing (similar to the relative preservation of the disc in tuberculous spondylitis). Marginal bone erosion is characteristic of tuberculous arthritis of the hip, knee, and ankle. There is minimal periostitis or sclerosis in the early stage. In later stage disease, there is severe joint destruction and sometimes fibrous ankylosis. Bone ankylosis is rare, more usually being reported in pyogenic disease (Fig. 10a).

The early abnormalities are best visualised on MRI: joint effusion has high signal intensity on T2-weighted sequences, while any debris, septas, foreign bodies, calcifications, or haemosiderin produce low signal intensity. The bone has low signal intensity on T1 and high signal intensity on T2. Soft tissue abnormalities such as cellulitis, myositis, fistula, or paraarticular fluid collection are visible on MRI. Fluid collections are unusual in that they produce slightly increased signal intensity on T1, and are bordered by a contrast-enhancing strip (Fig. 10b, c).

Arthritis of tuberculous origin can be distinguished from that of pyogenic origin based on various signs:

- suggestive of tuberculosis: more significant bone erosion, minimal disruption to the bone marrow signal, paraarticular abscesses are contained, with fine and regular margins, and the synovium is very thick;
- suggestive of a pyogenic agent: minimal bone erosion, bone marrow oedema is often present, and paraarticular abscesses have thick and irregular margins.

In the smaller joints, it is difficult to distinguish the two.
Figure 5. Chronic osteomyelitis: heel pain in a 7-year old girl whose initial radiography investigations were considered to be normal. An MRI was carried out two months later due to persistent pain: a: initial plain film radiography showing osteolysis of the calcaneal tuberosity at the point where it meets the growth plate; b: T1-weighted MRI in the sagittal plane carried out two months after the radiography; c: diffusion MRI with fat saturation in the sagittal plane carried out two months after the radiography; d: contrast-enhanced T1-weighted MRI in the axial plane with fat saturation carried out two months after the radiography. The osteolysis corresponds to the site of infection with low T1 signal intensity, high signal intensity on diffusion FS, contrast-enhancing. There is a non-enhancing sequestrum with low signal intensity on all sequences. An oedema can be seen within the calcaneus.

**Tuberculous osteomyelitis**

The onset of tuberculous osteomyelitis is insidious and all the bones can be affected. Infection is haematogenous although in rare cases it can be due to contiguous spread from an abscess, a cutaneous fistula, bursitis, tenosynovitis, etc.

On plain film radiography, osteolysis can be seen, and this may be central, outside the centre or, very rarely, in the cortical bone.

MRI can demonstrate a tuberculous granuloma with low signal intensity on T1-weighted images and variable signal intensity on T2, with variable enhancement on gadolinium, which can be surrounded by an enhancing peripheral capsule with slightly raised signal intensity on T1, and variable signal intensity on T2. The associated soft tissue abnormalities (juxtacortical abscess) are suggestive of KB.

Tuberculous dactylitis mainly affects children, and adults only rarely, involving the bones of the hands and feet, especially the proximal phalanges of the second and third rows, the metacarpals of the third and fourth rows and the metatarsals. Caseous material accumulates in the bone that causes lysis in the diaphysis and widens the cavity by cystic expansion. Addressing differential...
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Figure 6. Femoral osteitis in a 30-year old patient; osteosynthesis implant following a trauma; discharge at the skin: a: CT: site of pseudoarthrosis proximal to the screw, detached bone fragments; b: MRI after removal of the material: SPAIR diffusion-weighted sequence in the axial plane; c: MRI after removal of the material: gadolinium-enhanced T1-weighted sequence in the coronal plane with fat saturation. Fluid collection in the diaphysis, cortical bone rupture and spread to the soft tissue.

Diagnosis with sarcoidosis or a blood disorder remains challenging.

Tuberculous infection in children

In children, the distribution of tuberculous localisation in the skeleton follows the same pattern as in adults, involving the spinal column in 60 to 70% of cases, the joints in 20 to 25% of cases and the long bones and flat bones in 10 to 15% of cases. In tuberculous arthritis, as in adults, the joint cartilage is preserved for longer than in septic arthritis, due to the absence of proteolytic enzymes in the exudate of KB.

Imaging findings in tuberculous osteomyelitis are similar to those in pyogenic osteomyelitis. There are some features that may be suspicious, such as involvement primarily in the epiphysis or the highly destructive character of the lesions. Pandiaphyseal osteomyelitis may be seen, with a mixture of destruction and deposition. Osteolytic lesions in both the long and flat bones can take on a pseudo-cystic appearance that is sometimes multifocal (cystic tuberculosis of the bone).

Specific territories

Newborn babies

Invasive interventions in newborn babies who have an immature immune system encourage S. aureus infections to develop. Bone infections in newborn babies can also be due to maternally transmitted Streptococcus B and E. coli infections. Fetopathies (syphilis, rubella, CMV) can cause congenital bone infections [13].

Congenital syphilis

This is rare today, and it is due to Treponema pallidum passing across the placenta in the second or third trimester of pregnancy. At birth, internal organ or neurological presentations dominate. Bones are affected in 80% of cases but
they can be asymptomatic and involvement discovered later (Parrot’s pseudoparalysis).

Classically it is the long bones that are predominantly affected, bilaterally and symmetrically. Signs identifiable on radiology appear later or may be absent altogether if it is treated early. These signs are non-specific: irregular metaphyses with a “saw-tooth” appearance, dense or lucent metaphyseal bands, or Wimberger’s sign (cortical bone destruction with metaphyseal osteolysis). The diaphysis becomes involved later, with periosteal reaction. Localisation to other areas is common (skull and face bones, flat bones, ribs).

Congenital rubella

Congenital rubella involves the bones in 25 to 50% of cases, predominantly affecting the long bones close to the knee. It leads to delayed bone maturation and metaphyseal abnormalities: radiolucent bands or non-homogenous condensation. A classic finding is the presence of longitudinal striations, or the "celery stick sign".

CMV inclusion body disease

This disease has an inconsistent bone presentation, with signs ranging from metaphyseal demineralisation to bone destruction, without delaying bone maturation.

Children with sickle cell disease

Bone disease is common in children with sickle cell disease, the two main pathologies being infarction and infection, with infarction being much more common (around 50/1) [1].

The bacteria that are usually involved in osteomyelitis, in decreasing order of importance, are salmonella, S. aureus and Gram-negative bacteria (E. coli). In septic arthritis, encapsulated pathogens such as pneumococcus...
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Figure 8. Septic arthritis: acute pain with tumefaction of the right knee in a febrile 4-years-old boy: a: plain film lateral radiography of the right knee showing an isolated intraarticular effusion; b: sonogram of the knee (suprapatellar sagittal plane) confirming the presence of an voluminous echogenic intraarticular effusion with septations. An emergency needle aspiration of the joint was carried out.

and Haemophilus Influenzae are most commonly involved due to hyposplenism. It is difficult to distinguish infarctus from infection based on clinical signs and laboratory test results, because fever and signs of inflammation can be present in both cases. Signs are also non-specific on radiography. Imaging may be difficult to interpret due to old infarctions. Sonography is useful for investigating whether there is any intraarticular effusion or subperiosteal fluid collection. An infarction or a haematic fluid collection in the subperiosteal area may be present but indistinguishable from an abscess. Drainage of the fluid assists in adding weight to the diagnosis.

MRI must also be interpreted with great care in this context, due to bone marrow hyperplasia and recurrent bone infarctions. T1-weighted sequences may be particularly useful for distinguishing infarction (high T1 signal intensity due to erythrocyte sequestration) from osteomyelitis (bone oedema with low T1 signal intensity) [19]. Contrast-enhanced sequences with subtraction may also prove relevant (high signal intensity in osteomyelitis, low signal intensity in infarction).

Diabetic foot [3,20–22]

Perforating foot ulcers are a multifactorial disease, combining mechanical, vascular and neurological causes; there is a significant risk of infection. The value of MRI lies in differentiating between osteomyelitis and neuroarthropathy, although these pathologies are often confused for one another and MRI is sometimes lacking in specificity.

At the early stage of neuroarthropathy MRI demonstrates soft tissue oedema and localised bone signal abnormalities, associated secondarily with bone deformities and fragmentation. It begins in the joints, affecting the tarsometatarsal joints and metatarsophalangeal joints. Neuroarthropathy can be complicated by infection. MRI is the imaging modality of choice for diagnosing the infection, with 90% sensitivity and 83% specificity (Fig. 11); bone signs are more widespread and one sign known as the "ghost sign" appears to be specific: bone disappears on T1-weighted images and reappears in T2-weighted images or on gadolinium-enhanced sequences in infection, while this sign is absent in neuroarthropathy. An argument in favour of osteomyelitis is that infection spreads contiguously from a soft tissue abnormality: ulcer, fibrous skin thickening, fistula, cellulitis, abscess, and less commonly foreign body or gangrene. Ulcers predominantly affect the first and fifth metatarsal heads, the end of the hallux, the cuboid bone, the calcaneus and the malleolus. It is rare for the infection to localise in the mid-foot. A periosteal reaction is classically seen in the malleoli and metatarsals [23].

Arthritis readily localises close to any fluid collection in the soft tissue or any ulceration: dorsal ulcerations at the interphalangeal joints, lateral ulcerations at the metatarsophalangeal joints, and at the talo-crural or sub-talar joints if there is ulceration of the malleolus or calcaneus. If bone erosion is present close to a bone oedema this is suggestive of a septic cause. Infectious tenosynovitis may also be present (in the fibula with lateral malleolar ulceration, Achilles tendon with ulceration of the calcaneus, or the flexors where there is plantar ulceration to the ball of the foot). The tendon is rarely destroyed.

Infection of the soft tissues [18,24–26]

This usually occurs following a trauma or surgical intervention that breaks the skin. Haematogenous infection is less common. Risk factors are diabetes, alcohol and drug use, malnutrition and immune suppression.
Infectious cellulitis

This is when the skin is affected and it usually occurs in immune suppressed patients in territories of venous stasis. Sonography is not specific, demonstrating skin thickening with hyperechoic fat lobules in the hypodermis circled by anechoic linear bands of fluid; however, colour Doppler sonography shows hyperaemia in these bands which points to an infectious origin.

On MRI, cellulitis appears as subcutaneous fat infiltration with low T1 signal intensity on T1 and high T2 signal intensity, which is gadolinium-enhancing (in contrast to stasis of lymph or interstitial fluid, which does not enhance). This infiltration can sometimes spread to the muscle and the fascia.

Phlegmon and pyomyositis

These are muscle infections that are caused by *S. aureus* in over three quarters of cases. The incidence of HIV infections explains the significant rates of cases of pyomyositis occurring in immune suppressed or diabetic territories. Other risk factors are rhabdomyolysis and trauma. Multiple areas may be affected (40%). Standard radiography has minimal value, being able to show gas in the soft tissue.

In the early stages of phlegmon, sonography demonstrates increased muscle volume, disorganised and hyperechoic muscle fibres, and thick, hypoechoic septas. In later stage disease (abscess), there is hypoechoic purulent central necrosis, and there may be concomitant debris (Fig. 12).
Sometimes, air-fluid levels may be present within a fluid collection.

On CT the fluid within the collection is hypodense, although it may be hyperdense if it contains protein or haemorrhage. Dense areas of gas are sometimes visualised. The wall of the fluid collection is thick, irregular, and iodine-enhancing. On MRI, in early stage disease, there is increased muscle volume, the fibres are disorganised, and there are non-homogenous areas with low signal intensity on T1-weighted images and high signal intensity on T2-weighted images. An abscess appears as a collection with a fluid-like or variable signal depending on its protein content, surrounded by a gadolinium-enhancing rim with low T1 and T2 signal intensity, combined with a peripheral oedema and sometimes cellulitis.

Rapid diffusion sequences are used and may be valuable as a complementary investigation in some bone and joint pathologies, especially those that are infectious. They may be used as a substitute for contrast-enhanced sequences when diagnosing abscess if gadolinium injection cannot be done (renal failure). In these cases, infectious fluid collections show diffusion restriction and so low signal intensity on diffusion sequences and a decreased signal on the ADC map [27].

**Gangrene**

The presence of gangrene can be identified by the production of gas within the site of infection. On CT scanning it appears as dense areas of gas, and on MRI as markedly low signal intensities.

**Necrotising fasciitis**

This is a rare condition of necrosis to the subcutaneous tissue spreading to the fascias. If the infection has spread to the depth of the fascia this is indicative of a poor prognosis, as is the presence of gas. It arises in areas affected by immune suppression, diabetes, transplant, alcoholism or peripheral vascular disease. It can affect any part of the body, and sometimes several sites. Clinical diagnosis is difficult and the treatment is surgical.

On sonography, cellulitis and infiltration of the fascias can be seen.

MRI demonstrates an appearance of cellulitis combined with abnormalities of the intermuscular deep and superficial fascia with low signal intensity on T1-weighted images and high-signal intensity on T2. These abnormalities are gadolinium-enhancing although when the necrosis progresses, the fascias do not enhance as strongly. Intramuscular oedema points to later stage disease, as do abscesses, which are rare. Muscular abnormalities in the early stage signify a serious case.

**Septic bursitis**

On sonography, septic bursitis is indicated by the presence of an effusion that is sometimes echogenic. The synovium is thick, with hyperaemia on power Doppler scanning.

**Septic tenosynovitis**

In septic tenosynovitis, infection is introduced to the tendon sheath, usually the flexor tendons of the fingers and toes.
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Figure 11. Infected diabetic foot: a: radiography: osteolysis of the midfoot with spread to the metatarsals; b: CT: osteolysis and diffuse oedema of the soft tissue; c: MRI: gadolinium-enhanced T1-weighted sequence in the sagittal plane with fat saturation: osteolytic abscessed fluid collection; d: MRI diffusion mapping: the abscess has diffusion restriction.

On sonography, the tendon is thick and has effusion in its sheath, which is thickened, irregular and shows increased vascularisation (Fig. 13).

On MRI, the sheath and tendon are both thickened, contain oedema, and sometimes a reactive bone oedema.

Figure 12. Thigh abscess in an immune suppressed patient (hepatitis C, HIV); *Staphylococcus aureus* infection around the spinal column with an abscess that was later surgically drained; development of a tumefaction to the thigh during surgery. Sonogram: fluid-filled collection with anechoic contents; peripheral and wall hyperaemia in the crural muscle: confirmation of septic embolic origin on ultrasound-guided needle aspiration.

Tuberculosis and the soft tissue

Primary disease in the soft tissue is rare (more often it is affected due to contiguity with an infected bone site). Tuberculous bursitis can localise to the trochanter, subacromial bursa, radioulnar bursa or subgluteal bursa. Bursitis calcifies as it progresses and the infection can spread to the bone opposite. MRI can detect bursitis with sensitivity and can visualise any development of fistulae or abscesses. Tuberculous tenosynovitis typically localises to the flexor tendons of the hands and feet and the fibular tendons. This may be combined with bone involvement and fistulae are rare. Caseous infiltration can calcify and release foreign bodies. In advanced disease the tendon may tear.
**TAKE-HOME MESSAGES**

*General points*
- Diagnosis and treatment are emergent: imaging assists in diagnosis.
- Standard radiography is always carried out; signs develop later, but sometimes point toward infection and eliminate other diagnoses (tumour, fracture etc.).
- Sonography: simple, readily available in an emergency, especially in children. Do not forget it, and always use colour or power Doppler. Look for:
  - joint effusion in arthritis, a subperiosteal abscess in acute osteomyelitis (AOM) in children, an abscessed fluid collection, bursitis, tenosynovitis, cellulitis;
  - suggest diagnostic needle aspiration if it can be ultrasound-guided.
- CT scan: useful for visualising sequestra in acute reactivation of chronic osteomyelitis, usually following a history of trauma; for detecting gas, an abscess of the soft tissue (with iodine contrast medium); and allows differential diagnosis to be addressed.
- MRI is the imaging modality of choice for early diagnosis of AOM: bone abscess, Brodie abscess (present in the metaphysis in subacute osteomyelitis), oedema, soft tissue, localisation, and extent of the infection. MRI technique:
  - always use one plane in T1-weighted sequences (anatomical, without fat saturation);
  - one or two planes in T2-weighted sequences with fat saturation: oedema, fluid;
  - gadolinium contrast medium (and fat saturation): two planes;
  - consider diffusion sequences.

*Specific characteristics of different age groups*
- Newborn babies and infants: osteoarthritis in children in intensive care: sonography detects effusion and multiple areas are often affected.
- Maternally transmitted forms of arthritis: rubella, CMV, syphilis, with suspicious signs on radiography.
- Children with sickle cell disease: arthritis or AOM. Sonography detects joint effusion and subperiosteal abscess. MRI is useful for distinguishing AOM from infarction (its main differential diagnosis).
- Diabetic foot: MRI is useful for backing up the diagnosis of osteomyelitis or osteitis against a background of neuroarthropathy.

*Tuberculous bone infection*
Develops in areas with predisposing conditions and frequently affects the lower limbs.
- AOM: in children: identical signs to pyogenic infection, but often affects the epiphysis and the whole of the diaphysis; in adults: tuberculous granuloma that can be assessed on MRI.
- Concomitant abnormalities of the soft tissue: characteristic of KB.
- Arthritis: marginal osteolysis, paraarticular abscess with thick walls.

**Soft tissue infection**
- Cellulitis, pyomyositis, fasciitis, bursitis: sonography confirms soft tissue involvement, localises the lesions and can guide a needle aspiration where there is a fluid collection.

![Figure 13. Infectious tenosynovitis of the carpal extensors; background of RA, with immune suppression. Sonography: thick fluid-filled effusion in the sheaths of the extensors, with hyperaemia seen on Doppler sonography. Ultrasound-guided needle aspiration: infection.](image)

**Clinical case**

**History of the illness**

Léa, aged 8, presents with left ankle pain that has been progressing for just over a month. These pains are progressively worsening and though they were initially noted on exertion, they are now felt with the slightest weight bearing. She is afebrile and in good general health. Laboratory test results are normal (ESR, CRP, full blood count). She has come to you for radiology investigations.

**Questions**

1. How would you interpret the plain film radiography (Fig. 14a, b)?
2. What further investigations would you suggest? Why? What would you be looking for?
3. What are the main differential diagnoses to suggest in principle in a child with subacute osteomyelitis and a Brodie abscess?

**Answers**

1. Plain film AP and lateral radiography of the left ankle demonstrate a metaphyseal lacuna bordered by a strip of sclerosis. The radiography findings, in this patient, are suggestive of subacute osteomyelitis.
2. An MRI must be carried out to confirm the diagnosis and make assessments with a view to surgical management:
it is important to look for the target sign which is the typical appearance of abscesses (necrotic centre with low signal intensity on T1, iso/high signal intensity on T2, non gadolinium-enhancing; intermediate halo with relative high signal intensity on T1, high signal intensity on T2, enhancing, that corresponds to granulation tissue; and a still more peripheral area with low signal intensity on T1 and T2 that is non-enhancing, and that corresponds to peripheral sclerosis). It also is essential to define whether the growth plate and epiphysis are involved. In this case, MRI clearly visualises the metaphyseal lesion with low signal intensity on T1, high signal intensity on diffusion sequences with fat saturation, and it is contrast-enhancing except in its very small central section and in the peripheral sclerotic area. A peripheral bone marrow oedema in the metaphysis and epiphysis can also be seen, as well as infiltration of the soft tissue (Fig. 15a–d).

3. In children, the differential diagnoses to explore are eosinophilic granuloma, and possibly osteoid osteoma. In this case study, the findings and the localisation could also point to chronic recurrent multifocal osteomyelitis and other localisations would need to be investigated. A surgical biopsy was carried out and the examination by pathological anatomy confirmed the subacute infection. However, all microbiology investigations were negative. An empirical antibiotic regimen was started (dual IV antibiotic therapy for 10 days followed by treatment per os for a total duration of six weeks).
Figure 15. MRI of the left ankle: a: T1-weighted MRI in the sagittal plane; b: diffusion-weighted FS MRI in the sagittal plane; c: gadolinium-enhanced T1-weighted MRI in the sagittal plane with fat saturation; d: gadolinium-enhanced T1-weighted MRI in the axial plane with fat saturation.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References


