Acute osteomyelitis, septic arthritis and discitis: Differences between neonates and older children

A.C. Offiah *

Department of Radiology, Great Ormond Street Hospital for Children, London WC1N 3JH, UK

Received 22 June 2006; accepted 13 July 2006

Abstract

There are aetiological, clinical, radiological and therapeutic differences between musculoskeletal infection in the neonate (and infant) and in older children and adults. Due to the anatomy and blood supply in neonates, osteomyelitis often co-exists with septic arthritis. Discitis is more common in infants whereas vertebral body infection is more common in adults. This review article discusses the important clinical and radiological differences that in the past have led many authors to consider neonatal osteomyelitis a separate entity from osteomyelitis in the older child.

Keywords: Neonate; Infection; Osteomyelitis; Arthritis; Discitis; Imaging

Contents

1. Nomenclature ................................................................. 221
2. Pathogenesis .................................................................................. 222
3. Anatomical considerations and pathophysiology ............................................. 224
4. Clinical presentation and laboratory findings .................................................. 224
5. Imaging .......................................................................................... 225
  5.1. Radiography .............................................................................. 225
  5.2. Ultrasound ............................................................................. 226
  5.3. Scintigraphy ............................................................................ 227
  5.4. Magnetic resonance imaging ....................................................... 229
  5.5. Computed tomography ............................................................... 231
6. Complications .................................................................................. 232
7. Summary ...................................................................................... 232
References ....................................................................................... 232

1. Nomenclature

The term osteomyelitis refers to infection of bone and/or bone marrow. Depending on both the virulence of the organism and the immune response mounted by the host, osteomyelitis may be acute, subacute or chronic. Acute osteomyelitis is not common in adults [1]. Conversely, in neonates osteomyelitis is usually acute [2].

Septic arthritis refers to infection of a joint. While this may occur in isolation, in neonates it is much more likely to occur as a consequence of bony infection (osteomyelitis) with spread into the adjacent joint.

Discitis refers to infection of a disc space and adjacent vertebral end plates.

Vertebral infection indicates infection of the vertebral body. Because of the differences in vascular supply (see below), ver-
Fig. 1. AP chest of an infant with septic arthritis of the right shoulder. Notice Salter Harris I injury of the shoulder (compare the relationship of epiphysis and metaphysis with the normal left side) as a result of a large joint effusion.

tubercular infection is less commonly seen in infants and young children than in teenagers and adults.

2. Pathogenesis

Infection may reach the bone (or joint) via three main routes:

- The bloodstream, i.e. haematogenous spread. This is the commonest route of infection in the neonate.
- Direct contamination, e.g. penetrating or puncture wounds, surgery. This route of infection is commoner in older children and adults.
- Indirect contamination from a nearby infection, e.g. cellulitis.

The causative organism depends on the age of the patient, and in the neonate is most commonly *Staphylococcus aureus*. Other organisms include *Escherichia coli*, Group-B *Streptococci*, other Gram-negative rods and *Candida albicans* [6–8].

Since the introduction of the HiB vaccine, the incidence of *Haemophilus influenza* infection in infants and older children is much reduced [9], with *S. aureus* and Group-A *Streptococci* being the more common causative organisms.

Infection with *Neisseria gonorrhoeae* occurs in adolescents. *Salmonella* should be considered in children with sickle cell disease. Fungal, parasitic and mycobacterial infection may occur, particularly in the immunocompromised host and in endemic regions [10].

In childhood discitis, a causative organism is not commonly isolated [11] and biopsy should be reserved for those failing to respond to anti staphylococcal therapy. Atypical

---

Fig. 2. Sequential radiographs in a neonate with osteomyelitis of the left femur. (A) Lateral of both knees on day of presentation. Note significant swelling of the left knee compared to the right. There is early periosteal reaction of the distal femoral shaft (arrow). There is possibly increased metaphyseal and epiphyseal radiolucency compared to the normal side. (B) AP radiograph left knee on day of presentation. Periosteal reaction of the distal femur (arrows) is better appreciated on this radiograph. (C) AP and lateral radiographs left knee 4 days following initial radiographs. Periosteal reaction of the distal femur (arrows) is better demonstrated. (D) AP and lateral radiographs left knee 16 days following initial radiographs. The soft tissue swelling has resolved. Periosteal reaction has consolidated. (E) AP radiograph left knee 2.5 months after initial radiographs. There is almost complete resolution of changes following adequate antibiotic therapy.
Fig. 2. (Continued).
infections include tuberculosis, brucellosis, and fungal disease [12].

3. Anatomical considerations and pathophysiology

The unique vascular anatomy of the epiphyses in neonates and infants accounts for the frequency with which osteomyelitis and septic arthritis co-exist.

The reduced rate of blood flow within vessels at the metaphysis renders this region more susceptible to haematogenous seeding of infection [13]. Before the appearance of secondary ossification centres, the cartilaginous epiphyses receive their blood supply directly from metaphyseal blood vessels. Hence, septic arthritis is a relatively common sequel to osteomyelitis in the neonate, particularly in joints such as the hip, in which the metaphysis is intracapsular. It is said that in neonatal osteomyelitis, infection leads to epiphyseal insult or septic arthritis in 76% of cases [4].

Because of the lax nature of the surrounding muscles, the presence of a joint effusion in neonates may lead to subluxation or dislocation of the affected joint (Fig. 1).

In addition, the accumulation of inflammatory exudate within the joint causes vascular compression and may result in avascular necrosis of the affected epiphysis. Septic arthritis is a clinical emergency, and prevention of significant long-term morbidity depends on timely diagnosis and relief of pressure; either by ultrasound guided joint aspiration or more invasive surgical techniques.

In older children and adults, the epiphyses and metaphyses have a separate blood supply, and spread of infection from bone to joint (or vice versa) is far less common. Furthermore once epiphyseal fusion has occurred, long-term complications relating to epiphyseal damage and limb length discrepancies are less of an issue.

Bones and joints of the lower limb are most commonly affected. Other sites include the upper limbs, and more complicated locations such as the pelvis and the spine (discitis).

Discitis in the neonate and young child most commonly affects the lumbar spine. Infection is more likely to reach the spine through the nutrient arteries than via the paravertebral venous system [14]. In a similar way to metaphyseal infection, spinal infection follows arterial septic embolisation. In infants and young children, the cartilaginous vertebral end plates are traversed by numerous canals through which small blood vessels pass. These vessels terminate adjacent to the intervertebral disc thus rendering the disc susceptible to infection. The vascular channels disappear by the third decade of life [15], hence the reduced incidence of discitis in older children and adults. The vertebral bodies of infants and small children have a large network of interosseous collateral arteries which is not found in adults. This renders the vertebral bodies of infants less susceptible to infarction from septic emboli and more able to clear bacteria following septic embolisation. This explains the reduced incidence of vertebral body infection in infants and young children compared to older children and adults [12].

4. Clinical presentation and laboratory findings

Osteomyelitis and arthritis are commoner in young children than in older children and adults, peaking at around the age of 3 years for osteomyelitis and 2 years for septic arthritis [2–5].

Compared to older children and adults, there are fewer clinical signs and the diagnosis of osteomyelitis and/or arthritis may
therefore be harder to make. This is largely because of the poorly
developed immune system of neonates, rendering them less able
to mount an immune response. For this reason, they are at greater
risk of infection by less virulent organisms and may not present
with fever. Furthermore, neonates with osteomyelitis and/or sep-
tic arthritis may have a normal leucocyte count and erythrocyte
sedimentation rate [2].

Clinical symptoms include poor feeding and/or irritability.
There may be a history of swelling or failure to move the affected
limb (pseudoparalysis). An older child with discitis may com-
plain of back pain. Younger children will have reduced mobility
or may present with a limp. The young child with discitis may
be afebrile. Because of these non-specific clinical symptoms, a
high index of suspicion is required in order to make an early
diagnosis of osteomyelitis, septic arthritis or discitis.

Risk factors in neonates and young children include prema-
ture birth, umbilical catheterisation (artery or vein), urinary tract
infections and other pre-existing disease. Risk factors in adults
include diabetes mellitus and a compromised immune system
(including HIV).

5. Imaging

The role of imaging is to confirm the presence and site of
infection, to differentiate unifocal from multifocal disease, to
locate and guide aspiration of collections and to identify present
or impending complications such as joint or extradural involve-
ment.

Radiography is usually the first radiological investigation in
a neonate with suspected osteomyelitis/septic arthritis/discitis.
Other modalities include ultrasound (US), bone scintigraphy,
magnetic resonance imaging (MRI) and computed tomography
(CT). These are each discussed separately below.

5.1. Radiography

Radiographic features in osteomyelitis and/or septic arthritis
include deep soft tissue swelling, widening of the joint space
with or without subluxation (Fig. 1) or frank dislocation, osteo-
porosis, periosteal new bone formation and bony destruction
(Figs. 2–5). Deep soft tissue swelling may be difficult to recog-

Fig. 5. Sequential radiographs in an infant with osteomyelitis of the left humerus. (A) Radiograph obtained at time of referral to tertiary center. Bony destruction
is better defined than in the patient illustrated in Fig. 4. The soft tissues plains do not appear obliterated (however see MRI obtained at the same time, Fig. 11). (B)
Radiograph obtained 8 months after that shown in (A). Almost complete return to normal following adequate therapy.
nise in the neonate because of the poor definition of fascial planes and relative lack of subcutaneous fat present at this age [2]. It should be noted that radiographs have a low sensitivity for detecting the presence of a joint effusion [16]—suspicious features include widening of the joint space and bulging of the soft tissues. Radiography allows the exclusion of other conditions such as fractures and is useful for the long-term follow up of complications.

Soft tissue swelling can be detected as early as 48 h after onset of infection [17]. However, bony destruction is not detectable radiologically until at least a third of the matrix has been involved [18]. This accounts for the low prevalence of abnormal radiographs at presentation, e.g. Capitanio and Kirkpatrick reported that only 20% of radiographs were abnormal at 10–14 days [19]. A high index of suspicion and further imaging with other modalities will often be required.

Initial findings in the spine may be limited to a loss of the normal lumbar lordosis. Subsequently disc space narrowing (Fig. 6) with end plate erosions will develop. Long standing infection may lead to pressure erosion of the superior and inferior margins of the adjacent vertebral body. Although contiguous disease is recognised, infection is more commonly seen to affect a single level.

5.2. Ultrasound

Although non-invasive, ultrasound is an operator dependant technique. In able hands, changes of acute osteomyelitis may be detected as early as 48 h after onset of infection [20]. Ultrasound allows the detection of subperiosteal collections [21] and joint effusions and therefore is extremely useful in neonates suspected of having a septic arthritis. It should be emphasised however,
that neither the size nor the echogenicity allows the radiologist to firmly conclude whether the detected effusion is infected or otherwise [22]. Conversely, the same authors showed that septic arthritis of the hip was extremely unlikely in the absence of an effusion [22]. Note that a normal ultrasound scan does not exclude osteomyelitis [23].

Mah et al. documented the chronology of ultrasound findings in acute osteomyelitis. The earliest finding was deep soft tissue swelling, followed by elevation of the periosteum by a thin layer of fluid (Fig. 7), a definite subperiosteal collection (Fig. 8) and finally cortical erosion. The prevalence of these findings depended on the duration of clinical signs; thus soft tissue swelling was at a maximum prevalence in patients with symptoms of 1–3 days duration while cortical erosions were commonest at 2–4 weeks. Concurrent septic arthritis was diagnosed in just under a third of patients. All ultrasound scans had returned to normal by 4 weeks after clinical cure [24].

In addition to allowing the confirmation of a joint effusion, ultrasound serves to guide needle aspiration of the affected joint(s).

5.3. Scintigraphy

Bone scintigraphy is more sensitive than radiography for the detection of osteomyelitis in the early stages of disease; for example, in one study it was found that in the first week of disease, radiography and technetium ($^{99m}$Tc)-labelled bone scans were positive in 42% and 87% of cases, respectively [25]. Scintigraphy is useful for detecting multiple foci of infection.
Multifocal disease is more commonly seen in neonates than in older children in whom either monoarticular septic arthritis or unifocal osteomyelitis is the norm [5,26].

Because of the increased vascularity of the metaphyseal region in neonates and children, high quality images, magnification and pin-hole collimation are required to differentiate physiological from pathological increased uptake [1]. Single photon emission computed tomography (SPECT) and positron emission tomography with 18F-labelled FDG further increase the spatial resolution, allowing improved visualisation of abnormal sites [27].

Various isotopes may be employed. Typically bone scans are performed using a 99mTc-labelled phosphonate complex. When infection is suspected then a triple phase bone scan is performed. In the past, the use of gallium-67 citrate (Ga) has been advocated; it should be noted that Ga does not differentiate soft tissue from bony uptake, and for this, as well as radiation dose considerations, is increasingly being replaced by 99mTc hexamethylpropylene amineoxamine (99mTcHMPAO) labelled white blood cells [1].

Diagnostic (but non-specific) features on scintigraphic studies include evidence of hyperperfusion (Fig. 9) with increased...
uptake in all three phases (perfusion, blood pool activity and bone metabolism) of the triple phase bone scan. In contrast to adults, infection in children rarely involves the entire length of the diaphysis [1]. The radiologist should beware of cold spots (photopaenic areas), which in neonates may lead to a false negative scan. These cold spots occur as a result of decreased blood flow secondary to oedema and infection (subperiosteal or articular) [27].

Bone scans are often reserved for cases in which clinical suspicion is high, yet radiographs and/or ultrasound are equivocal, and in neonates for suspected multifocal infection. Bone scans are also useful in suspected chronic multifocal osteomyelitis CRMO, in the older child and to confirm suspected discitis in children whose radiographs are normal.

5.4. Magnetic resonance imaging

MRI plays an important role in defining the (multiplanar) extent of soft tissue involvement. This is particularly true in complex sites such as the spine (discitis) for the exclusion of extradural collections causing spinal cord compression. MRI gives excellent soft tissue and bone contrast, and is particularly useful in the neonate and young child, allowing the assessment of cartilaginous (including growth plate) involvement.

Active inflammation and infection returns a low signal on T1 weighted and a high signal on T2 weighted and STIR sequences (Fig. 10C). The degree of bony involvement in osteomyelitis may be overestimated as areas of reactive/sympathetic inflammation will return a similar signal pattern. In isolated septic
Fig. 11. Coronal T1 pre- and post-gadolinium left arm (same patient as Fig. 5). On the pre-contrast image (A), the humeral shaft is seen to return a lower signal than the metaphysis and epiphysis. The post-contrast image (B) illustrates the degree of soft tissue inflammation (which is not apparent on the radiograph—Fig. 5). The proximal humeral epiphysis is spared from the infective/inflammatory process, and does not enhance.
Fig. 12. Contrast enhanced T1 weighted MR images of the spine: (A) axial and (B) sagittal. Both images demonstrate a collection beneath the anterior longitudinal ligament (arrows). On the sagittal images, notice the enhancement of superior and inferior end plates of the adjacent vertebral bodies.

Fig. 13. Axial CT scan spine (same patient as Fig. 12). CT guided aspiration of the collection identified on MRI.

Arthritis, abnormal signal from bone marrow should rarely be seen. The use of gadolinium (Fig. 11) allows the definition of soft tissue, subperiosteal and interosseous collections which are identified following peripheral enhancement (of their walls) with central low signal non-enhancement (debris/pus/fluid).

MRI of the spine is useful in children not responding to therapy and/or to detect complications such as extradural and paraspinal collections that will require surgical treatment (Fig. 12).

5.5. Computed tomography

CT has a limited role in the diagnosis of acute haematogenous musculoskeletal infection in the neonate. It is more useful in chronic osteomyelitis where it is superior to MRI for the demonstration of cortical destruction, air and sequestra [28]. It may also be used to guide aspiration and biopsy, especially when the spine and paraspinal soft tissues are involved (Fig. 13).

Fig. 14. AP pelvic radiograph of a child aged 5 years and 2 months. This patient had a history of septic arthritis of the left hip. There is significant abnormality of the left hip which is dislocated with secondary acetabular dysplasia. There is no ossified femoral head. There is partial resorption of the femoral neck and proximal shaft. Notice the pelvic tilt—compensating for the leg length discrepancy.
6. Complications

Considerable morbidity may be associated with neonatal osteomyelitis and/or septic arthritis. Early diagnosis and treatment are critical if complications are to be minimised. This is particularly true of septic arthritis, as damage to articular cartilage (secondary to proteolytic enzymes released from synovial cells) begins rapidly [4]. Complications include:

- damage to the growth plate with premature and/or asymmetrical closure of the growth plate;
- avascular necrosis of the femoral head with or without complete dissolution of the femoral head and neck (Fig. 14);
- pseudoarthrosis;
- limb length discrepancies, made more obvious as the child grows;
- angular deformities at joints, also made more obvious with progressive growth;
- joint dislocations;
- joint arthrodesis;
- vertebra magna (with narrowing of the spinal canal);
- block vertebrae.

Many of these will require surgical intervention including limb lengthening procedures, contralateral arthrodesis, insertion of prostheses, etc.

It has been documented that as many as 40% of children with septic arthritis of the hip will develop a serious complication, and long-term follow up for early identification of complications is mandatory [4].

7. Summary

There are anatomical and pathophysiological differences that account for differences in the patterns of musculoskeletal infection seen in infants and young children compared to older children and adults.

The various imaging techniques outlined above each play an individual role in the diagnostic work up of a neonate with suspected osteomyelitis and/or septic arthritis. They should be seen as complimentary tools [29], and any particular child will often have multiple investigations.

The sequelae of late diagnosis and delayed treatment may be devastating, and a high index of suspicion is always required, particularly in neonates where clinical findings are often non-specific.

References