Paediatric Bone Infection: An Imaging Overview

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MRI of paediatric bone infection - some take home messages

This is not a complete overview of paediatric osteomyelitis but an illustration of some useful points from our institution that will help guide accurate diagnosis of this uncommon paediatric condition. It must be understood that the pathogenesis of paediatric osteomyelitis differs to that in adults. Additionally, the MR imaging appearances of bone marrow undergoing normal development may appear unduly abnormal to the untrained eye.

There are 2 broad subtypes of osteomyelitis:

- **Haematogenous**: bacteraemia leads to bone infection. Most common in children. Often a history of systemic illness.
- **Contiguous/focus**: from adjacent contaminated or infected soft tissue. Most common in adults. Often a history of penetrating trauma or instrumentation. May see an adjacent pressure point ulceration.

Paediatric pathogenesis *(Fig. 1 on page 2)*:

- In children, nutrient vessels end in the metaphysis where there is an underdeveloped reticuloendothelial system and tortuous sluggish flow.
- With bacteraemia, organisms seed and proliferate in these metaphyseal slow flow vessels (B).
- In children <18 months, transphyseal vessels allow metaphyseal infections to cross the physis and infect the epiphysis and joints (A).
- There is also an increased risk of septic arthritis if the involved metaphysis is intra-articular (hip, shoulder, elbow, ankle).
- In adults however, once the physis is closed, there is vascular continuation between metaphysis and epiphysis (C).

Images for this section:
Fig. 1: Illustration demonstrating the nutrient arteries in infant long bones (A), children (B) and adults (C). The paediatric nutrient arteries terminate in the metaphyses and sluggishly drain into the venous sinusoids predisposing to metaphyseal sites of infection. In infants however the transphyseal vessels are patent and may promote the spread of infection through the relatively avascular physis to the epiphysis. In adults there is vascular connection between the metaphysis and epiphysis.
Methods and Materials

Bone Marrow maturation:

- Skeletal maturation is a dynamic and predictable process that must be differentiated from pathologic processes.
- In the neonate, marrow is entirely haematopoietic and therefore of low signal on T1 images and high signal on water-sensitive images.
- During the first year of life, the conversion from haematopoietic (red) to fatty (yellow) marrow begins.
- This conversion is almost complete in the appendicular skeleton by the time of skeletal maturity, but proceeds in the axial skeleton throughout life.
- Pattern is from periphery to centre.
- Epiphysis first, then the diaphysis and proceeds towards the metaphyses.
- Therefore, the last parts of the appendicular skeleton to convert are the proximal humeral and femoral metaphyses.

Normal imaging characteristics of RED marrow:

- Red marrow: 40% fat, 40% water, 20% protein
- Fatty marrow: 80% fat, 15% water, 5% protein
- Therefore healthy Red marrow has a similar or higher T1 signal than that of muscle and similar signal to muscle on water sensitive sequences.
- Diseased Red marrow will have very low T1 signal and increased signal on water sensitive sequences.
- Red marrow is more highly vascularised than fatty marrow and therefore enhances better with contrast.

Key Points to consider:

- Confusing marrow appearances in normal children include isolated foci of residual red marrow that often have a vertically orientated 'flame-shaped' configuration. These are usually adjacent to the physis and should always be of equal or greater signal relative to muscle on T1.
- Speckled marrow appearance of the hind or mid foot of children with altered weight bearing, frequently following trauma. These hypointense spots on T1 and hyperintense spots on water sensitive images may be perivascular foci of red marrow and can be bilateral. They do not represent post-traumatic oedema.

Results
Cases:

**Case 1: 14-year old boy who presented with an acutely tender right shoulder.**

MRI was performed (Fig. 2 on page 7) and he was treated for a septic arthritis with multiple washout procedures. On review of the imaging by musculoskeletal radiologists, note was made of subperiosteal pus (Fig. 3 on page 8) with raised periosteum. The subperiosteal pus was relatively hyperintense compared with muscle on T1 weighted sequences and high signal on fluid sensitive sequences. However, these appearances were more conspicuous on fat suppressed fluid sensitive sequences (Fig. 4 on page 9, Fig. 5 on page 10). It should be noted that contrast enhanced sequences may not be of added value in such cases.

**TAKE HOME MESSAGE:** *Infection may not just be confined within the joint. Where large joints are concerned, there must be a low threshold for reviewing the adjacent metaphyses for periosteal involvement.*

**Case 2: 9-year old girl who presented with swelling and tenderness in her right heel having earlier sustained a foreign body injury to an ipsilateral toe.**

MRI (Fig. 6 on page 11) showed extensive signal changes in and around the calcaneum with lifting of the periosteum. These imaging findings would be more in keeping with osteomyelitis rather than Sever's disease due to the peri-apophyseal hypointensity on T1 and hyperintensity on fat saturated fluid sensitive images.

**TAKE HOME MESSAGE:** *Symmetrical peri-apophyseal growth plate changes on fat suppressed fluid sensitive images can be normal, but not when they are as severe as this.*

NB. Comparison is offered with the normal paediatric ankle (Fig. 7 on page 12). Peri-apophyseal marrow changes are noted. Patchy 'flame shaped' hyperintense bone marrow is noted with a 'starry sky' like appearance on fat suppressed fluid sensitive images (Fig. 8 on page 13). These were unchanged in this patient over many years and there were no localising signs. Note is made of the absence of any 'band of oedema'.

**Case 3: 3-year old boy with a limp and a fever one week post varicella zoster infection:**
MRI revealed bone marrow oedema in the distal femoral metaphysis with extension into both diaphysis and epiphysis with very low signal on T1 (Fig. 9 on page 14) and high signal on fat saturated fluid sensitive sequences (Fig. 10 on page 15). Synovial fluid culture grew group A, B-haemolytic streptococcus. The patient was treated for an acute haematogenenous osteomyelitis and septic arthritis.

**TAKE HOME MESSAGE:** *Haematogenous spread of infection to metaphyseal bone marrow should be considered in the unwell child with a limp. Care must be taken not to miss multifocal sites of involvement.*

**Case 4: 11-year old girl with a six month history of non-settling pain in the left leg and ankle exacerbated by movement.**

MRI of the ankle showed marked hypointensity on T1 weighted images either side of the distal tibial growth plate (Fig. 11 on page 17). This was overlooked and repeat examination with fat saturated fluid sensitive and gadolinium enhanced sequences were requested. These demonstrated a matching region of hyperintensity (Fig. 12 on page 19) consistent with a low-grade infection. This was confirmed on biopsy.

**TAKE HOME MESSAGE:** *T1 weighted images are the most sensitive for bone marrow changes. Fat saturated fluid sensitive images are contributory. There is no requirement for contrast enhanced imaging.*

**Images for this section:**
**Fig. 1:** Illustration demonstrating the nutrient arteries in infant long bones (A), children (B) and adults (C). The paediatric nutrient arteries terminate in the metaphyses and sluggishly drain into the venous sinusoids predisposing to metaphyseal sites of infection. In infants however the transphyseal vessels are patent and may promote the spread of infection through the relatively avascular physis to the epiphysis. In adults there is vascular connection between the metaphysis and epiphysis.
**Fig. 2:** Axial T1 image of the right shoulder with joint effusion
**Fig. 3:** Sagittal T1 image of the right shoulder with subperiosteal collection relatively hyperintense to muscle.
**Fig. 4:** Axial STIR (fat suppressed fluid sensitive) image of the right shoulder with hyperintense periosteal collection.
**Fig. 5:** Sagittal STIR (fat suppressed fluid sensitive) image showing hyperintense periosteal collection involving metaphysis and diaphysis.
Fig. 6: Sagittal STIR (fat suppressed fluid sensitive) image with gadolinium demonstrating florid, hyperintense bone marrow oedema involving the calcaneal apophysis and the majority of the calcaneum. Planter fascia and achilles tendon are also involved and there is lifting of the calcaneal periosteum.
Fig. 7: Sagittal STIR (fat suppressed fluid sensitive) image of the ankle demonstrating normal marrow appearances of the distal tibial growth plate, talus and posterior calcaneum.
Fig. 8: Sagittal proton density (fat suppressed fluid sensitive) image of the ankle demonstrating normal marrow appearances of the talus and calcaneum. Note is made of the patchy hyperintense peri-vascular foci of red marrow.
Fig. 9: Axial T1 image of the right knee showing markedly hypointense metaphyseal marrow signal.
Fig. 10: Coronal STIR (fat suppressed fluid sensitive) image of the right knee demonstrating marrow oedema centred within the distal femoral metaphysis but extending into both diaphysis and epiphysis.
Fig. 11: Coronal T1 image of the left ankle demonstrating markedly hypointense epiphyseal and metaphyseal bone marrow.

Fig. 12: Sagittal post gadolinium T1 fat saturated image of the left ankle showing abnormal marrow signal intensity at the distal tibial epiphysis and metaphysis. These contributory appearances are suspicious of a low grade osteomyelitis.
Conclusion

TAKE HOME MESSAGES:

• Paediatric bone marrow appearances can vary and it is important to know the range of normal. Foci of residual red marrow are usually metaphyseal but may be epiphyseal. They are usually 'flame-shaped' and vertically orientated.

• Speckled marrow appearance of the hind/mid foot of children with altered weight bearing frequently follows trauma and does not necessarily represent post-traumatic oedema.

• Infection may lie away from the joint. Where large joints are involved, there must be a low threshold for reviewing the adjacent metaphyses for periosteal involvement.

• Haematogenous spread of infection should be considered in the unwell child with a limp. Care must be taken not to miss multifocal sites of involvement.

• T1 weighted images are the most sensitive for bone marrow changes. Fat saturated fluid sensitive images are contributory. Contrast enhanced imaging can sometimes be helpful but is not always a requirement.

References

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