Childhood osteomyelitis - findings with MRI evaluation

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Learning objectives

To describe and illustrate the spectrum of magnetic resonance findings of osteomyelitis in children. To emphasize magnetic resonance imaging (MIR) significance in the diagnosis, evaluation of extension and complications and to the therapeutic decisions. To correlate MRI findings with findings of conventional radiographic studies. To contextualize the radiographic evaluation in the knowledge of the pathophysiology, epidemiology, manifestation, clinical diagnosis, treatment and follow-up.
Background

Epidemiology

Osteoarticular infections (OAI) are severe diseases relatively common in pediatric patients, with an estimated incidence in Western countries of 5 to 20 cases per 100,000 children per year. Pediatric OAI affect predominantly the male gender. OAI have potential for serious and long-lasting complications, thus requiring timely diagnosis and early appropriate treatment.¹

Pathophysiology

Osteomyelitis (OM) is the infection of bone with involvement of the bone marrow. There are three major routes for microorganism seeding - hematogenous, by contiguous spread and by direct implantation.

The hematogenous route gains particular significance in the pediatric population, where the medullar cavity is initially involved. A non-controlled infection then involves by contiguity to the cortex, periosteum and, finally, the surrounding soft tissue. In this case, infection affects usually the long bones.

A contiguous route of bone infection progresses in a reverse manner, with initial involvement of the soft tissues. This route is not so common in childhood and gains relevance in immunocompromised patients.

Direct inoculation can occur if there are exposed fractures, iatrogenic inoculation during surgical procedures and/or open woods. In this last case, the initial involved structure may be the medulla, the cortex or the soft tissues. Independently, soft tissue involvement is frequent.

The localization of lesions caused by hematogenous seeding, particularly those affecting the long bones, depends on the age of the patient.

The vascular anatomy varies with age, changing during growth. In infants, epiphysis is the most frequent site affected (usually by Group A streptococcus) due to the communication of diaphyseal and metaphyseal arterial vessels with the epiphysis. Attending to the rich vascularity and to the ease with which the bone reacts - with lifting of periosteum and formation of new bone - involucrum formation is frequent. Septic arthritis may coexist.
In children with more than 12 months, lesions are frequently metaphyseal (usually by *Staphylococcus aureus*) attending to the existence of terminal arterial vessels is this localization. Epiphysis may be involved by contiguity as the joints with intra-articular epiphysis. Abscesses and sequestra are frequent complications.

After the closure of growth plates, lesions are more frequently epiphyseal, attending to the communication of metaphyseal vessels with the epiphysis. Articular involvement is also frequent.

**Clinical presentation and diagnosis**

The clinical presentation is variable with signs and symptoms lacking specificity. The most frequent ones are pain, restriction of limb/joint motility and fever.¹

Depending on the microorganism and on the immunological status, symptoms may be acute (presenting for less than 7 days) or more indolent - with signs and symptoms lasting for weeks or months - in the sub-acute and chronic forms of presentation (at least 14 days and 6 weeks, respectively).

Acute presentation is the most frequent at our institution, followed by subacute and chronic forms.¹

White blood cell count (WBC) is not a reliable indicator of OAI, C reactive Protein (CRP) and erythrocyte sedimentation rate (ESR) are. Nonetheless, normal values of inflammatory markers do not exclude OAI. Blood cultures lack sensitivity.¹

Therefore, the radiographic diagnosis is one important part of the correct diagnosis formulation process.

**Differential diagnosis**

Other pathologic conditions - with a vascular, traumatic or neoplastic nature - may sometimes mimic OM. Examples of these conditions are vaso-oclusive disease, septic emboli, stress fracture and tumors such as, osteoid osteoma, condroblastoma, metastatic neuroblastoma, ALL, Ewing's sarcoma and osteosarcoma. In the spectrum of OAI, septic arthritis must be differentiated from OM. The differentiation of these conditions based on MRI findings goes beyond the main objectives of this work.

**Complications**
Relatively frequent complications of OM are related to local complications, recurrent osteomyelitis and complications related with sequelae and growth disturbance. Toxic shock syndrome, endocarditis, septic venous thrombosis and squamous cell cancer are rare complications.

Possible local complications are abscess, sinus tract, pyomyositis, septic arthritis and deep venous thrombosis.

Sequestrum harbors microorganisms and gives rise to recurrent episodes of clinical infection. Usually results from untreated acute osteomyelitis, from a complication of surgical procedures (e.g. open reduction and internal fixation of fractures) or after traumatic injuries and it requires aggressive treatment with a combination of surgery and prolonged antibiotic courses.

Possible sequelae related to growth disturbance are limb length discrepancy, angular deformity, limitation of joint mobility, osteonecrosis, and occurrence of a pathologic fracture.

At our institution, these complications are significantly more frequent in the chronic and sub-acute forms.

**Treatment and surveillance**

Treatment is done with parenteral antibiotic treatment with or without surgical treatment as an adjunct. A targeted parenteral antibiotic treatment is done when the causative microorganism is isolated. If not possible an empiric antibiotic treatment is done and then changed if necessary.

After treatment, surveillance is mainly based on clinical data, laboratory tests and findings of sequential radiographs.

Monitoring CRP levels after onset of antibiotic treatment is a reliable indicator of response to treatment. Unlike ESR, CRP levels begin to decline in an early phase of adequate treatment and, in acute OAI reach normal values in 7-10 days.

The value of MRI in the evaluation of the response to treatment is not established.
OM represents a diagnostic challenge for the clinicians and radiologists. The diagnosis should be based on the combination of several factors: clinical and laboratory findings, bacteriologic data and imaging studies. Cooperation between the clinician and radiologist is a very important aspect for adequate diagnosis and treatment.

MR has high diagnostic accuracy and sensitivity due to the high capability of tissue characterization and spatial resolution. The lack iodinated radiation is particularly important in childhood.

MR detects pathologic anomalies of OM at an early stage. It allows detection or exclusion of anomalies and evaluation of the extent. With special relevance is the capability to detect complications, which is particularly important at surveillance after therapeutic institution - mainly when facing an incomplete or absent clinical response, or a recurrence. At a chronic stage, it allows detection of activity signs.

However, because of the elevated costs and the specificities of the pediatric patients, often requiring sedation, MRI is not routinely used for diagnosis and is reserved for specific situations.

The MRI protocol that gains particular relevance at MRI evaluation of osteomyelitis - used at our institution - is described in Table 1.

Possible findings in osteomyelitis at MRI evaluation are described in Table 2 and Table 3. Illustration of these findings is done in Figures 1-4.

A review and description of a series of clinical cases seen at our Department, with a complementary review of relevant scientific literature was done. Images of various examinations done with MR are presented.
MRI protocol for osteomyelitis:

- T1-weighted sequences;
- Fast T2-weighted or STIR sequences;
- At our institution, proton density-weighted sequences with fat suppression are frequently performed;
- T1-weighted sequences with fat suppression techniques after intravenous contrast administration, usually with subtraction techniques. These sequences are important to distinguish an abscess from an inflammatory mass due to phlegmon/ cellulitis and to better depict sinus tracts and sequestra.

The best plans to perform depend on the anatomic site:

- Multiplane images for the foot;
- Sagittal and axial plans for the spine, knee, ankle and elbow;
- Coronal and axial plans for the shoulder, wrist, pelvis and hip.

**Table 1:** MRI protocol for osteomyelitis evaluation

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Table 2: MR findings of osteomyelitis

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MRI findings of osteomyelitis at the various stages of the disease

**Acute osteomyelitis:** The first sign is medullary edema that obliterates the normal medullary fat. Medullary edema is not a specific sign for osteomyelitis but MRI is highly sensitive for its detection. Lifting of the periosteum follows. Periosteum and cortex are separated by pus/inflammatory fluid. At the same time, periosteal reaction and soft tissue edema are accompanying phenomena. Later, there is cortical destruction with blurring and and/or clear interruption; and/or periosteal destruction with cloaca formation. Cloaca allows drainage of pus to the soft tissues. In this stage, there usually edema and/or phlegmon in the soft tissues. Finally, sinus tract and/or abscesses may form.

**Sub-acute osteomyelitis:** In children, Brodie’s abscess is a frequent finding, affecting predominantly the tibia and femur and usually the metaphysis. It appears as a well-defined serpiginous lesion with the typical signal pattern of an abscess. As a sub-acute abscess it has well-defined borders and is surrounded by a hypointense rim on all sequences, due to fibrosis or reactive bone. Usually edema of the medulla and soft tissues and periosteal reaction are coexistent findings. Articular effusion may be sympathetic or infectious in nature.

**Chronic osteomyelitis:** In the chronic phase of the disease there is sclerosis with thickening of the periosteum, endosteum and trabeculae, with or without cystic changes. Findings as sequestrum, intramedullary abscess, cloaca, subperiosteal fluid collection and/or sinus tract are suggestive of active chronic disease, being sequestrum the most specific.

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**Table 3:** MRI findings of osteomyelitis at the various stages of the disease

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Fig. 1: Acute osteomyelitis of the right femur

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Image 2. Acute osteomyelitis of the left femur with abscess formation. A 11-years old girl with a previous minor trauma - 10 days ago – presenting with pain in the left knee with enabled mobilization and fever lasting for 3 days. Clinical signs of arthritis were present.

MRI evaluation reveals:

• A diffuse signal abnormality in the distal metaphysis of the left femur, affecting the adjacent physis - for 2 cm - and extending to the epiphysis of the medial condyle. This area has high signal intensity on STIR and T2 sequences and low signal on T1 sequences and diffuse enhancement after contrast administration due to inflammatory hyperemia (orange arrows).

• In the center of this area of medullar edema there is a focal abnormality with 5cm and irregular borders there is in contact with the adjacent physis in a extent of 2 cm. This area shows peripheral enhancement after contrast administration with a central hypointense non-enhancing area – denoting an abscess (yellow arrows).

Correlation with radiographic findings is done – in figures g and h a lytic lesion with irregular borders and a permeable pattern of bone destruction is seen.

Fig. 2: Acute osteomyelitis of the left femur with abscess formation

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**Fig. 3:** Subacute osteomyelitis of the tibia with a Brodie abscess

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**Fig. 4: Active chronic osteomyelitis of the femur**

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Conclusion

The clinical diagnosis of osteomyelitis in children is difficult due to the variety of possible manifestations. MR is an important diagnostic technique that is useful in the detection or exclusion of bone anomalies, in the evaluation of the extent, to depict complications and in the differential diagnosis with other pathologies. The correct diagnosis is only possible with a multidisciplinary approach. Being familiarized with the spectrum of radiographic findings - particularly those of MRI - is therefore important as is the knowledge of the pathophysiology, clinical manifestation, prognostic and treatment possibilities of this disease.

MRI appears as an useful imaging technique with high accuracy for the diagnosis. The role of MRI in the follow-up is not well established must seems promising.
Personal information

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