Role of MRI in detecting early physeal changes due to acute osteoarticular infection around the knee joint: a pilot study

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Abstract Physeal changes of any aetiology in children are usually diagnosed once the deformity is clinically evident. Between January 2006 and June 2007, 15 children who suffered from acute osteoarticular infection around the knee joint were studied. They were called up for follow-up six months after the onset of infection. All patients were evaluated by clinical and roentgenographic examination before undergoing magnetic resonance imaging (MRI) study of both knees “with the unaffected knee serving as control”. Abnormal findings in the physis, metaphysis and/or epiphysis on MRI were observed in five children. This group of five children was compared with the other ten children for clinical presentation and course of disease. We believe that MRI is a useful tool in the evaluation of growth plate insult in the early period following acute osteoarticular infection, and we can diagnose and prevent the catastrophic complications of the same.

Résumé La modification de la physe chez l’enfant, quelle que soit l’étiologie en cause est habituellement diagnostiquée après que la déformation devienne évidente. Entre janvier 2006 et juin 2007, 15 enfants présentant une infection ostéo articulaire aiguë autour du genou ont été étudiés et ont été

suivis pendant six mois après le début de l’infection. Les patients ont été évalués de façon clinique et radiographique ainsi qu’avec une étude IRM au niveau des deux genoux, le genou sain servant de contrôle. Des modifications anormales de la physe ou de la métaphyse sur l’IRM ont été observées chez 5 enfants. Ce groupe de 5 enfants est comparé avec l’autre groupe de 10 enfants. Nous espérons que l’IRM sera un examen utile quant à l’évaluation de la lésion précoce de la plaque de croissance avec possibilité d’un diagnostic précoce après une infection ostéo articulaire de façon à prévenir une complication catastrophique.

Introduction

Osteoarticular infection of the skeletal system in children is a very common problem and increasing day by day in developing countries [2, 6]. However, the incidence has declined in developed countries in recent years [5]. The orthopaedic complications of acute osteomyelitis can be in the form of progression to chronic osteomyelitis, physeal arrest resulting in shortening or angular deformity or both or physeal stimulation resulting in overgrowth. The involvement of growth plate “physeal cartilage”, a cause of subsequent limb deformities, is a concern for the treating orthopaedic and paediatric surgeons and should be diagnosed early [12]. This diagnosis has traditionally been based on clinical findings and plain radiographs, but these manifestations are usually late. Though the plain radiographs can show the details of the metaphysis and the secondary ossification centre in the epiphysis, they do not reveal the cartilaginous physis. Computed tomography does not add much information about the cartilaginous physis [11]. It has only been after the advent of magnetic resonance imaging (MRI) that the physis can now actually

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be visualised and injuries to the growth plate can be defined in detail [6]. There are studies where within six months after trauma physal changes were documented on MRI [4, 13]. However, there have been no studies in the literature to document early physal changes after osteoarticular infection. Accordingly this study was planned.

Materials and methods

In a span of 18 months, 19 children between the ages of one month and 15 years who were diagnosed with septic arthritis of the knee or acute osteomyelitis of the distal femur or proximal tibia were included in this prospective study after obtaining informed consent from the parents. Of these, 15 children could be followed up for six months after disease onset. The initial diagnosis of acute osteomyelitis had been made using Peltola and Vahvanen's criteria [8] and of septic arthritis using Morrey et al.'s criteria [6]; those not meeting the criteria were excluded from the study. Of the 15 children, nine were boys and six were girls. At initial diagnosis their age ranged from 45 days to 14 years, with an average of 6.7 years. Eight suffered from septic arthritis of the knee and seven had acute osteomyelitis. Of the osteomyelitis group six had osteomyelitis of the upper tibia and one of the distal femur. Nine children had involvement of the left side, five of the right side and one had bilateral involvement of the knee. Four (cases 5, 8, 10 and 11) had a history of a precipitating factor: two had a history of trivial trauma, one had an umbilical cord infection and one had pyrexia of unknown origin for three weeks. Of the four children with precipitating factors, three had osteomyelitis. The mean duration for clinical presentation was six days for septic arthritis and eight days for osteomyelitis with cumulative seven days (range: 2–15 days). Of the eight children with septic arthritis, seven had pus on arthrocentesis while one was negative. Of the children with osteomyelitis, three had positive aspirations and four were negative. The initial treatment protocol consisted of intravenous antibiotic, i.e. cloxacillin and gentamicin for an average of seven days

(range: 5–14 days), and was subsequently changed according to sensitivity of culture if positive [15]. Subsequently children were given a course of four weeks of oral antibiotic usually a first- or second-generation cephalosporin. The average total duration of antibiotic therapy was six weeks. All cases had surgical intervention (débridement, arthrotomy) except one, case no. 10, who was a seven-year-old boy with a diagnosis of osteomyelitis of the upper tibia, whose needle aspiration did not yield any aspirate, and was treated conservatively.

At the six-month follow-up from the start of symptomatology, patients were again evaluated by clinical and roentgenographic examination. After a detailed physical examination, radiographs of both limbs were done. Then the children underwent an MRI study for the involved and uninvolved knees. The MRI machine used was 1.5-T with a surface coil. The following sequences were included: coronal T1-weighted spin echo, coronal T2-weighted gradient echo and sagittal T2-weighted spin echo (Figs. 1 and 2). Fat suppression imaging was done if required. Patients who were not able to cooperate for the scan were sedated by triclofos 30 mg/kg body weight orally and none were subjected to general anaesthesia.

On the basis of clinical and roentgenographic examination, we categorised our patients as:

- **Active:** those who had clinical and roentgenographic evidence of persistent infection
- **Dormant:** if only roentgenographic evidence of infection was present
- **Healed:** if there were no clinical and roentgenographic findings

Results

At the six-month follow-up of the 15 cases, four children had some evidence of persistent infection with two children having active and two having dormant disease. The remaining 11 were categorised as healed. On MRI 30 knees with 60 physes were examined in 15 patients; all of the physes

Fig. 1 a, b Findings 6 months after acute septic arthritis of the left knee. X-ray is normal; MR image, T1-weighted coronal view shows involvement of the physis with a bony bar crossing the physis with obliteration of the plate at mid-portion. Signal changes are seen in both epiphyseal and metaphyseal areas

Fig. 2 MRI, T1- and T2-weighted coronal sections show infection crossing the physeal plate on the lateral side with obliteration of the physeal plate. The adjacent epiphysis shows involvement

studied were well visualised on MRI. A comparison was made of the involved and uninvolved sides: a subgroup of five children were shortlisted as having some abnormal findings as compared to their opposite sides.

Physeal involvement: four of the physes studied had changes in their character as compared to the physes of the opposite side (cases 1, 3, 4 and 5). The involvement was partial “involvement of less than 50% of the physis” in three cases and complete “involvement of more than 50% of the physis” in one case.

Physeal bar: one of the cases studied had physeal bar formation on MRI. The patient (case 3) was a ten-year-old boy who had osteomyelitis of the distal right lower femur; the bar appeared osseous in nature, central in location and involved around 20% of the growth plate area.

Epiphyseal and metaphyseal signal changes: five cases had signal changes vis-à-vis their counterparts irrespective of diagnosis.

Knee joint changes: none of the cases had any abnormal findings in their knees, even those cases with septic arthritis (Table 1).

Discussion

The physis is a cartilaginous structure unique to the immature skeleton that is responsible for the longitudinal growth of all long bones. Involvement of the growth plate as a complication secondary to osteoarticular infection assumes significance due to the potential for future growth disturbance. Being one of the most active parts of the skeletal system, any growth plate involvement needs to be diagnosed early to avoid future deformities [12].

In this study, the most common abnormality on MRI evaluation was obliteration of the growth plate as compared to the opposite side. “Complete involvement” was diagnosed when MR signal changes involved more than 50% of the growth plate area and when involvement was less than 50% it was labelled as “partial”. Three children (cases 1, 3 and 4) had partial involvement: cases 1 and 4 showed narrowing of the lateral one third of the upper tibial physis and case 3 had obliteration of the central part of the femoral physis. One case (case 5) had complete obliteration of almost the entire upper tibial physis leaving around a 10% rim at the periphery. Localised or diffuse narrowing of the growth plate has been identified as a risk factor for future growth disturbance. Smith et al. [13] in their study of 12 patients with MRI evaluation after a mean of ten weeks following injury had found that physeal narrowing correlated with a significant risk of growth arrest. This alteration in our series probably represents a period of decreased growth of the physis that can be due to damage to the rapidly proliferating cell layer of the physis. Ideally histological evidence of the exact cause of such hypoplasia of the growth plate would be required, but any kind of biopsy of these physes for this purpose is not possible due to obvious ethical implications. In these patients, no statistically significant correlation could be found for the narrowing of the growth plate with parameters such as age and sex of the patient, duration of symptoms, diagnosis, side, site, time since start of treatment, surgery, aspiration of pus and precipitating factors if any. Maybe the number of cases in our series is small, and a larger group of patients might make the role of some of these factors clear.

A definite indication of an impending growth disturbance is the development of a fibrous or osseous bar within

Table 1 Patient characteristics

Case No.	Age	Sex	Diagnosis	Duration of symptoms (days)	Side involved	Pus aspirated	Any precipitating factor	Patient's category at follow-up
1	5 years	M	Acute OM upper tibia	7	Left	Yes	No	Dormant
2	12 years	F	Septic A	3	Left	Yes	No	Active
3	10 years	M	Acute OM lower femur	5	Right	Yes	No	Healed
4	14.5 years	M	Acute OM upper tibia	2	Right	Yes	No	Dormant
5	12 years	M	Acute OM upper tibia	12	Left	No	History of trauma 2 weeks	Active
6	5 months	F	Septic A	10	Left	Yes	No	Healed
7	4 years	F	Septic A	3	Right	Yes	No	Healed
8	45 days	M	Septic A	9	Bilateral	Yes	Septicaemia due to umbilical cord	Healed
9	8 years	F	Acute OM upper tibia	10	Left	No	No	Healed
10	7 years	M	Acute OM upper tibia	5	Left	No	History of trivial trauma 10 days	Healed
11	60 days	M	Acute OM upper tibia	15	Left	No	PUO 3 weeks	Healed
12	13 years	F	Septic A	5	Left	Yes	No	Healed
13	4 years	M	Septic A	7	Right	No	No	Healed
14	2 years	M	Septic A	5	Left	Yes	No	Healed
15	4.5 years	M	Septic A	7	Right	Yes	No	Healed

OM osteomyelitis, A arthritis, PUO pyrexia of unknown origin

the physis [7]. It is believed that small bars might undergo resolution as time progresses, while the larger bars are permanent and lead to growth arrest or deformity [7, 9]. As there are no studies in the literature on altered MRI findings in the early period following osteoarticular infection, available information is mostly derived from post-traumatic physal changes. While some osseous bridging may be detected within a few weeks after an injury [4, 13], it may not become evident clinically for months to years afterwards. This factor highlights the necessity to follow up any child who has a physal injury, for an adequate period, if not until skeletal maturity. This could be particularly true for a patient who has had metaphyseal osteomyelitis. Jaramillo et al. [6] found that all cases with persistence of either a fibrous or osseous bar at six months after injury went on to develop growth anomaly. In the series of Smith et al. [13], four of five cases that had large physal bars (>25%) on MRI developed a growth anomaly significant enough to warrant surgery. Two cases in their series had bars of smaller size that resulted in 1 cm shortening in one case and a normal outcome in the other. At present there is no study available in the literature that has reliably predicted the size of a physal bar significant enough to cause a deformity.

One of the cases studied in our series had physal bar formation on MRI (case 3, 10-year-old boy who had osteomyelitis of distal right lower femur). The bar appeared osseous in nature, central in location and involved around 20% of the growth plate area. Ogden [7] described three basic patterns of partial physal arrest: peripheral (type 1),

linear (type 2) and central (type 3). In our study the bar was of the central type (type 3), the most severe type and the most difficult to rectify with surgery.

Signal intensity changes at both epiphyses and metaphysis at respective sites of involvement were observed in five cases (1, 2, 3, 4 and 5). Case 2, who initially had septic arthritis, later developed femoral osteomyelitis. Interestingly this patient had an intact growth plate on MRI evaluation. This suggests that a cross connection still persists between the epiphysis and metaphysis, and the role of the growth plate as a barrier for preventing cross infection maybe doubtful. Diaphyseal vessels can penetrate the growth plate and reach the epiphysis where they end in sinusoidal lakes. This situation provides a vascular connection between the metaphysis and epiphysis and therefore a greater chance for cross infection [3, 7, 14]. According to Rhem and Delahay [10], the growth plate lacks vascular connections from one year of age until puberty. But according to a histological study done by Alderson et al. [1] and others, transphysal blood vessels were present in growing chickens and were a likely explanation for the frequency of the occurrence of acute osteomyelitis and adjacent joint infection following intravenous injection of bacteria. All patients in our series were between one and 15 years of age. No statistically significant correlation of the epiphyseal and metaphyseal signal changes on MRI was observed between parameters such as age and sex of the patient, duration of symptoms, diagnosis, side, site, time since start of treatment, surgery, aspiration of pus and precipitating factor if any. All of the knee joints were

evaluated by MRI and were well visualised. We found no abnormal findings in any of the joints. Even in case 2 who initially had septic arthritis the knee joint appeared to be normal. The MR signal changes with the patient's clinico-radiological profile such as age and sex, duration of symptoms, diagnosis, side, site, time since start of treatment, surgery, aspiration of pus, other precipitating factors if any and clinico-roentgenographic profile at follow-up. There are no studies in the literature correlating these parameters with MRI findings following osteoarticular infection.

In this study a statistically significant correlation was observed between the patient's age and MRI findings. Of the five cases with abnormal MRI findings, four were more than eight years of age, which suggests that the higher the age the greater is the chance of growth plate disturbance. This could be attributed to the level of activity at the growth plate that might be occurring at a higher age, corresponding to the growth spurt that occurs between ten and 14 years of age.

A statistically significant correlation was also found between the X-ray findings at follow-up and MRI findings. In our study the four cases that had abnormal X-ray findings all had abnormalities on their MRI scans. Thus X-rays appear to be a good screening tool for detecting any abnormal findings before an MRI study. MRI could even detect one additional case, which was not appreciated on clinical and roentgenographic grounds.

Our sample size is not large enough to draw statistically significant conclusions with regards to the risk factors for physal growth arrest, and the validity of the MRI findings needs to be confirmed by further follow-up evaluation of more patients for a longer duration. Some patients with osteoarticular infection do show MRI alterations in the affected physis; these changes have been seen to bear relationship with the age profile of the patient. The higher age group patients are at a greater risk for residual MRI changes which could lead to future growth plate abnormalities; they need more vigilant follow-up.

Conclusion

MRI proved to be an excellent imaging modality to visualise not only the growth plate but also to show in detail the extent of infection. Of the 15 cases, ten had absolutely normal growth plates and no evidence of residual infection at six months. These patients can be relatively assured of an optimum outcome and need not be

maintained on a strict follow-up. We have been able to shortlist five patients who had evidence of a significant insult to the growth plate or showed evidence of persistent infection. These patients can be informed of the need for early treatment, regular follow-up and the guarded prognosis with regard to a future growth disturbance.

We believe using MRI as an aiding tool for evaluation of growth plate insult should be included in the regular follow-up protocol for cases with acute osteoarticular infection. It can prevent catastrophic complications which are otherwise not possible to detect until irreversible changes occur and preventable measures can be taken accordingly.

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