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Relevance of MRI for management of non-displaced lateral humeral condyle fractures in children

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Introduction: The treatment for non-displaced (<2 mm displacement) fractures of the lateral humeral condyle in children is controversial. Most studies recommend non-surgical treatment. However, plain radiographs are not sufficient to evaluate extension of the fracture line through the articular cartilage. This explains the high frequency of secondary displacements and non-unions, despite well-conducted conservative treatment. We hypothesized that MRI could be used to analyse whether the fracture is complete or incomplete. This could help to determine whether surgical or conservative treatment is indicated.

Material and methods: This prospective study enrolled children being treated for a non-displaced (<2 mm gap) fracture of the lateral humeral condyle. All patients were treated with a long-arm cast in the emergency room. An MRI was done later on without sedation. A specific protocol was used to reduce the duration of the examination. T2-weighted and proton density fat-saturated sequences were used.

Results: Twenty-seven patients were enrolled: 16 boys and 11 girls with a mean age of 5 years (2–10). The MRI was performed an average of 7 days (1–23) after the fracture. The MRI could not be interpreted in two cases because the child had moved during the examination. In the other 25 patients, the fracture was incomplete in 17 patients and complete in 8 patients. Two children had secondary displacement diagnosed 7 and 11 days after the fracture event. These two patients underwent open reduction and internal fixation. There was no correlation between patient age and the fracture being complete or incomplete. There were no cases of non-union.

Conclusion: MRI appears to be a reliable method for determining whether the fracture line is complete or incomplete. It can be performed without sedation, even in children as young as 2 years of age. Use of an injury-specific MRI protocol reduces the length of the examination, thereby improving its performance. We recommend that it be used to analyse non-displaced fractures of the lateral humeral condyle in children.

Level of evidence: 3 Prospective study.

1. Introduction

Lateral humeral condyle fractures make up 12% of distal humerus fractures in children [1]. The surgical indication is driven by the amount of displacement visible on standard X-rays. In the literature, conservative (non-surgical) treatment is recommended for non-displaced fractures (<2 mm gap between fragments) while

surgical reduction and fixation is performed for displaced fractures [2–5].

With non-displaced fractures, standard X-rays have two limitations related to the cartilaginous nature of the distal epiphysis of the humerus in children. The first is misjudging an incomplete fracture, in which the fracture line is limited to the epiphysis, and does not extend into the joint space. The second is underestimating the amount of displacement in cases of complete fractures [4,6,7], even though the sensitivity can be improved by taking an internal oblique view [6,7]. In addition, radiographic monitoring of casted fractures can lead to errors [3]. Conservative treatment of fractures that appear non-displaced on radiographs can result in up to 14.9%

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of cases having secondary displacement [5] and a 13% non-union rate [8]. For these reasons, Wadsworth recommends percutaneous pinning of all non-displaced fractures [9].

While CT arthrogram [10] or arthroscopy [11] can be done to evaluate possible extension of the fracture through the articular cartilage, both techniques require general anaesthesia. Ultrasonography monitoring [12] requires a trained radiologist and is not feasible once the arm is in a cast. On the other hand, MRI seems to be an appropriate method for this analysis [13,14].

The primary objective of this study was to evaluate the ability of MRI to determine whether the fracture line is complete or incomplete in cases of non-displaced lateral humeral condyle fractures in children. The secondary objectives were to assess the feasibility of MRI without sedation in a paediatric population and to determine the optimal time frame for performing it.

2. Methods

We carried out a prospective study between August 2015 and March 2017 that included all the children seen in our emergency department for a non-displaced fracture (< 2 mm gap) of the lateral humeral condyle. All children were treated with a long-arm cast in the emergency room. An MRI (with shoulder coil) was done as soon as practical afterwards without sedation. Coronal T2-weighted, coronal proton density with fat saturation (PD Fat Sat) and axial T2-weighted sequences were done. A 3-mm slice was taken every 0.3 mm over a $17 \times 17 \text{ cm}^2$ field of view. The images were read by a senior radiologist specialized in paediatric radiology. The analysis consisted of measuring the size of the displacement on MRI and whether the fracture line was incomplete (limited to epiphyseal cartilage) or complete (extension through articular cartilage).

2.1. Statistical analysis

For the descriptive analysis, percentages were calculated for the categorical variables and averages for the quantitative variables. Wilcoxon non-parametric tests were used for non-paired samples to compare the group with complete fractures to the one with incomplete fractures. The analysis was carried out using Easymedstat[®] software (Neuilly-Sur-Seine, France).

3. Results

The study enrolled 27 patients who averaged 5 years of age (2–10). There were 16 boys and 11 girls. The results are shown in Table 1. The MRI was done an average of 7 days (1–23) after the fracture. The coronal sequences took an average of 2.5 minutes and the axial sequences an average of 3.5 minutes, for a total time of about 15 minutes including the scout scans. The images from two children (ages 2, 4) were not usable because of movement during the examination. Hence, the MRI analysis was done on 25 patients. The fracture was incomplete (Fig. 1) in 17 patients (68%) and complete in 8 patients (32%). The T2 and PD FatSat sequences always provided the same conclusion when determining whether the fracture was complete or incomplete. There was no correlation between age and the fracture being complete ($P > 0.05$). In cases of complete fracture, the fragment was displaced less than 2 mm in six cases (Fig. 2) and more than 2 mm in two cases (Fig. 3) on MRI. The latter two patients underwent surgical fixation 7 and 11 days after the fracture event, with no intraoperative difficulties. The operative time was 40 minutes for patient no. 9 and 46 for patient no. 19. The non-surgical treatment was continued in the other patients. Fracture union was achieved after an average of 30 days (21–48), at which point the cast was removed. There were no cases of non-union.

4. Discussion

Paediatric lateral humeral condyle fractures have been classified using various systems. The most well-known [15,16] does not differentiate between complete and incomplete fractures. Song's [17] classification best deals with this problem by differentiating between incomplete fractures (types 1, 2), non-displaced complete fractures (type 3) and displaced complete fractures (types 4, 5) (Fig. 4). The limitations of standard radiographs stem logically from the cartilaginous nature of the distal humeral epiphysis in children.

Our study shows that MRI can be used to determine whether a fracture is complete or incomplete. Two studies have previously described use of MRI for analysing minimally displaced fractures of the lateral humeral condyle. Kamegaya et al. [13] found 7 incomplete fractures in 12 patients. Haillotte et al. [14] found 10 incomplete fractures in 14 patients. The percentage was similar in our study: 17 incomplete fractures in 25 patients.

We chose to use T2-weighted and PD FatSat sequences to analyse these fractures. The T2 sequences were used to analyse the bone, thus the metaphyseal fracture line. The PD FatSat sequences were used to analyse the cartilage, thus the epiphyseal fracture line. Neither sequence was superior to the other for analysing the fracture, since both sequences provided the same conclusion. Echo gradient sequences also appear to be a good alternative for studying cartilage [18].

Despite the patients being very young, MRI was carried out without general anaesthesia or sedation; the images could be interpreted in 25 to 27 cases. The two cases that could not be interpreted corresponded to some of the youngest patients in our study (2 and 4 years old). Nevertheless, age does not seem to be a limiting factor, as MRI could be done without problems in other patients of the same age. Cast immobilization likely contributed to reducing movement in these children, as shown with hip spica casting during MRI analysis of congenital hip dysplasia after reduction [19]. By limiting the MRI exam to only the sequences and slices required to analyse the fracture line, the duration of the exam was reduced, which also contributes to its performance.

With incomplete fractures, despite the presence of a hinge that protects it from secondary displacement, immobilization seems necessary until the fracture is healed.

In our study, the MRI revealed two displaced fractures that were easily reduced and fixed surgically. Since the MRI was done on Day 6 and Day 10 for these patients, it is impossible to know whether these fractures were initially displaced and missed on radiographs or underwent secondary displacement.

Our study has several limitations. While it is the largest study on this topic published up to now, the sample size is still relatively small. The timing of the MRI varied greatly, as it was done 1 to 23 days after the fracture. This reveals challenges related to MRI access. In fact, if the patient who underwent an MRI 23 days after the injury had required surgical reduction, this may have been more difficult given bone callus formation.

MRI can be used to determine accurately whether a fracture is complete or incomplete. In our opinion, its non-invasive and non-irradiating nature makes it the benchmark for evaluating fractures that are not displaced on radiographs. If the fracture is incomplete, the non-surgical treatment can be continued. If the fracture is complete and displaced, surgical reduction and fixation are indicated. Conversely, the treatment of a non-displaced, complete fracture is controversial. In the Kamegaya study [13], all these fractures were treated by closed pinning. Song et al. [17] also recommend percutaneous fixation. However, it seems that conservative treatment can be carried out. Haillotte et al. [14] described three patients with non-displaced complete fractures who had good outcomes. This was also the case in six of our study patients. This implies the possibility of monitoring the fracture by MRI to get around

Table 1
Demographic and MRI data.

Patient	Age (years)	Delay before MRI (days)	Fracture line on MRI		Duration of immobilization (days)
			T2	PD FatSat	
1	9	3	I	I	29
2	4	3	I	I	27
3	5	4	CND	CND	32
4	4	10	NI	NI	22
5	5	1	I	I	31
6	5	8	I	I	31
7	5	13	I	I	27
8	6	23	I	I	30
9	7	6	CD	CD	34
10	4	4	I	I	25
11	7	3	CND	CND	29
12	2	7	NI	NI	21
13	3	9	I	I	28
14	6	8	I	I	33
15	2	4	I	I	23
16	4	12	I	I	26
17	6	7	I	I	26
18	8	2	I	I	28
19	5	10	CD	CD	38
20	5	8	CND	CND	34
21	4	11	I	I	48
22	4	7	CND	CND	28
23	3	2	CND	CND	28
24	3	19	I	I	42
25	10	5	I	I	36
26	4	5	I	I	40
27	3	13	CND	CND	31

I: incomplete; CND: complete non-displaced; CD: complete displaced; NI: not interpretable. For patient no. 9; the duration of immobilization corresponds to 6 days of cast treatment + 28 days of postoperative immobilization. For patient no. 19; the duration of immobilization corresponds to 10 days of cast treatment + 28 days of postoperative immobilization.

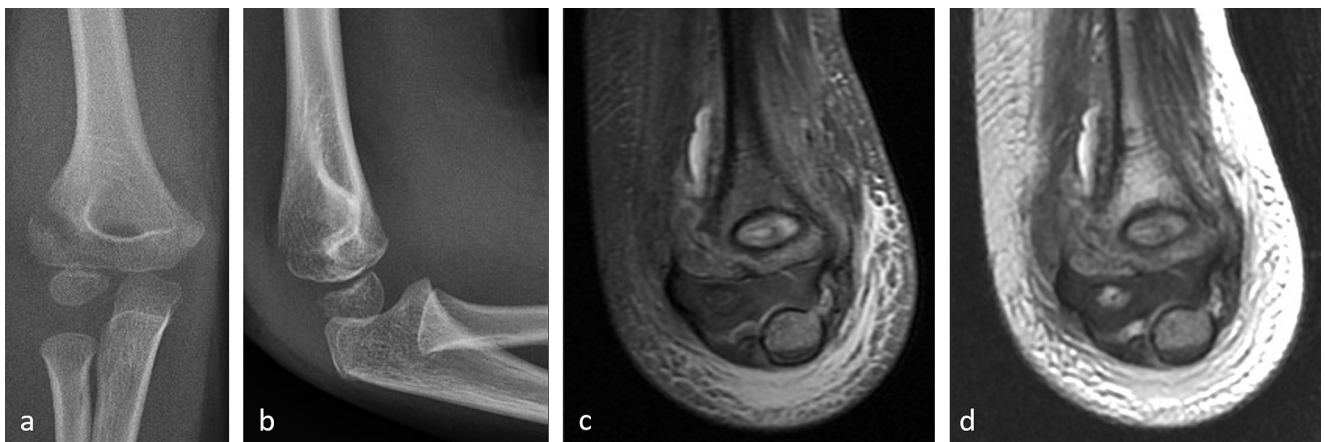


Fig. 1. Patient no. 6 – Standard radiographs (a, b). MRI PD FatSat (c) and T2-weighted (d) sequences showed an incomplete fracture line that stops in the epiphysis.

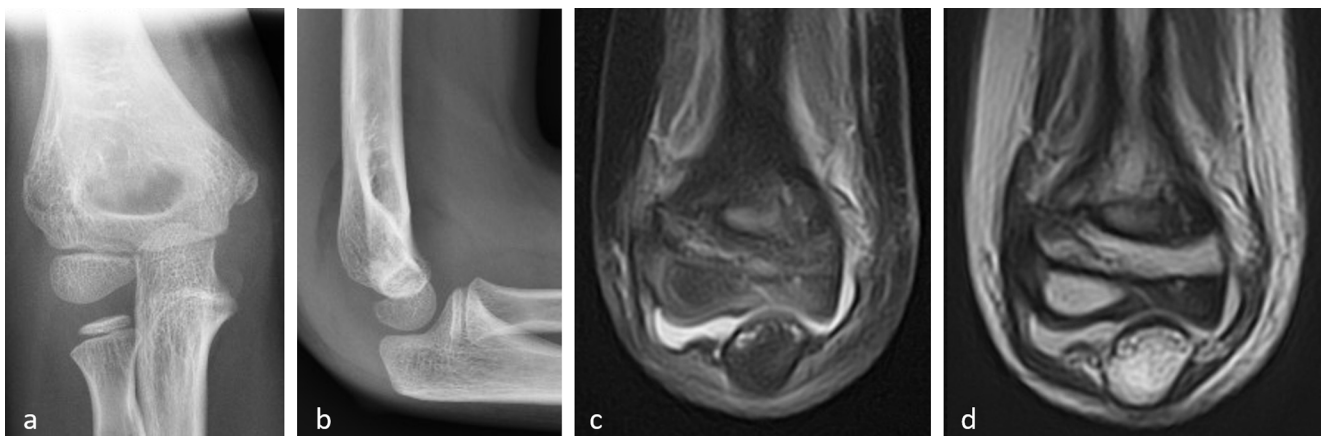


Fig. 2. Patient no. 11 – Standard radiographs (a, b). MRI PD FatSat (c) and T2-weighted (d) sequences showed a complete but non-displaced fracture.



Fig. 3. Patient no. 19 – Standard radiographs (a, b), MRI PD FatSat (c) and T2-weighted (d) sequences showed a complete displaced fracture.

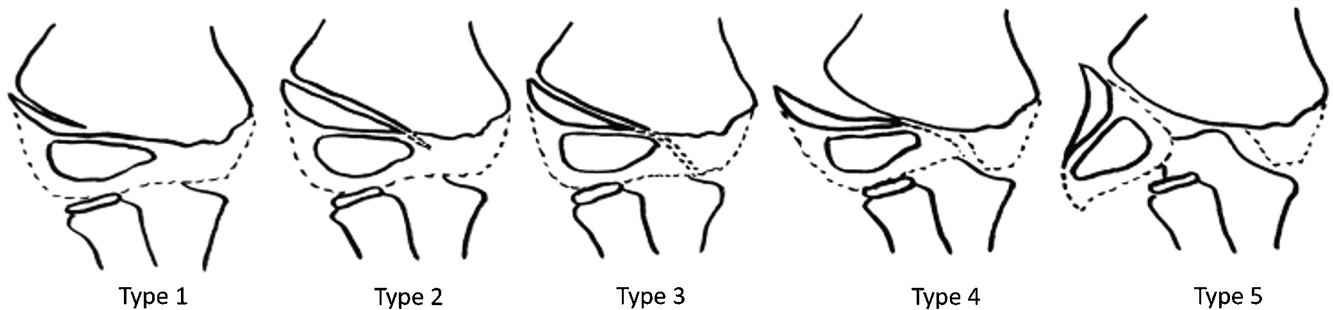


Fig. 4. Song classification of the displacement and fracture pattern for lateral humeral condyle fractures (based on Song et al. [17]).

the challenges associated with interpreting radiographs of a casted limb.

Haillotte et al. [14] present a treatment algorithm in which they propose that an MRI be done on an emergency basis for all non-displaced fractures of the lateral humeral condyle in children. If the fracture is complete but non-displaced, a second MRI must be done 6 to 8 days later to determine whether secondary displacement has occurred. It has been reported that secondary displacement occurs within the first 5 days after the fracture [2,5]. Given the difficulty of doing a MRI on an emergency basis, we feel it is appropriate to cast all fractures that are not displaced on the initial radiographs and to perform the MRI 7 to 10 days later. If secondary displacement is discovered at this point, it could be that it was displaced initially but missed on the radiographs or that true secondary displacement occurred in an initially non-displaced fracture. In either case, the fracture can be surgically reduced and fixed easily at this point in time.

5. Conclusion

MRI makes it possible to accurately evaluate the location of the fracture line in the epiphyseal and articular cartilage of children with lateral humeral condyle fractures. In fractures that appear non-displaced on radiographs, we recommend performing an MRI 7 to 10 days after a cast has been applied. By using a standardized MRI protocol to reduce the duration of the exam, MRI is feasible, even in the youngest patients.

Disclosure of interest

The authors declare that they have no competing interest.

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