Use of MRI assisting the diagnosis of pediatric medial condyle fractures of the distal humerus
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The aim of this study was to describe the radiographic appearance and to evaluate the elbow function with the Mayo elbow performance score (MEPS) in children with medial condyle fracture of the distal humerus (MCFH) who were treated surgically. During the period of 2011–2017, a total of 10 patients (three boys, seven girls) were retrospectively reviewed after obtaining institutional review board approval. All patients underwent open reduction and percutaneous pinning fixation. The average age at the time of injury was 7.7 years (range: 4.0–12.5 years), and the mean follow up was 43.9 months (range: 8.1–67.1 months). The clinical and radiographic outcomes of medial condyle fracture were retrospectively evaluated. Among 10 patients, half were diagnosed with MCFH initially by the radiograph, four out of 10 patients had their diagnosis confirmed with the aid of MRI, and an intraoperative diagnosis was made in only one individual. The average humeral-ulnar angles of the injured and noninjured sides were 9.7°±5.3° and 9.3°±4.7°, respectively (P=0.679). The average MEPSs of the injured and noninjured sides were 95.5±2.8 and 96.5±2.4 points, respectively (P=0.168). In this retrospectively evaluated cohort submitted to surgical management of medial condyle fracture of the distal humerus, MRI has been proven beneficial assisting the diagnosis and allowing effective joint restoration with mid-term good functional outcome. J Pediatr Orthop B 29:445–451 Copyright © 2019 The Author(s). Published by Wolters Kluwer Health, Inc.

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Introduction
Medial condyle fracture of the humerus (MCFH) is the most rare type of elbow injury in children, and MCFH contributes to less than 1% of elbow injuries and 4% of distal humeral epiphyseal injuries [1,2]. Due to the low incidence of MCFH, delayed diagnosis or misdiagnosis commonly occurs; thus, previous studies regarding this type of fracture have mostly been published by cases [3,4]. Additionally, similar to the lateral condyle fracture of the humerus, MCFH also requires anatomical reduction because of compromise to the articular surface and epiphysis. Delayed treatment can result in serious consequences such as osteonecrosis and cubitus varus [5–7].

Recently, it has not been difficult to make an accurate diagnosis of MCFH due to the growing application of MRI and arthrograms. This study seeks to obtain data on MCFH that will help clarify the radiographic features associated with the gradual emergence of ossification of the distal humerus epiphysis and treatment outcomes.

Patients and methods
Well written informed consent was obtained from all the patients enrolled in the study, and Ethical Committee approval was obtained. From January 2011 to July 2017, inpatients with elbow injuries were retrospectively reviewed. Of the 10 patients (three boys and seven girls, 10 elbows) who were identified as being diagnosed with MCFH, 0.52% (10/1931) had distal humeral fractures, and 1.85% (10/540) had distal humeral epiphyseal injuries (Table 1). The injury was associated with the left side in five patients and with the right side in the other five patients; patients were injured at an average age of 7.7 years (4.0–12.5 years). Patients received correct diagnosis and treatment after a mean time of 13.5 days (1–79 days), and two of the 10 patients were diagnosed and treated over 2 weeks after injury. Moreover, ectopic callus around the medial condyle was noted in two patients at 23 and 79 days (patients 9 and 10) after injury, respectively. With regard to the injury mechanism, all injuries were caused by falling while walking or playing.

Open reduction and Kirschner wire (K-wire) fixation were performed under general anesthesia, including two patients with delayed presentation. Following 4 or 5 weeks with cast immobilization, K-wires were removed in the clinic.

Radiographic assessment
All patients had plain radiographs taken after injury. Moreover, positive plain radiographs were demonstrated in eight patients (patients 1–7, and 10 in Table 1). Five of these eight patients were correctly diagnosed with...
MCFH directly by radiograph (patients 2–6). In addition, one patient was misdiagnosed with humeral medial epicondyle fracture initially but without further MRI examination, eventually the diagnosis was corrected because it was determined that the fracture line extended to the trochlear cartilage during the operation (patient 1) (Fig. 1); two patients with visible small medial metaphyseal spikes were diagnosed by additional MRI examinations (patients 7 and 10) (Fig. 2). MRI was likewise performed for the remaining two patients with negative plain radiographs but with swelling on the medial aspect of the elbow (patients 8 and 9) (Fig. 3). Referred to the Salter-Harris classification, eight out of 10 patients were type IV; the two remaining patients were type III, and their plain radiographs were negative due to the fact that the medial epicondyle epiphysis and trochlear epiphysis were still absent. According to the Kilfoyle classification [8], two patients were type II and eight were type III (Table 1).

At the last follow-up visit, all patients underwent anteroposterior (AP) and lateral radiographs of the injured and of the uninjured elbows; the humeral-ulnar angle (AP view; angle between the axis of the humerus and the axis of the ulna) was measured bilaterally in all patients. In the meantime, the morphology and development of the medial condyle and the trochlea were assessed.

**Functional assessment**

With reference to Kalem’s method [9], patients in our study were all asked to complete the Mayo elbow performance score (MEPS) in the clinic. The MEPS was developed by Morrey and Adams [10], and it was characterized by a scale consisting of four components, corresponding to different symptoms experienced by the patient (pain: 45 points; daily function: 25 points), and to clinical signs measured by the examiner (arc of motion: 20 points; stability: 10 points). The overall MEPS ranges from 0 (most severe functional compromise) to 100 points (normal function). Elbow function is defined as excellent, if the final score is 90 or higher; as good, if the score ranges between 75 and 89; as fair, if the score is between 60 and 74; or as poor, if the score is lower than 60.

**Statistical analysis**

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) software, Version 17 (IBM Corp., New York, USA). The paired sample Student’s t-test was performed to assess parameters such as the humeral-ulnar angle and MEPS at the time of follow-up. The threshold for significance was set at $P < 0.05$.

**Results**

Nonaccidental injury was ruled out in all patients. The mean follow-up was 43.9 months (range: 8.1–67.1 months). At the last follow-up visit, the humeral-ulnar angle of the injured elbow was $9.7^\circ \pm 5.3^\circ$ and that of the uninjured side was $9.3^\circ \pm 4.7^\circ$ ($P=0.679$); excellent

### Table 1  Demographic information of patients with medial condyle fracture of humerus

| Gender | Age (years) | Time from trauma to surgery (days) | Affected side | Salter-Harris classification | Kilfoyle classification | Follow-up (months) | Humeral-ulnar angle | MEPS |
|--------|-------------|-----------------------------------|---------------|------------------------------|------------------------|-------------------|-------------------|-------|
| Girl   | 8.9         | 2                                 | Right         | IV                           | III                    | 66.5              | 6.9               | 95.5  |
|       | 9.1         | 1                                 | Left          | IV                           | III                    | 42.7              | 10.5              | 95.5  |
|       | 11.7        | 2                                 | Left          | IV                           | III                    | 45.9              | 9.2               | 95.5  |
|       | 6.8         | 7                                 | Right         | IV                           | III                    | 44.9              | 6.9               | 95.5  |
| Boy    | 6.8         | 7                                 | Left          | IV                           | III                    | 45.6              | 8.1               | 95.5  |
|       | 5.6         | 12                                | Right         | III                          | III                    | 35.6              | 9.9               | 95.5  |
| Girl   | 8.7         | 4                                 | Right         | IV                           | III                    | 35.6              | 10.9              | 95.5  |
|       | 5.3         | 4                                 | Left          | IV                           | III                    | 45.6              | 10.9              | 95.5  |
| Girl   | 12.5        | 1                                 | Left          | IV                           | III                    | 45.9              | 10.9              | 95.5  |
|       | 1.7         | 4                                 | Left          | IV                           | III                    | 45.9              | 10.9              | 95.5  |

MEPS, Mayo elbow performance score.

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function was noted on the affected elbow of all patients; the average MEPSs of the injured and non-injured sides were 95.5 ± 2.8 and 96.5 ± 2.4, respectively ($P = 0.168$).

In patient 10, who underwent surgery at 79 days after trauma, had a normal elbow flexion range but a 20° loss of extension.

No instances of infection, redisplacement, osteonecrosis or nonunion were discovered during the last follow-up.

**Discussion**

Medial condyle fracture of the humerus is the rarest type of elbow injury in children, and this type of fracture was first mentioned by Desault in the 18th century. Due to the low incidence of this type of fracture, Ingersoll [11] once doubted its existence in 1965. In our research covering a 7-year interval, we found that MCFH contributed to 0.52% of distal humeral fractures and 1.85% of distal humeral epiphyseal injuries, respectively, which are similar to those of previous studies [1,2].

Hence, delayed diagnosis or misdiagnosis commonly exists [3,4,12,13]. Delayed diagnosis was observed in two patients of our group; formation of a medial condylar ectopic callus was found 23 and 79 days after the injury, respectively. Despite this delayed diagnosis, both patients eventually received open reduction and K-wire fixation, considering that the fracture segment was immersed in the articular fluid rather than healing in a similar manner to a missed lateral condyle fracture. On the other hand, MCFH can be encountered in children of any age. The youngest patient in the published study was 6 months old [14]; the younger the patients, the more likely the fracture is to be misdiagnosed because secondary ossification around the elbow develops gradually. Similar, the two patients with delayed diagnosed in our series had the youngest ages of 4 and 4.8 years.

![An 8.9-year-old girl (patient 1) with Salter-Harris type IV right medial condyle fracture of the distal humerus. Initially, she was misdiagnosed with medial epicondyle fracture (a), due to the displacement of the metaphyseal fracture segment (white arrow). After open reduction and percutaneous pinning fixation was undertaken (b), the healing of the fracture was confirmed by follow-up radiographs (c) and (d).](image-url)
Age before medial epicondylar ossification

Generally, medial epicondylar secondary ossification appears at the age of approximately 6 years, while secondary ossification of the trochlea appears at approximately 9 years [15]. The diagnosis of MCFH before medial epicondylar ossification (at ages younger than 6 years) is very challenging. MCFH has always been known as having a mirror relationship to the lateral condyle fracture; thus, MCFH is believed to be Salter-Harris type IV because the fracture line passes through the medial condylar metaphysis and the trochlea. Interestingly, Salter-Harris type III MCFH was found in our study, and this type was never reported or characterized by a fracture line extending from the epicondylar physis to the trochlea without involvement of the metaphysis (Fig. 3).

Once the medial metaphysis is involved, radiography can demonstrate a high-density shadow near the elbow joint (Fig. 2); usually, this finding is more likely to be misdiagnosed as medial epicondyle fracture. Comparing this radiograph to a plain radiograph of the contralateral side can help us to decide whether the high-density shadow is representative of medial epicondylar secondary ossification center or the metaphyseal fracture. Additionally, further examination, such as sonograph, arthrogram and MRI, can be performed to identify this cartilaginous injury. We preferred MRI because it provides excellent multi-planar images. Nonetheless, the high cost of MRI and the need for sedation of noncooperative young children are the main reasons that this approach is not widely applied. In our research, three out of 10 patients underwent MRI with sedation. Therefore, patients with suspected medial elbow injury during this age period, with negative radiography, but tenderness and swelling of soft tissue or with a medial high-density shadow are in particular need of additional examinations, such as arthrography, and radiograph imaging of the contralateral elbow, to exclude MCFH.

Age between medial epicondylar ossification and trochlear ossification

The radiographic feature of the distal humerus at this age is the appearance of the medial epicondylar epiphysis but
the lack of appearance of the trochlear epiphysis. MCFH at this age (from age 6 to 9) is characterized by the displacement of the medial epicondyle on radiograph imaging, which also easily leads to the misdiagnosis of medial epicondyle fracture. In McGarey’s report, a 7-year-old girl was initially diagnosed with medial epicondyle fracture, but the diagnosis was ultimately corrected to MCFH due to the arthrogram findings of trochlear fracture involvement [16]. Furthermore, a similar case of an 8.5-year-old boy was noted by Fahey and O’Brien [17]. In our study, MCFH was also ultimately confirmed during the operation of an 8.8-year-old girl (patient 1).

To differentiate these injuries, Harrison et al. [18] developed a radiograph method. This group thought that MCHF was an intra-articular fracture, but that medial epicondyle fracture was an extra-articular fracture; therefore, MCFH was highly suspected when a positive fat pad sign was observed on the initial radiograph with a diagnosis of medial epicondyle fracture. Nevertheless, sometimes the fat pad sign was positive when the articular capsule was torn due to medial epicondyle fracture; thus, Harrison et al.’s method was unreliable.

Considering the completely different treatment regimens administered for MCFH and medial epicondyle fracture, MRI examination is beneficial to patients of this age diagnosed initially with medial epicondyle fracture. Otherwise, an arthrogram provides another choice for determining the existence of a trochlear fracture.

Age after trochlear ossification
At this age (usually more than 9 years old), MCFH is not easily to be missed or misdiagnosed when trochlear and medial epicondylar secondary ossification center are both clearly indicated (patients 3, 4 and 6) (Fig. 4).

The Kilfoyle classification (grades I to III) is related to the stage of displacement, which is beneficial for treatment.
Grade I (incomplete fracture) was not observed in our series, two patients were grade II (complete fracture but less than 2 mm displacement), and eight patients was grade III (complete fracture with angulation and rotation) [8].

Most studies support conservative treatment for Kilfoyle grade I and II fractures, while grade III requires open reduction and internal fixation [1,2,5,13]. We agree with these previous studies on this point, but we still aggressively favor open reduction concerning complications such as secondary displacement. Fortunately, two patients with Kilfoyle grade II underwent open reduction and fixation in our study, and both had a good outcome. Alternatively, close follow-up (at least once a week) with conservative treatment should be given to patients with grade II. Therefore, a good outcome can be obtained if accurate diagnosis occurs and if anatomical reduction is performed in a timely manner. Only one patient in our group had a delayed diagnosis after 79 days. At the final follow-up, there was a 20° loss of extension in the injured elbow. If the diagnosis of MCFH is delayed for a long period of time, nonunion, fishtail deformities and even worse complications such as progressive cubitus varus are inevitable [19,20].

In summary, medial condyle fracture of the distal humerus is the rarest type of elbow injury in children, which easily results in misdiagnosis because of the gradual emergence of ossification of the distal humeral epiphysis. In this retrospectively evaluated cohort submitted to surgical management of medial condyle fracture of the
distal humerus, MRI has been proven beneficial assisting the diagnosis and allowing effective joint restoration with (mid-term) good functional outcomes, especially when the trochlear and medial epicondylar epiphyses do not appear on the radiography but swelling of the soft tissue around the elbow joint is revealed at the age of 9 years or younger.

Acknowledgements
Conflicts of interest
There are no conflicts of interest.

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