Humeral lateral condyle fractures in children: redefining the criteria for displacement

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The aim of this study is to define paediatric lateral humeral condyle fractures prone to later displacement. The authors reviewed 106 children who were treated surgically for this fracture. There were 74 boys and 32 girls with an age range of 3–10 years. The study included 27 minimally displaced and 79 displaced fractures. The average follow-up was 50 months. Binary logistic regression model indicated that 6–8-year-old children with minimally displaced fractures and who underwent immediate surgery have a better chance for satisfactory results. The authors concluded that routine use of 2 mm displacement for treatment decisions should be changed to avoid delayed surgery. ***J Pediatr Orthop B*** **25:429–433**

Journal of Pediatric Orthopaedics B 2016, **25**:429–433

Keywords: children, condyle, humerus, lateral

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Introduction

Humeral lateral condyle fractures (LCF) account for 10–20% of all childhood elbow fractures, and yet, their diagnosis and treatment remain challenging [1–5]. Although the Milch classification for LCFs that is based on the location of the fracture line through the epiphysis of the distal humerus [6] is the most commonly cited classification system, it has not been shown to be predictive of outcome or suggestive for the recommended treatment method [2].

Depending on the degree of displacement, different treatment modalities have been described [1,7,8]. Although there is consensus that the treatment of displaced fractures is closed or open reduction and internal fixation [9–11], the treatment of nondisplaced or minimally displaced fractures remains controversial. Although nonoperative treatment has been proposed, these latter fractures are not predictable and may displace further, leading to complications [1,2,5]. Moreover, delayed surgery with attempts to mobilize the fragment by stripping soft tissues have often led to avascular necrosis [12]. The risk for subsequent displacement of these fractures has been reported to be 11–42%. Therefore, some investigators have recommended closed reduction with percutaneous pinning for minimally displaced fractures [3–5,7,13].

Jakob *et al.* [14] described two types of nondisplaced fractures of LCF in children. The first type is a complete fracture that extends all the way through the epiphysis into the joint. This fracture is at risk for subsequent displacement because of the pull of the extensor muscles on the fragment. The second type is an incomplete fracture with a cartilaginous bridge that prevents later displacement. Many attempts have been made to establish methods for the primary differentiation of these two fracture types [5,10]. Arthrography, MRI, and ultrasonography are frequently used; however, these procedures are either invasive or expensive [3,13,15,16].

The aim of this study is to determine the factors affecting the outcome after surgical treatment of LCFs in children and to identify the rule of the plain radiographs to predict possible subsequent displacements to avoid delayed surgery.

Materials and methods

After obtaining approval from the ethical committee at our institution, the authors reviewed retrospectively the charts and radiographs of all children who were treated surgically for LCF at our institution between January 2004 and January 2010. We included only those patients who had complete information documented in their charts, full and informative radiographic examinations and who completed at least 4 years of follow-up after definitive treatment. Patients who had an associated injury of the same limb or were known to have neuromuscular disorders affecting rehabilitation and/or altering the final assessment were excluded.

The diagnosis of LCF was made on the basis of a radiographic examination and then classified according to the maximum amount of displacement in any view. The

DOI: 10.1097/BPB.0000000000000306

classification system of our institution's clinical practice pathway for paediatric LCF was used to classify all fractures, in which hairline fracture is considered nondisplaced, a fracture gap of up to 2 mm is considered minimally displaced and greater than 2 mm is considered displaced fracture [3,17]. The authors used the same classification system in their blind review and reassessment of all patients' radiographs.

In our institution, children with nondisplaced and minimally displaced fractures were managed nonoperatively and reassessed at the first fracture clinic visit for possible subsequent displacement. Children with later displacement were subsequently treated by delayed surgery. Children with displaced fractures were treated by primary surgical fixation. Closed reduction and percutaneous pinning could be achieved in some cases where the condylar fragment was not widely separated or rotated. Otherwise, open reduction and pinning was the treatment provided in most cases. Wires were left outside the skin to be removed in the clinic after fracture healing was achieved. A long arm back slab cast was used for all patients for 4–6 weeks depending on the confidence of fracture union. Removal of wires was performed along with discontinuation of cast immobilization.

All patients were then monitored until they showed solid radiographic healing, regained their motion, became asymptomatic and had no residual problems. Patients with residual complications were managed accordingly, but this issue was not addressed in this report because it is beyond the scope of the present study. At the last follow-up visit, each patient was evaluated clinically and radiologically. The outcome for each patient was graded according to the Cardona *et al.* [4]. modification of the Hardacre functional rating system by including radiographic criteria to assess the healing of the fracture (Table 1).

SPSS software, version 17 (SPSS Inc., Chicago, Illinois, USA) was used for data entry and analysis. The data were presented as percentages. The χ^2-test was used to compare demographic and clinical variables, and for crude analysis of the association between the studied variables and the outcome. All analyses were carried out at a significance level of 0.05.

Results

One hundred and six children fulfilled our inclusion criteria and were enrolled in the present study. This study included 74 boys (69.8%) and 32 girls. Their ages at the time of fractures ranged from 3 to 10 years (average, 5.8 ± 2.069). The patients were divided into three groups according to their ages: the first group was 3–5 years old (51 patients, 48.1%), the second group was 6–8 years old (42 patients, 39.6%) and the third group was 9–10 years old (13 patients, 12.3%). Fracture of the right elbow occurred in 42 patients (39.6%) and fractures of the left elbow occurred in 64 patients.

The initial plain radiographic assessment for treatment decision-making resulted in the diagnosis of 27 minimally displaced fractures, which showed further displacement during follow-up (25.5%), and 79 displaced fractures (74.5%). All displaced fractures were treated primarily by surgical fixation within 24 h after injury. However, all minimally displaced fractures in the present study were treated by delayed surgery within 7–13 days after injury. The authors' assessments upon blinded review of all patients' radiographs were compared with the initial assessments (Table 2). Statistical analysis showed a significant association between both assessments ($P < 0.001$), and between minimally displaced fractures and the time lag from injury to surgery ($P < 0.001$). There were no significant interobserver or intraobserver differences among authors' assessments.

The internal oblique radiographic view was obtained as a part of the initial assessment methods in 92 patients (86.8%) and of these patients, 65 were diagnosed with displaced fractures and 27 were diagnosed with minimally displaced fractures. The internal oblique radiographic view showed the maximum displacements in all these 92 patients according to authors' assessment.

Table 3 shows the distribution of the surgical procedures and the methods of fixation according to different age groups. There was a significant association between open reduction and older age group ($P = 0.046$). Assessment during surgery indicated displacement alone in 38 patients (35.8%). However, displacement and rotation were identified in 68 patients (64.2%). Rotation of the condylar fragment showed a significant association with patients who had displaced fractures ($P = 0.027$) and those who were treated by open reduction ($P < 0.001$).

The mean cast time for all patients was 5 weeks $\pm$ 0.75 (range, 4–6) and their average follow-up period was 50 months $\pm$ 3.2 (range, 48–61). During follow-up, nine children showed superficial infection at the site of wire

Table 1 Assessment of the results of the study by Cardona and colleagues

	Clinical and radiological assessment
Excellent	No loss of motion, normal carrying angle, the patient is asymptomatic and radiographs indicated a healed fracture
Good	An extension loss of no more than 15°, mild alteration of the carrying angle and radiographs indicated a healed fracture
Poor	Significant and disabling loss of motion, a conspicuous alteration of the carrying angle, ulnar neuritis or radiographic findings of nonunion or avascular necrosis.

Modification of the functional rating system by Hardacre and colleagues.

Table 2 Agreement between the initial assessments and authors' assessments

Initial assessment	Authors' assessment Minimally displaced	Displaced
Minimally displaced ($N=27$)	23	4
Displaced ($N=79$)	0	79
Total ($N=106$) [n (%)]	23 (21.7)	83 (78.3)

Table 3 Distribution of surgical procedures and methods of fixation according to different age groups

	Surgical procedure and method of fixation			
Age group in years	Closed reduction 2K-wires	Open reduction 2K-wires	Open reduction 3K-wires	Total
3–5	5	42	4	51
6–8	10	21	11	42
9–10	0	8	5	13
Total	15	71	20	106

entry, which resolved easily by local wound care only. Twenty-nine children underwent a rehabilitation programme to improve the range of motion of the injured elbow. Seven of them required an extended period of intensive physiotherapy because of persistent elbow stiffness. Thirteen patients had 16 major complications that could affect the final outcome; of these, 11 patients had poor results. Overgrowth of the lateral condyle occurred in six patients, cubitus varus occurred in five patients, avascular necrosis occurred in three patients and nonunion occurred in two patients. Older children were significantly more likely to have complications ($P=0.003$). Table 4 shows the distribution of the final results according to initial assessments of the fractures. The final results showed a significant association with the initial assessments and the time lag from injury to surgical treatment ($P=0.001$).

The crude analysis was repeated between all variables and the final outcome after recoding the results as binary variables (satisfactory and unsatisfactory) by merging the excellent and good results. Three variables, specifically age of the patients, initial assessment and time lag from injury to surgery, were significantly associated with the final outcome by crude analysis ($P=0.041$, $P<0.001$ and $P<0.001$, respectively). Significant associations in the crude analysis were used in a binary logistic regression model to determine the independent factors associated with satisfactory results and to calculate the adjusted odds ratio and its 95% confidence level (Table 5). However, because of the colinearity between the initial assessment and the time from injury to surgery, we included both variables in the final model as an interaction term. The final model showed that children in the 6–8 years age group with minimally displaced fractures and had undergone immediate surgical treatment were likely to achieve satisfactory results.

Table 4 Distribution of the final results according to the initial assessments

	Final result			
Initial fractures' assessments	Excellent	Good	Poor	Total
Minimally displaced	14	5	8	27
Displaced	61	15	3	79
Total [n (%)]	75 (70.7)	20 (18.9)	11 (10.4)	106

Sensitivities and specificities of the authors' radiographic readings of fracture displacement for cases with delayed surgery were used to plot a receiver operating characteristics (ROC) curve to determine a cutoff point with the optimal sensitivity and specificity (Fig. 1). The resulting ROC curve had an area under the curve of 0.75 and 0.79 for different authors. The area under the curve corresponded to a good ability of the diagnostic test (radiographic displacement measurement) to correctly identify satisfactory and unsatisfactory results. The coordinate points of the ROC curves were recorded and the point with the highest specificity was selected. This point represents the most reliable performance to effectively differentiate between satisfactory and unsatisfactory outcomes. The cutoff point for authors' readings in the ROC curve was 1.6 mm, which indicates that having a fracture displacement greater than 1.6 mm will increase the likelihood of achieving unsatisfactory results if surgery is delayed.

Discussion

The results of the present study highlight the significance of the initial assessment in deciding the optimal treatment of paediatric LCF. Most of the poor results reported were because of inaccurate initial evaluation and thus inadequate management [1,18].

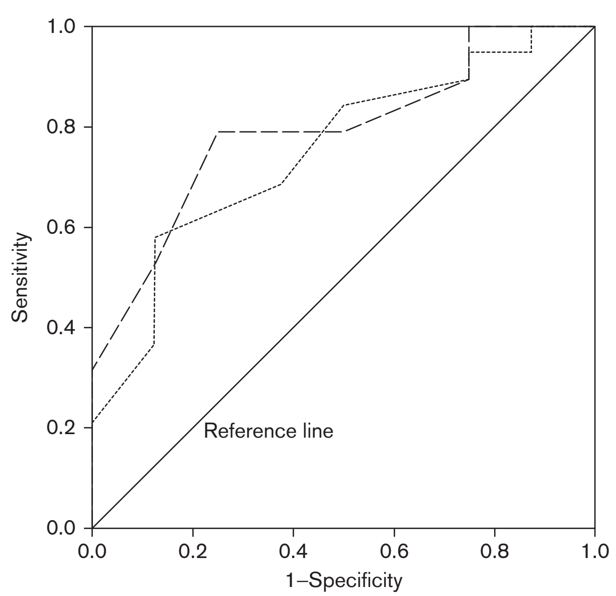
The classification systems for LCFs in children are numerous. Nevertheless, most of them do not recommend treatment or predict the outcome [2,8,10,19,20]. Song *et al.* [11] designed a comprehensive classification system that is linked to a treatment algorithm; however, it appears somewhat complicated for use in emergency situations. Another major quandary emerged in terms of the treatment of LCF in children is the subsequent displacement of minimally displaced fractures that is detected at the first visit after cast immobilization. The reported incidence of later displacement ranges up to 11.7% [3,7]. Many authors have discussed the cartilaginous hinge, which provides stability and prevents subsequent displacement. However, most of them were in fact advocating an imaging modality to detect the stabilizing cartilaginous hinge [13,15,16]. Nonetheless, subsequent displacement is still noted even in the presence of this cartilaginous hinge [10]. Later displacement occurs 3–5 days after cast treatment in most reports [3,16]. This potential occurrence leads to a dilemma of whether to pin all questionable fractures or to monitor for

Table 5 **Binary logistic regression analysis**

							95% CI for exp(*B*)	
	B	SE	Wald	*d.f.*	Significance	Exp(*B*)	Lower	Upper
All age groups			8.222	2	0.016			
Age group (6–8 years)[a]	1.863	0.936	3.965	1	0.046	6.443	1.030	40.314
Age group (9–10 years)[a]	4.018	1.433	7.866	1	0.005	55.570	3.353	920.905
Initial assessment by time from injury to surgery	1.804	0.559	10.392	1	0.001	6.071	2.028	18.177
Constant	−5.561	1.277	18.965	1	0.000	0.004		

CI, confidence interval.
[a]The age group of 3–5 years was used as a reference group.

Fig. 1



Receiver operating characteristics (ROC) curves of different authors' readings to determine the cutoff point with optimal sensitivity and specificity.

the occurrence of subsequent displacement. However, the first option may lead to unnecessary surgery in some children, whereas the second option requires strict compliance of the patient and family or leads to inadequate treatment and consequent poor outcome [5,18].

Standard anteroposterior and lateral elbow radiographs for LCFs in children are not always sufficient to identify actual displacement or to determine fracture stability. The importance of the internal oblique radiograph to show the maximum displacement has been well established [1,4,11,17,21] and is supported by our results. Many previous studies have suggested stress radiography, magnetic resonance imaging, arthrography and ultrasonography as additional tools to evaluate fracture stability and to differentiate between complete and incomplete fractures. However, each modality has its inherent drawbacks and, as might be predicted, the advocates for each modality have criticized the use of the other modalities [3–5,11,13,15,16].

Many fractures that were treated with open reduction and internal fixation could be reduced by closed means [11,14]. However, most closed reduction attempts for displaced and rotated fractures were not successful and were converted to an open reduction [4,10]. Launay *et al.* [10] found that the use of three K-wires resulted in more loss of motion and a higher incidence of lateral spur formation than did the use of two K-wires. We did not observe any influence of the method of reduction or the type of fixation on the final outcome. However, it is essential to avoid attempting repeated closed reduction, which might be time consuming. In addition, we agree with Wattenbarger *et al.* [12] that anatomic reduction is not always possible in delayed surgery and that fragments should be fixed in a position that provides the best motion and the most normal alignment of the arm.

The results of the present study are not in agreement with the hypothesis stating that minimally displaced fractures with up to 2 mm gap could be simply managed conservatively under close supervision [1,3,7,10]. Twenty-seven patients in our study had minimally displaced fractures and showed later displacement during follow-up, and of these, eight children (29.6%) showed a poor outcome. During the retrospective evaluation of all cases with delayed surgery, the authors observed that the lowest reading for initial displacement showing subsequent migration was 1.3 mm. However, some of the cases that showed subsequent displacement and were treated by delayed surgery achieved satisfactory results. According to the ROC curve, a fracture displacement greater than 1.6 mm increases the likelihood of achieving unsatisfactory results if surgery is delayed. Apparently, there is a cutoff point of initial fracture displacement below which subsequent displacement is unlikely to occur. In addition, there is a higher cutoff point of displacement below which later displacement may occur; however, the outcome will be satisfactory even with delayed surgery. Identification of these plain radiographic points will help differentiate potentially unstable minimally displaced fractures without the use of other invasive imaging modalities. This fracture category will be treated as displaced fractures by an immediate surgical intervention, eventually increasing the likelihood of satisfactory results.

The present study included only patients with LCFs who were treated surgically; thus, the cutoff point for deciding the treatment modality remains to be determined in further studies that should also include fractures treated nonoperatively. Knutsen *et al.* [21] reported that true fracture displacement measurements were significantly larger than apparent radiographic displacements. Therefore, any future study should also analyse the sensitivity of the radiographic measurements in detecting real displacements. Minimally displaced LCFs should be monitored carefully for subsequent displacement until the safe cutoff displacement point could be identified by future studies.

Conclusion

A careful initial assessment using the internal oblique view in addition to standard views is crucial for deciding early and adequate treatment of LCFs in children. To avoid delayed surgery because of subsequent displacements, the classic use of 2 mm initial displacement for deciding surgical treatment must be changed.

Acknowledgements

The study was financially supported by King Saud University through Vice Deanship of Research Chairs, Orthopedic Surgery Research Chair. The authors thank Abdelrahman M. M. Zamzam (MSc) for his great help in statistical analysis of the data.

Conflicts of interest

There are no conflicts of interest.

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