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The safety and efficacy of closed reduction and percutaneous pinning with an intraoperative arthrogram for Grade 2 and Grade 3 pediatric lateral condyle fractures

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ABSTRACT

Objectives: It is controversial whether pediatric lateral humeral condyle fractures (LHCFs) with >2 mm displacement can be managed using closed reduction and percutaneous pinning (CRPP) as opposed to open reduction. This study assesses the clinical, radiographic outcomes, and complication rates of patients undergoing arthrogram-assisted CRPP for fractures with >2 mm of displacement rather than open reduction and internal fixation.

Methods: This study was conducted retrospectively, looking at all children presenting acutely with LHCFs that were displaced >2 mm between January 2017 and December 2019 whom one surgeon treated within 48 hours of the initial injury. Sixteen patients met the inclusion criteria. Pre-operative and post-operative anteroposterior as well as lateral radiographs were used to measure displacement and classify fractures. A subgroup analysis was done to compare the results in Grade 2 and 3 fractures as per Weiss classification.

Results: Signs of union were observed in all patients at 2 weeks and all fractures were healing well at 6-week follow-up, regardless of fracture grade or displacement. Post-operative complications including pin site infections, valgus deformity, non-union, or malunion were not seen. A higher proportion of Grade 3 patients developed heterotrophic ossification and limitation of range of movement.

Conclusion: Arthrogram imaging is a valuable tool to help visualize the articular cartilage surface and determine the suitability of CRPP for LHCF with >2 mm displacement. It is a safe option with good outcomes and provided that there is no significant articular cartilage incongruity seen under fluoroscopy.

Keywords: Arthrogram, Closed reduction, Humeral fracture, Lateral condyle, Pediatric, Percutaneous pinning

INTRODUCTION

Lateral humeral condyle fractures (LHCFs) are the second most common pediatric elbow fractures representing 10–20% of all elbow injuries in children.[1] Accurate patient assessment

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and diagnosis are crucial for optimal management.[2] Management guidelines are largely dependent on the grade of displacement and fracture stability. Fractures displaced >2 mm should be managed operatively to avoid complications such as non-union and avascular necrosis (AVN), leading to undesirable deformities and functional impairment.[3] On the other hand, non-operative management of minimally displaced fractures remains controversial.[4,5]

Operative management can be through open reduction and internal fixation (ORIF) or closed reduction and percutaneous pinning (CRPP). ORIF is associated with a greater risk of complications such as AVN and hypertrophic ossification, making CRPP a safer alternative, albeit a less stable one.[6,7] In fractures displaced >2 mm, ORIF is generally preferred. However, in fractures with 2 mm displacement or less, the decision remains unclear. CRPP is more commonly used for minimally displaced fractures with intact articular cartilage congruency.[8] Some surgeons have shown that CRPP can be performed safely even when displacement is >2 mm, provided that there is no significant articular incongruity.[9,10] However, this procedure demands a greater skillset and surgical expertise.

Articular cartilage integrity is the main determinant of the stability of the LHCF and the surgical pathway taken.[11] Measuring the degree of intra-articular displacement can be difficult due to the cartilaginous nature of the capitulum in pediatric patients making it hard to visualize using plain radiography.[4] Disturbance to the articular cartilage means that the fracture is complete indicating instability and the likelihood of greater displacement.[12] Intraoperative arthrogram can be helpful in diagnosis and assessing the status of the articular cartilage and the possibility of late displacement to help assess whether CRPP can be performed or if ORIF is necessary.[13] Despite the widespread use of arthrogram, there are no clear guidelines on arthrography's indications and routine use.

Our study looked at the use of intraoperative arthrogram of the elbow in pediatric LHCF undergoing CRPP at the authors' institution. The aim was to assess the safety and efficacy of this procedure in LHCF with displacement >2 mm. We hypothesize that arthrogram use helps with surgical planning and allows for CRPP to be used even when displacement is >2 mm.

MATERIALS AND METHODS

This study was conducted retrospectively and included all pediatric patients that underwent CRPP for LHCF with >2 mm displacement from January 2017 to December 2019 who were treated under the care of one surgeon. A total of 16 patients with LHCF and displacement >2 mm were found and included in the final list. All patients presented to the hospital with pain, ecchymosis, and tenderness. Written informed consent was obtained from the legal guardians of all the patients. Pre-operative and post-operative anterior-posterior and lateral radiographs were used to measure displacement and classify fracture grade according to Weiss and colleagues' criteria.[14] Displacement was measured from the point of greatest displacement, which consistently occurred at the lateral cortex of the metaphysis of the Thurston-Holland fragment. Exclusion criteria included patients with open fractures, simultaneous extremity fractures, refractures, or secondary fractures.

Surgical technique: CRPP

All fractures were manipulated and reduced before surgery. Patients were placed in a supine position on a radiolucent table. Cases were performed under general anesthesia without the use of a tourniquet. Arthrogram was carried out just before the beginning of the operation in all 16 patients to assess articular cartilage congruency. A contrast was injected using a 22-gauge needle posteriorly through the olecranon fossa. About 1–2 ml of iohexol contrast mixed with saline (1:1 ratio). Fluoroscopy was utilized to obtain images of the joint cartilage before operative intervention. Stabilization was carried out using two or three Kirschner (K) wires. The fracture was returned into place by direct manipulation using either a K-wire or the surgeon's thumb while applying a simultaneous pressure to achieve reduction.

Post-operative care and follow-up

A long arm cast was applied in supination with a collar and cuff sling for comfort. K-wires were removed in the clinic at 6-week follow-up. Patients with a significant range of motion loss were referred for physical therapy. Patients with reasonable healing were allowed to resume normal activities gradually. Patients were followed up at 2 weeks, 6 weeks, 3 months, and 6 months to assess fracture healing, hypertrophic ossification, range of motion, and other post-operative complications, including delayed union, malunion, valgus deformity, surgical site infection, and AVN. Patients who had a Grade 2 fracture (no articular disturbance) were compared to those who had Grade 3 fractures (articular disturbance).

Statistical analysis

Categorical data, including patient characteristics and post-operative complications, were presented in the form of tables. Odds ratio calculations were done to compare the odds of certain complications in patients with Grade 3 to those with Grade 2 fractures. Mean pre- and post-operative displacement was calculated for all patients and then Grade 2 and 3 patients individually. Standard deviation and median

calculations were also done. Independent *t*-tests were done to compare mean displacements between Grade 2 and 3 fractures with a significance set at $P < 0.05$. Statistical Package for the Social Sciences (SPSS; 22nd release, IBM Corp, Armonk, NY) was used for all statistical calculations.

RESULTS

There was a total of 16 patients (four females and 12 males). The average age of participants was 4.3 for females, 5.3 for males, and 5.02 for all patients combined. Displacement was measured pre- and postoperatively along with fracture grade. Patients' characteristics are presented in [Tables 1 and 2]. The most common complications were assessed at 3 and 6 months after surgery. These include range of motion, which was categorized as full or limited and hypertrophic ossification, categorized as per Weiss *et al*. none, mild, and severe.[14]

Pre-operative and post-operative fracture displacement

The mean pre-operative and post-operative displacement in Grade 3 patients was significantly higher than in Grade 2 patients. Six of the seven Grade 2 patients had no displacement following surgery, hence, the mean displacement score of 0. Grade 3 fractures were harder to stabilize completely and most patients had some remaining displacement postoperatively.

Post-operative complications

All post-operative complications have been recorded. Regardless of fracture grade, all patients had clinical and radiographical signs of fracture healing at 6-week follow-up and good healing was seen up to 3 months with no cases of malunion or non-union. In addition, no valgus deformities or surgical site infections occurred (OR 3.82, CI = 0.155–94.1, $P = 0.411$) [Figure 1].

Hypertrophic ossification

Hypertrophic ossification was observed in both Grade 2 and 3 patients. At 3 months, the odds of developing excessive hypertrophic ossification in Grade 3 fractures were about twice as likely as in patients with Grade 2 fractures. However,

Table 1: Patient characteristics.

Patient No.	Age (years)	Gender	Pre-operative classification (Weiss *et al.*)	Pre-operative displacement (mean±SD)	Post-operative displacement mm (mean±SD)
1	5.6	M	2	3.1	0
2	5	M	2	3.2	0
3	1.9	M	3	5.3	1.5
4	8	M	3	4.2	1.4
5	4	M	3	6.7	1.5
6	2	M	2	2.5	0
7	6.25	F	3	7.5	1.9
8	10	M	3	4.5	0
9	3	F	3	5.5	1.6
10	3	F	3	4.3	1.2
11	5	M	2	3.6	0
12	4.6	M	3	4.5	0
13	5	F	3	4.2	0
14	6	M	2	3.8	0
15	4	M	3	5.7	0
16	7	M	2	3	0
Mean	5.02	-	-	4.48±1.33	0.57±0.75
M: F ratio	-	3:1	-	-	-

M: Male, F: Female

Table 2: Comparison of pre- and post-operative displacement.

	Total no.	Pre-operative displacement (mean±SD)	Post-operative displacement mm (mean±SD)	*P*-value
Grade 2 fractures	6	3.20±0.42	0±0	$P<0.05$
Grade 3 fractures	10	5.24±1.08	0.91±0.76	$P<0.05$

***Statistically significant at** $P<0.05$.

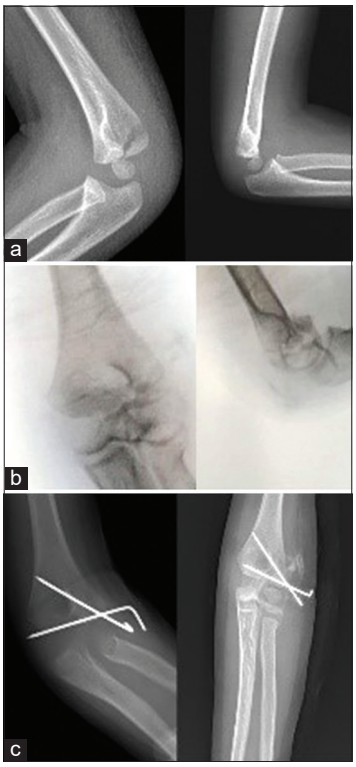

Figure 1: (a) Grade 2 LHCF in a 7-year-old boy (initial injury). (b) Intraoperative arthrogram induction. (c) Post-operative reduction.

Table 3: Range of motion and hypertrophic ossification are assessed 3 months and 6 months after surgery for all patients.

Patients	3-month post-operative		6-month post-operative	
	n	%	*n*	%
Grade 2				
Range of motion				
Full range of motion	7	100.0	7	100.0
Limited range of motion	0	0.0	0	0.0
Hypertrophic ossification				
None	2	28.5	3	43.0
Mild	2	28.5	1	14.0
Severe	3	43.0	3	43.0
Grade 3				
Range of motion				
Full range of motion	6	66.7	6	66.7
Limited range of motion	3	33.3	3	33.3
Hypertrophic ossification				
None	1	11.1	1	11.1
Mild	3	33.3	3	33.3
Severe	5	55.6	5	55.6
All patients				
Range of motion				
Full range of motion	13	81.0	13	81.0
Limited range of motion	3	19.0	3	19.0
Hypertrophic ossification				
None	3	18.8	4	25.0
Mild	5	31.2	4	25.0
Severe	8	50.0	8	50.0

no statistical significance was observed (OR = 1.6667, CI = 0.2273–12.22, P = 0.6153). Results at 6 months were exactly the same [Table 3].

Range of motion

All Grade 2 patients had full range of motion with no joint stiffness at follow-up, while 33% of Grade 3 patients had some restriction to elbow extension. Range of motion loss was between 10° and 20° of extension and a referral to physiotherapy was made for these patients. At 3 months, the odds of developing a limited range of motion in Grade 3 fractures were 8 times more likely than in patients with Grade 2 fractures, but this was not statistically significant (OR = 1.25, CI = 0.089–17.6, P = 0.869). These results did not change at 6 months [Table 3].

DISCUSSION

CRPP with intraoperative arthrogram for pediatric LHCFs with displacement >2 mm achieved good overall outcomes with 100% union rates regardless of fracture grade and articular congruity. Mild complications including non-union, malunion, pin site infection, and valgus deformity were not reported. Range of motion was full in all Grade 2 patients and 66.6% of Grade 3 patients, which is in agreement with the reports of current literature.[15-18] As for hypertrophic ossification, this was more severe in the Grade 3 fracture patients as over 50% of patients in this study went on to develop high levels of excess bony growth compared to around 40% in Grade 2 patients. This could be due to the nature of initial more aggressive trauma seen in Grade 3 fractures compared to the ones seen in Grade 2. The odds ratio of developing hypertrophic ossification and restricted range of motion between Grade 2 and Grade 3 patients was insignificant. These figures remain within the lower ranges of what the literature supports for Grade 3 fractures that undergo ORIF.[15-18] Although patients with articular cartilage congruency are less likely to develop complications, Grade 3 patients can also be managed with CRPP provided that the surgeon is experienced, well-skilled, and uses intraoperative arthrography to obtain a good view of the injury site and articular congruency.

The current literature advocates using CRPP for fractures with <2 mm displacement and ORIF for those with a greater displacement.[15] Although ORIF has excellent outcomes, post-operative complications are still a major burden.[16] Consequently, closed treatment of LHCFs has been a goal and

surgeons aim to replace ORIF with CRPP whenever possible, particularly when articular cartilage is intact or minimally disturbed.[9] Several studies have shown CRPP to be effective for Grade 2 fractures where displacement is >2 mm, but no or minimal articular cartilage disturbance is present; an arthrogram is used to confirm articular cartilage congruency.[9,17,18] Weiss *et al*. performed one of the largest studies on CRPP for pediatric LHCF management.[14] Sixty-five patients were treated, all of whom had fractures with >2 mm displacement, but intact articular cartilage as seen on the intraoperative arthrogram. Patients with articular cartilage incongruency were managed with ORIF. Patients who underwent CRPP had a lower rate of overall and major complications. A case of refracture was the only major complication seen in the CRPP group. However, their study did not include a direct control group to allow a direct comparison of ORIF to CRPP.[14-17] At our institution, CRPP is preferred by most surgeons as it is less invasive and reduces surgical time and post-operative complications. Our use of arthrogram allows us to assess the anatomy better and manage more complex cases (Grades 2 and 3) with CRPP. A minority of surgeons still prefer to use ORIF for Grade 2 as it gives them a direct view of the joint's surface. Our findings support the results by Weiss *et al*. in that CRPP should be used for fractures with displacement >2 mm with no or minimal articular cartilage disturbance.[14] In addition, Grade 3 fractures can also be managed with CRPP and provided that the surgeon is skilled and can use arthrography to view the articular cartilage congruency and correct it.

Arthrogram is useful to identify the articular cartilage status.[19] We believe that it guides the surgeons and helps them have a better understanding and visualization of the injury, especially in Grade 2 and 3 patients who are likely to have articular cartilage disturbance. Some studies compared patients managed with and without an arthrogram have not shown a notable difference between both patient groups.[19] Other studies demonstrate that arthrogram helps reduce the need for ORIF and its associated complications, which is itself a valid reason to use arthrogram.[13,20]

This study is limited by its small sample size of 16 patients, which may underestimate the difference between Grade 2 and 3 fractures and the rates of AVN. In addition, patients being treated by other surgeons were not included in the study, meaning that these results are not a complete representation of this specific patient population and that the reproducibility of these results has not been tested. ORIF is preferred as it is believed to achieve better stabilization and has a lower risk of developing arthritis in the future. To assess this, it is necessary that patients treated with CRPP are followed up in the long term. At our hospital, patients are discharged following complete healing and return of range of motion, which has led to a lack of long-term follow-up in our study. However, because our aim was to assess operative and radiological outcomes, the lack of long-term outcomes did not play a significant role in our study. It would have been useful to have a prospective design and a control group to compare CRPP to ORIF, although this was not the paper's primary goal.

CONCLUSION

CRPP for LHCF with >2 mm displacement is a safe option with good outcomes and provided that there is no significant articular cartilage disturbance with arthrogram-assisted imaging. Arthrogram is a valuable tool to help visualize the articular cartilage surface. Grade 3 fractures can be managed using CRPP if articular displacement parameters are within the acceptable range under imaging.

AUTHORS' CONTRIBUTIONS

AOA: Data analysis, production of written manuscript, and study design. HMA: Data collection and study design. AFK: Data collection, data analysis, and manuscript editing in all phases. MAA: Data collection. WQH: Data collection and write-up. AIA: Submission and edits to manuscript. TIN: Submission and edits to manuscript. SAA: Study design, data analysis, and supervision. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

ETHICAL APPROVAL

This study received ethical approval from the Kuwaiti Ministry of Health Ethical Committee on January 1, 2019 (Approval Reference: 2019/7288).

DECLARATION OF PATIENT CONSENT

The authors certify that they have obtained all appropriate patients consent forms. In the form, the legal guardians of the patients have given their consent for their images and other clinical information to be reported in the journal. The legal guardians of the patients understand that the patients' names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

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