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ORIGINAL ARTICLE • ELBOW - FRACTURES

Open versus closed reduction and K-wire fixation for displaced supracondylar fracture of the humerus in children

Alaa A. Hussein al-Algawy[1] · Adil Hasan Aliakbar[2] · Ibrahim H. N. Witwit[1]

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Abstract

Supracondylar fracture of the humerus is a common displaced type childhood fracture that is treated by two methods. To compare open and closed methods of reduction with 2 cross k-wire fixation, a retrospective comparative study of 66 paediatric patients with type III supracondylar fracture of the humerus, who were treated in two different hospitals utilizing two different protocols, was conducted. Group 1 was treated with open reduction and 2 cross k-wire fixation, and group 2 received the closed reduction and k-wire fixation protocol. Functional and cosmetic assessments were conducted utilizing the Flynn et al. outcome criteria. The test population consisted of 25 female (37.9%) and 41 male (62.1%) patients. There were 43 fractures (65.2%) in the right elbow and 23 fractures (34.8%) in the left. Group 2 (81.81%) stayed less than 4 days in the hospital, while 69.7% of group 1 stayed more than 5 days. Statistically, there were no significant differences ($P > 0.05$) between patients of both groups regarding the Flynn et al. criteria. Closed reduction technique was preferred because it required less hospitalization time and resulted in almost no visible surgical scars.

Keywords Closed reduction · Displaced fracture · Supracondylar fracture · Trauma

Introduction

Supracondylar humerus fractures in children account for 70% of elbow fractures, and they are considered the second most common (16.6%) type of fracture in patients around the age of 7 years [1–3]. The incidence of severely displaced (Gartland type III), among all cases, of supracondylar humerus fractures is low (16.7%) [4].

For those severely displaced supracondylar fractures, there is still a controversy regarding the optimal method of management. Effective treatment for such patients is necessary in order to avoid serious complications, such as cubitus varus, malunion, limitation of movement due to pain or stiffness and any nerve injuries [2–4].

The main difference in opinion among authors related mainly to whether utilizing closed reduction and percutaneous k-wire fixation [5–8] or open reduction and fixation under direct vision was the preferred protocol.

Some surgeons preferred closed treatment [9], but others found it did not yield optimal results when they applied it to their patients [10].

Potential complications that the surgeon tries to avoid are post-operative range of motion limitations that affect functional outcomes and the cosmetically unacceptable cubitus varus. In some studies, the incidence of cubitus varus may be as high as 60% and is considered the most common post-operative complication [11]. In this study, our aim was to compare the two methods of treatment (open and closed reduction with k-wire fixation) for the displaced type of supracondylar fracture of the distal humerus in children. Criteria taken into consideration were final (functional and cosmetic) outcomes, period of hospitalization, time needed for healing and the expected common complications.

✉ Adil Hasan Aliakbar
Adelhassan1122@gmail.com

Alaa A. Hussein al-Algawy
Alalgawy2002@yahoo.com

Ibrahim H. N. Witwit
Sw29r@yahoo.com

[1] College of Medicine, University of Babylon, Babil, Iraq

[2] Department of Surgery, College of Medicine, University of Babylon, Babil, Iraq

Patients and method

A clinical retrospective comparative study was conducted, consisting of 66 paediatric patients who presented to the emergency units in two different hospitals between September 2011 and October 2015 with cases of type III supracondylar fractures of the elbow, extension type (according to Gartland's classification). Diagnosis was based on clinical and X-ray findings. All patients received proper assessments and resuscitations. After their general condition was stabilized, patients were prepared to undergo a definitive surgical reduction and fixation. Patients were treated by two different surgical teams in two different hospitals utilizing different protocols. Group 1 primarily received open reduction and k-wire fixation. The second group primarily received closed reduction and k-wire fixation. Surgeons for each group worked according to their hospital protocol.

Data records regarding name, age, sex, left or right elbow, time of arrival and time of surgical treatment for each patient were collected. The institutional review board of the Department of Surgery, College of Medicine, University of Babylon, approved this study. The study registration number 204 was granted on 22 November 2017 by the Scientific Committee of the Department of Surgery, College of Medicine, University of Babylon.

Patients were excluded based on the following criteria: open fractures, presentation with associated neurovascular injuries, and unsuccessful closed reduction in a primary care clinic prior to referral and admission to our hospital.

The surgical technique for the ORIF group (group 1) was as follows. Patients were prepared on an ordinary operative table, in a lateral semi-prone position with the injured elbow up. Further preparation included using an Esmach tourniquet, painting and sterilization of the area and towelling. Using a posterolateral approach, the triceps was split, and the ulnar nerve was identified and protected. The fracture was reduced and fixed by two crossed k-wires, medially and laterally. Haemostasis was secured, and the wound was closed without leaving a drain.

For those treated utilizing the closed method (group 2), an elbow support device was placed at the lateral edge of the table to keep the joint stable during the k-wire fixation. After positioning, sterilization and towelling under X-ray control, the fracture was reduced closely. Two crossed k-wires were introduced laterally and medially without using a tourniquet. In both groups, a P.O.P. back slab was applied.

Post-operative care and follow-up during the hospital stay included assessing the accuracy of the reduction and looking for possible early complications such as nerve injury and compartment syndrome. Follow-up after the patient was discharged from the hospital assessed the timing and quality of union, range of motion, presence of any malunion or cubitus varus and presence of infection (Figs. 1, 2).

We depended on the Flynn et al. [5] criteria of evaluation to assess the results regarding any deformity and range of motion at the elbow joint (Table 1).

Active range of motion and early physiotherapy started at the day of wire removal.

All patients in each group were instructed to have a schedule of outpatient clinic visits at the 2nd, 3rd, 5th and 6th weeks. These clinic visits continued at the 3rd month and every 3 months to the end of the year. During the following year, patients were seen every 6 months. Twenty patients (60.6%) from group 1 and 16 patients (48.5%) from group 2 followed up for 2 years. The period of follow-up ranged from 11 to 17 months post-operatively.

Schedule of follow-up:

2nd week	3rd week	5th week	6th week	3rd month	6th month	9th month	12th month	18th month	24th month

Statistical data were presented by mean ± SD (standard deviation) and percentage. Analysis of data was done using SPSS version 22, utilizing independent sample *t* test and one-way ANOVA according to p value ($P \leq 0.05$).

Results

During the defined period of time for the study, we registered a total 66 patients in both groups, consisting of 25 female (37.9%) and 41 male (62.1%) patients. There were 43 fractures (65.2%) of the right elbow and 23 fractures (34.8%) of the left side (Table 2). The mean age of the patients was 7 years, and ages ranged from 3 to 11 years.

Group 1 (ORIF group) consisted of 33 patients. Only 10 of the patients presented early to the emergency room. They received early treatment of the fracture by having it fixed within the first 24 h. The remaining 23 patients (69.69%) were operated upon within 5–7 days after presentation in emergency room, after keeping them in back slab until oedema subsided (Fig. 1).

Group 2 (closed reduction technique) consisted of 33 patients. Only 17 patients were treated within the first day of sustaining the injury. Ten patients were treated from 3 to

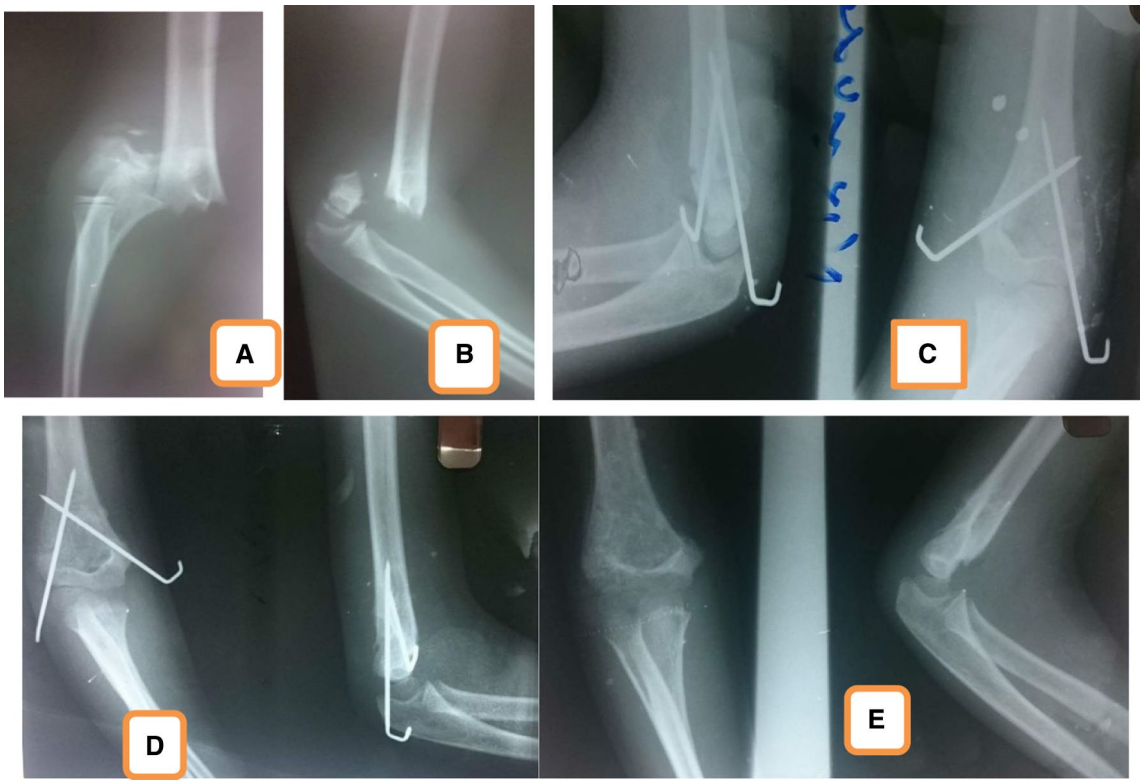

Fig. 1 Case treated by open method **a**, **b** before reduction, **c** after fixing by wires, **d** at the end of 3rd week, **e** after wires removal

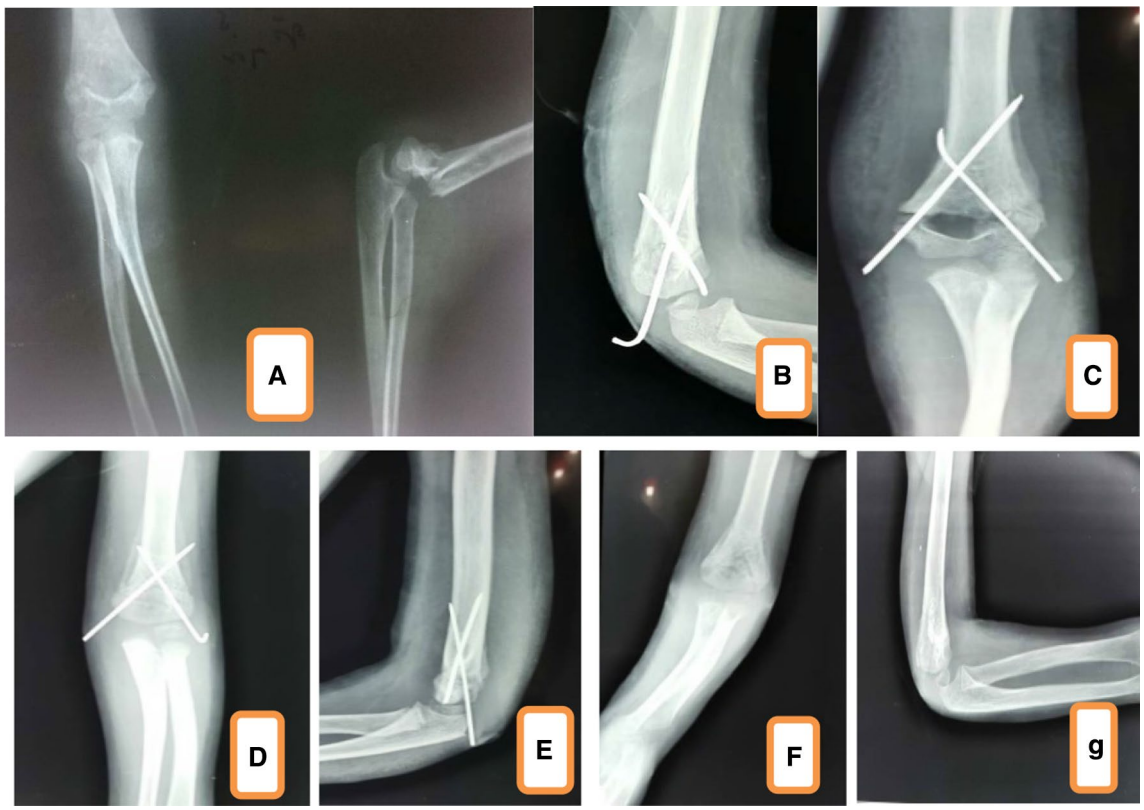

Fig. 2 Case treated by closed method , **a** at presentation, **b**, **c** after closed wire fixation, **d**, **e** after healing at 3rd week, **e**, **g** after wire removal

Table 1 Outcome criteria of Flynn et al. [5]

Result grade	Loss of carrying angle	Loss of motion
Excellent	0°–5°	0°–5°
Good	6°–10°	6°–10°
Fair	11°–15°	11°–15°
Poor	15°	15°

Table 2 Patient data

	%	No. 66	Group 1 = 33	Group 2 = 33
Rt. elbow	65.15	43	23	20
Lt. elbow	34.85	23	10	13
Males	62.12	41	19	22
Females	37.87	25	14	11

Table 3 Onset of surgery in each group

Group 1		Group 2	
10 patients	24 h	17 patients	24 h
23 patients	5–7 days	10 patients	3–4 days (6 in the second trial)
		6 patients	At 6th day (severe oedema)

4 days, and 6 out of those 10 received two trials of closed reduction. Six patients (18.18%) presented later as referred cases, so they were treated by closed method at the sixth day after the incidence of fracture. This group of 6 patients did not receive any trial of closed reduction in the primary care hospital, and they were referred to our hospital in back slab because they initially presented to the primary hospital with significant oedema (Table 3, Fig. 2).

Table 3 shows a hospital stay before surgery of less than 4 days in 27 patients (81.81%) from group 2, while 23 patients (69.7%) from group 1 stayed more than 5 days.

In group 1, for the patients kept under observation for 3–7 days after surgery, the average period of post-operative hospitalization was 4 days. In group 2, all patients were discharged after 2–3 days post-operatively.

K-wire removal for most of the patients in both groups was at the end of the third week, when we noticed adequate callous formation. This occurred as follows: 29 patients in group 1 (87.9%) and 31 patients in group 2 (93.93%).

In 6 patients, an adequate callous appeared only at the end of the fifth week. At that time, the k-wires were removed. This group of 6 comprised 4 patients from group 1 (12.1%) and 2 patients from group 2 (6%).

Table 4 The results of group 1, using the outcome criteria of Flynn et al

Result	No.	%	Notes
Excellent	21	63.6	
Good	7	21.2	3 cases of pin tract infection
Fair	3	9.1	Decrease in range of motion
Poor	1	3	20° varus

Table 5 The results of group 2, using the outcome criteria of Flynn et al

Result	No.	%	Notes
Excellent	22	66.66	3 cases as second trial reduction 1 case pin tract infection
Good	8	24.24	2 cases as second trial reduction 2 cases of pin tract infection
Fair	2	6	1 case as 2nd trial and had mild varus deformity 1 case, ulnar nerve neurapraxia
Poor	1	3	20 degree varus

As per the Flynn et al. criteria of evaluation, we obtained the following results.

Among all 33 cases in group 1, 21 patients (63.6%) scored an excellent result, 7 patients (21.2%) scored a good result, three patients (9.1%) scored a fair result, and only one patient (3%) scored a poor result (Table 4).

Among all 33 cases in group 2, only 22 patients (66.66%) scored an excellent result, 8 patients (24.24%) scored a good result, 2 patients (6%) had a fair result, and only 1 patient (3%) had a poor result (Table 5).

The varus angulation, even with an excellent functional outcome, was considered the main cause of fair and poor scores in group 2.

In group 1, three patients had significant range of motion loss, so they scored fair results, and one patient with a 20° varus angulation scored a poor result.

Pin tract infection occurred in 6 patients (three from each group), and all were treated with a simple short course of antibiotic.

A perfect range of motion outcome was observed in all patients from group 2, but a fair functional outcome was observed in three patients from group 1.

Ulnar nerve affection as post-operative weakness resulted in one case (3%) from group 2, but this patient regained neurological function after 3 weeks (neurapraxia). This case was considered a fair outcome. There

Table 6 Comparison between group 1 and group 2, using the outcome criteria of Flynn et al., level of significance $P > 0.05$

Result	Groups	No. of patients	Mean ± SD	Notes
Excellent	Group 1	21	3.8095 ± .81358	$P > 0.05$
	Group 2	22	3.9545 ± .99892	
Good	Group 1	7	6.8750 ± 1.12599	$P > 0.05$
	Group 2	8	7.000 ± 1.15470	
Fair	Group 1	3	12.000 ± 1.141	$P > 0.05$
	Group 2	2	12.000 ± 1.000	
Poor	Group 1	1		
	Group 2	1		

was no patient in need of re-operation in either group, and we found the crossed-pin technique was quite stable, so there was no patient with a significant loss of fixation.

Statistically, there is no significant difference ($P > 0.05$) between patients of group 1 and group 2 regarding the use of the Flynn et al. criteria (Table 6).

Discussion

In the issue of supracondylar fracture of the distal humerus, the aim of management is to achieve functionality as early as possible, a stable elbow joint and no obvious deformity.

There is no definitive, established method of fixation for displaced supracondylar fractures (Gartland type III). Surgeons who advocate for the closed method of reduction with k-wire pinning state that very few complications, such as infection and loss of movement, occur. Likewise, the closed reduction technique results in shorter hospitalization [9–12].

On the other hand, those who advocate for the open technique state that frequently, closed procedures require additional trials to restore perfect anatomical reduction. This may result in elbow joint stiffness and finally with myositis ossificans [13, 14].

In this study, the sample size was relatively small for the duration of the study, and we think that related to system of referral in our country and socio-economic status of our patients that affect commitment of patients to follow-up period and explain the late presentation of some cases to the hospital after initial injury.

In this study, we tried to evaluate the outcome of ORIF as a primary procedure. We had noted that in most of the published articles regarding the results of ORIF, there was not great precision or strict randomization. Furthermore, in previous studies, open reduction was performed after trials of closed reduction in which perfect reduction was not achieved. Typically, the cause of failure of closed reduction is the nature of the fracture, the severity of displacement, the complete detachment of the periosteum or the degree of comminution. In addition, the repetitive trials to achieve anatomical reduction increase the chance of myositis ossificans, or result in mild to moderate stiffness. Certainly, the results will be less optimum when utilizing the open technique compared to the higher success rating for the closed technique.

In this study, the surgeons in group 1 did not attempt any closed reduction. From the start, they had already decided to do ORIF, which was in accordance with hospital protocol.

We think this may explain why we found no significant statistical differences between the results of both groups.

In group 2, we encountered 6 difficult cases that failed to achieve good reduction in the first trial. A back slab was applied along with elevation and anti-inflammatory medication until oedema subsided. Then, in the second trial, good reduction was achieved and treated accordingly (3–4 days after admission). In other studies, we noticed that they exclude difficult cases from the start, after the failed first trial of reduction. This procedure will reflect a higher success rate in the group performing closed technique, because they included only the simple cases.

The outcome of our six patients, who had been treated by a second trial of closed technique (CRPF group 2), was as follows: 3 were excellent, 2 were good, and 1 was fair. The last one was scored fair as the patient had ulnar neurapraxia. This point makes our results more distinctive than those that have been achieved in other studies [15].

In this study, excellent and good results, which were considered as the satisfactory result, were about 84.8% for ORIF and 90.9% for CRPF.

In both treatment groups, these results actually are very similar to most of the published articles. This is true especially when considering the method of closed reduction as an option of choice for a displaced Gartland type III supracondylar fracture of the humerus [1, 9, 16–20].

Furthermore, as a comparison between the two methods, the ratio of excellent and good results, as well as the ratio of poor results, is almost identical in both treatment groups (3% in both groups). That is almost shown in other studies, as well, as mentioned by Ababneh et al. [10], in which even better results were shown using CRPF than ORIF. This occurred, as well, in other studies [9, 11, 12].

While the ratio of fair results (9.1%) was even better in the ORIF group than in the closed group (6.1%) (Table 6), one case of ulnar nerve neurapraxia (3%) in the closed treatment group is due to a bad trial of pin entry medially. This result is comparable to other studies [21–24]. In studies by (Cemal Kazim Oglu) [25], there was a high percentage of ulnar nerve insult in both types of treatment post-operatively, where it was 9.7% in the closed reduction group versus 5.4% in the ORIF group. [25].

In this study, only the crossed-pin method of fixation was used, as we think it is sufficient to provide good stability, and it is mentioned in many articles [9, 26–30]. The only hazard

of this technique is the possibility of ulnar nerve injury. To decrease the chance of getting this injury, they used to avoid the hyper-flexion of the elbow while inserting the medial pin. This advice is also mentioned in some articles [31].

Our one case of ulnar nerve injury recovered spontaneously after 3 weeks. This is consistent with most cases [25, 26]. As a comparison, although both techniques do not carry a significant rate of complication, in group 1, there was a longer pre-operative and post-operative hospitalization time, which carries a higher financial cost.

Additionally, there is the cosmetically permanent surgical scare of cubitus varus, which is a special concern for female patients.

Conclusions

Between the two groups of patients treated by closed and open reduction techniques with fixation by crossed k-wires, we found no significant difference in the final outcome for patients with Gartland type III supracondylar humerus fractures, as per the Flynn et al. evaluation criteria.

Although the sample size was relatively small, we recommend the closed reduction technique as the first choice of treatment for any displaced supracondylar fracture of the humerus, as long as the equipment and facilities are available and the surgical staff are expert enough. This conclusion was drawn for the following reasons: one or two trials of closed reduction are typically necessary because it requires less hospitalization pre- and post-operatively, and it results in almost no visible surgical scars. If circumstances do not support closed reduction, ORIF will produce nearly the same success rate with an almost negligible rate of complication.

Compliance with ethical standards

Conflict of interest All named authors hereby declare that they have no conflicts of interest to disclose.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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