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Displaced supracondylar humeral fractures in children: Comparison of three treatment approaches

Siniša Dučić[1,2], Marko Bumbaširević[1,3], Vladimir Radlović[2], Petar Nikić[4], Zoran Bukumirić[5], Radivoj Brdar[1,2], Zoran Radojičić[1,2], Bojan Bukva[2], Dušan Abramović[2], Tatjana Jaramaz Dučić[4]

[1]University of Belgrade, School of Medicine, Belgrade, Serbia;
[2]University Children's Hospital, Belgrade, Serbia;
[3]Clinical Center of Serbia, Belgrade, Serbia;
[4]Special Hospital for Cerebrovascular Diseases St. Sava, Belgrade, Serbia;
[5]Institute of Medical Statistics and Informatics, University of Belgrade, School of Medicine, Belgrade, Serbia

SUMMARY

Introduction Closed reduction and percutaneous pinning are the most widely used treatment options for displaced supracondylar humerus fractures in children, but there is still no consensus concerning the most preferred technique in injuries of the extension type.

Objective The aim of this study was to compare three common orthopaedic procedures in the treatment of displaced extension type supracondylar humerus fractures in children.

Methods Total of 93 consecutive patients (66 boys and 27 girls) referred to our hospital with Gartland type II or III extension supracondylar humeral fractures were prospectively included in the study over a six-year period. At initial presentation 48 patients were classified as Gartland type II and 45 as Gartland type III fractures. The patients were subdivided into three groups based on the following treatment modality: closed reduction with percutaneous pinning, open reduction with Kirschner wires (K-wires) fixation, and closed reduction with cast immobilisation. The treatment outcome and clinical characteristics were compared among groups, as well as evaluated using Flynn's criteria.

Results Excellent clinical outcome was reported in 70.3% of patients treated with closed reduction with percutaneous pinning and in 64.7% of patients treated with open reduction with K-wire fixation. The outcome was significantly worse in children treated with closed reduction and cast immobilisation alone, as excellent outcome is achieved in just 36.4% of cases (p=0.011).

Conclusion Closed reduction with percutaneous pinning is the method of choice in the treatment of displaced pediatric supracondylar humeral fracture, while open reduction with K-wire fixation is as a good alternative in cases with clear indications.

Keywords: supracondylar humeral fractures; closed reduction; open reduction; percutaneous pinning; treatment complications; functional outcome

INTRODUCTION

Supracondylar fractures are among the most frequent types of bone injuries in childhood, reported to occur in 55% to 75% of patients with elbow fractures [1]. Almost all cases are extension type fractures (97–99%), usually provoked by a fall onto the outstretched hand with elbow joint in full extension [2]. Associated neurological and vascular injuries of nearby soft tissue are not rare and depend primarily on the direction of displaced metaphyseal bone fragment and force. The fractures were classified according to radiological findings using the modified Gartland classification system [3]. Type I fractures are non-displaced fractures. Type II fractures have an intact posterior hinge, and were further subdivided according to Wilkins into the following: subtype IIa – posterior dislocation distal fragment without rotation, and subtype IIb – posterior dislocation distal fragment with rotation [1]. Type III fractures involve complete displacement.

Generally, medial displacement of the distal fragment is more common than lateral displacement, occurring in approximately 75% of patients in most series [4]. This type of displacement puts the radial nerve at risk, while posterolateral displacement compromises the median nerve and brachial artery. Decision on the method of treatment is based on the degree of displacement, the type of fracture and clinical examination. Although most displaced supracondylar fractures in children can be treated with closed reduction with percutaneous pinning, there is no consensus about the optimal method, the timing of procedure, or the required level of experience among the orthopaedic surgeons [5-8]. An accurate initial assessment is important in order to select the most suitable treatment option [9-12]. In addition, many of the studies examining the clinical course and treatment outcome of displaced supracondylar humeral fractures in children were retrospective and may be prone to the selection or outcome misclassification bias [13-16].

OBJECTIVE

The aim of our study was to compare the usefulness of the three most common orthopaedic procedures used in treatment of displaced supracondylar fractures in children.

Correspondence to:
Siniša DUČIĆ
University Children's Hospital
Department of Orthopedics and Traumatology
Tiršova 10, 11000 Belgrade
Serbia
sinisaducic@gmail.com

Table 1. Clinical characteristics of children with displaced supracondylar fractures based on the type of treatment

Characteristics		Closed reduction with percutaneous pinning	Open reduction with Kirschner wire fixation	Closed reduction and casting	p
Age (years), mean ± SD		6.7±1.7	6.8±2	6.1±2.1	0.410
Gender, n (%)	Male	29 (78.4)	23 (67.6)	14 (63.6)	0.419
	Female	8 (21.6)	11 (32.4)	8 (36.4)	
Arm, n (%)	Left	22 (59.5)	17 (50.0)	12 (52.4)	0.711
	Right	15 (40.5)	17 (50.0)	10 (47.6)	
Fracture type, n (%)	Gartland IIa	3 (8.1)	3 (8.8)	4 (18.2)	NS
	Gartland IIb	10 (27.0)	14 (41.2)	14 (63.6)	NS
	Gartland III	24 (64.9)	17 (50.0)	4 (18.2)	NS

n – number of patients; NS – nonsignificant

METHODS

We prospectively included 93 consecutive patients, aged 1.5–11.4 years (mean 6.5±2), admitted to the emergency department of the University Children's Hospital with the extension type of displaced supracondylar humeral fracture, in the period between May 2006 and May 2012. Demographic information, clinical data and radiological findings were obtained from notes and electronic medical records. Information on type of treatment, time from presentation to definitive treatment, procedural details, complications and outcome, were recorded and reviewed from patients' medical charts. Patients with Gartland type I fracture (non-displaced), patients with open fracture, and cases with serious neurovascular complications demanding other specific operative management were excluded.

Sixty-six patients were male (71%) and twenty-seven (29%) female. Among the injured children, the left elbow was fractured in 51 (54%) case and the right one in 42 (46%). The mean time from injury to therapeutic procedure was 6.35±4.64 hours. According to modified Gartland's system, based on the initial displacement, 48 fractures were classified as Gartland type II and 45 as Gartland type III. There was no significant difference in clinical and demographic variables, based on the type of treatment, among the three groups of patients (Table 1).

Based on the performed procedure, the patients were classified into three groups: a) those who underwent treatment by closed reduction with percutaneous pinning of fractured bone fragments (Group A, n=37); b) the cases treated by open reduction with K-wire fixation (Group B, n=34); and c) the patients treated by closed reduction and casting alone (Group C, n=22). The procedure with closed reduction and percutaneous pinning was performed under general anesthesia and consisted orthopaedic reduction followed by percutaneous fixation with two crossed K-wires. Lateral approach was used in order to perform open reduction and fixation with K-wires. The reduction of a displaced bone fragment was followed by fracture stabilization with two crossed K-wires and cast immobilisation. When closed reduction and cast immobilisation were used as the primary method of treatment, reduction was performed under general anesthesia with a cast immobilisation of the elbow, whereas selected degree of elbow flexion depended on the amount of swelling and neurovascular status, with maximum flexion of 90 degrees. The preferred

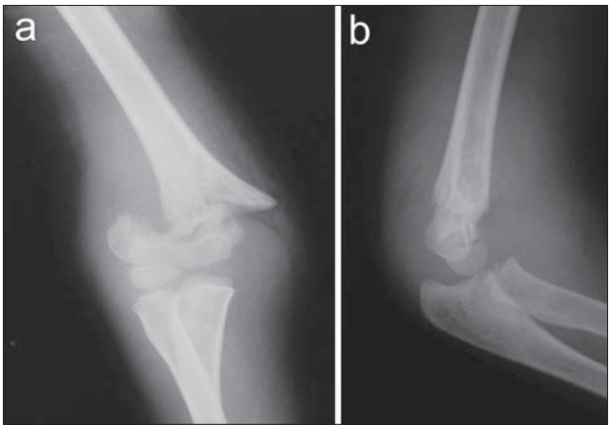

Figure 1. Gartland Type IIb supracondylar fracture: a) AP view; b) lateral view

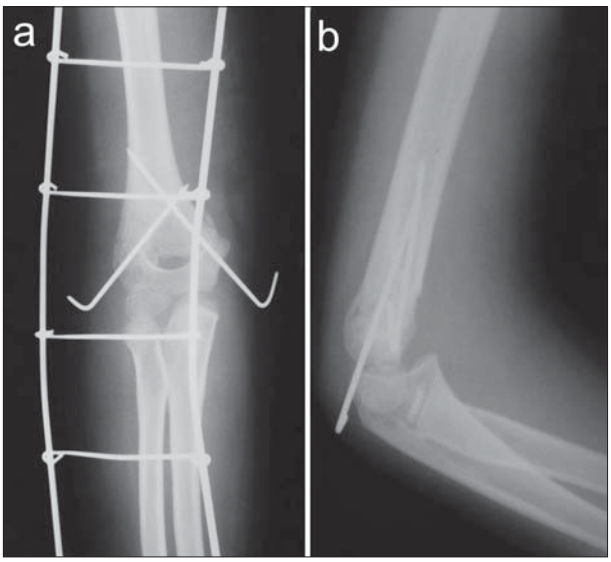

Figure 2. Close reduction and cross K-wire fixation: a) AP view; b) lateral view

splinting position of the forearm was selected based on the location of the bone fragment (pronation with posteromedial and supination with posterolateral fragment displacement). Following the procedure, radiographic evaluation, including anteroposterior and lateral views of the entire upper extremity, was performed in order to estimate the reduction outcome (Figures 1 and 2). K-wires and the cast were removed three to four weeks after the procedure. The average time from the elbow fracture to clinical evaluation was 11.2±2.3 months.

Table 2. Functional and cosmetic outcomes according to Flynn's criteria among three different procedures

Outcome		Number of patients (%)			p
		Closed reduction with percutaneous pinning	Open reduction with K-wire fixation	Closed reduction and casting	
Functional, loss of range of motion (degrees)	Excellent (0–5)	31 (83.8)	26 (76.5)	12 (54.5)	0.020
	Good (6–10)	6 (16.2)	8 (23.5)	6 (27.3)	
	Fair (11–15)	0 (0.0)	0 (0.0)	2 (9.1)	
	Poor (>15)	0 (0.0)	0 (0.0)	2 (9.1)	
Cosmetic, difference in carrying angle (degrees)	Excellent (0–5)	29 (78.4)	28 (82.4)	12 (54.5)	0.049
	Good (6–10)	6 (16.2)	3 (8.8)	6 (27.3)	
	Fair (11–15)	2 (5.4)	2 (5.9)	2 (9.1)	
	Poor (>15)	0 (0.0)	1 (2.9)	2 (9.1)	

We evaluated and recorded several clinical variables as follows: degree of flexion and extension of the elbow joint in both arms, loss of range of motion (functional) and difference in "carrying angle" (cosmetic) between affected and unaffected arms. The carrying angle of the elbow is defined as the angle formed by the long axis of the arm and the long axis of the forearm in the frontal plane. The carrying angle was measured with a goniometer and compared with that of the unaffected opposite extremity. Treatment outcomes were classified according to Flynn's criteria that include two factors, "functional" and "cosmetic", which are defined by the motion loss in degrees and the loss of carrying angle in degrees. The outcome is rated based on the measured degrees: excellent 0–5; good 6–10; fair 11–15; and unsatisfactory or poor score >15 degrees [17]. The overall rating in those patients who had changes both in the carrying angle and in function was made on the basis of the greater clinical loss, that is, a good functional rating and a fair cosmetic rating resulted in a fair rating. The study was approved by the local Research Ethics Committee, and informed consent was obtained from all patients.

Statistical analysis was carried out using the SPSS 18 software (SPSS, Chicago, IL, USA). Summarizing data are displayed as mean and standard deviation if not otherwise specified. Continuous normally distributed variables were compared using Student's t-test or the Mann–Whitney U-test for non-normally distributed variables. The Kruskal–Wallis test is used for the comparison of more than two independent groups. Differences among categorical variables were analyzed using the chi square test. P-values less than 0.05 were considered statistically significant.

RESULTS

Using Flynn's modified classification system, the functional result was excellent in 69 patients (74.1%) and good in 20 (21.5%). The fair and poor functional outcome was noted in four patients (4%), all of them treated with closed reduction and casting (Table 2). Using Flynn's modified classification system, the cosmetic result was excellent in 69 patients (74.1%) and good in 15 (16%). Fair and poor cosmetic outcome was noted in nine patients (9.6%), fair result in six patients (two treated with closed reduction and percutaneous pinning, two with open reduction and K-wire fixation, and two with closed reduction and cast immobilisation), and poor result in three patients (two treated with closed reduction and cast immobilization, and one treated with open reduction and K-wires fixation) (Table 2).

Table 3. Treatment outcome based on performed procedures

Treatment outcome	Frequency (%)		
	Closed reduction with pinning	Open reduction with pinning	Closed reduction and casting
Excellent	70.0	65.0	36.0
Fair	24.0	27.0	36.0
Good	6.0	5.0	9.0
Poor	0	3	19.0

Table 4. Comparison between outcomes of closed reduction with percutaneous pinning, open reduction with K-wire fixation, and closed reduction with casting techniques

p		Group A / Group C	Group B / Group C	Group A / Group B
Flexion (degrees)	Affected arm	0.002	0.018	NS
	Opposite arm	0.008	NS	NS
Functional / loss of range of motion		0.008	0.045	NS
Cosmetic / difference in carrying angle		0.042	0.031	NS
Treatment outcome		0.004	0.021	NS

NS – nonsignificant

A – closed reduction with percutaneous pinning; B – open reduction with K-wire fixation; C – closed reduction with casting

There was a significant difference in the treatment outcome among the three forms of initial procedures (p=0.011) (Table 3). All children with poor outcome had a Gartland type-III supracondylar fracture.

Functional and cosmetic treatment outcomes were significantly different between the groups of closed or open reduction with K-wire fixation compared to the group of conservatively managed displaced supracondylar humeral fractures. There was no statistically significant difference in any radiograph or clinical outcome measures between the two non-conservative treatment groups, closed and open reduction with K-wire fixation, in the treatment of supracondylar humeral fractures. Excellent clinical outcomes have been reported with both closed and open reduction with K-wire fixation, and these patients had significantly better outcomes compared to those treated with cast immobilisation only (Table 4).

Treatment complications regarding supracondylar fractures in children most often include soft tissue injuries (involving blood vessels and/or nerves), as well as axial abnormalities in the affected elbow joint. A total of 11 complications were recorded in the study (11.8%).

Neurological complications, such as ulnar nerve lesions, were detected in four patients (4.3%) following surgery, specifically in three patients treated by closed reduction and percutaneous fixation, and in one patient treated by open reduction. Spontaneous nerve healing was observed 12 to 24 weeks after the intervention in all patients. Vascular complications were observed in four patients, in whom radial pulse had been present before surgery; radial pulse was lost following the procedure, but the collateral circulation was sufficient and showed no ischemic signs. Therefore, these patients did not require any further intervention. Angular deformities of the cubitus varus type were noted in three patients (3.2%), two treated by closed reduction with cast immobilization and one treated with open reduction. The patients were subjected to surgical treatment – closing wedge corrective osteotomy. In two patients, the results of corrective osteotomy were good, while in one patient angular deformities of the cubitus varus type persisted even after the corrective surgical treatment. When it comes to elbow stiffness, a decrease in range of motion of over 15 degrees was noted in two patients, both treated with closed reduction. There were no other treatment complications.

DISCUSSION

Displaced supracondylar fractures of the humerus are the most common fractures in children. Even though closed reduction accompanied by percutaneous fragment fixation is the method of choice of most authors for the treatment of these severe fractures in children, there is no universal agreement among orthopaedic surgeons on the most appropriate treatment [18, 19]. In the past, the displaced extension fractures (Gartland type II and type III) were associated with numerous complications and impaired functional final outcome. However, the rate of post-procedural complications dramatically decreased with the advances in modern operative pinning techniques and the increase in surgical experience [3]. Most orthopaedic surgeons now accept closed reduction and percutaneous pinning as the initial treatment of choice for most displaced supracondylar fractures of the humerus in children. Nevertheless, many issues are still open to discussion for a number of reasons, including the pinning technique used for fixation (number and configuration of pins), the effect of delaying operative treatment etc. [6]. The functional and cosmetic outcomes, according to Flynn's criteria, were excellent in the majority of patients treated by closed or open reduction with K-wire fixation. This is in accordance with the two observational clinical studies by Skaggs et al. [20, 21], using closed reduction with percutaneous pinning as initial treatment for type II fractures. The authors concluded that there is a high probability of satisfactory outcome after orthopaedic treatment with closed reduction and percutaneous pinning of type II supracondylar fractures compared with previous studies of children treated with cast immobilization only.

In our study, we used closed or open reduction and stabilization with two crossed pins. The advantages of crossed-pin fixation are based on the fact that this method ensures good biomechanical stabilization, while unilateral fixation brings weaker biomechanical stability [22].

On the other hand, the risk of ulnar nerve injury is higher if the pins are in crossed configuration. The frequency of iatrogenic ulnar nerve injuries, caused during the placement of pins on the medial side, ranges from 1.4% to 15.6% [23]. In our study, neurological complications following surgery, such as ulnar nerve lesions, were noted in four patients (4.3%) – three patients treated with closed reduction and percutaneous fixation, and one patient treated with open reduction. Spontaneous nerve healing occurred between 12 and 24 weeks following intervention in all patients. The possibility of causing iatrogenic injury to the ulnar nerve during crossed percutaneous pinning is the reason why a large number of authors preferred lateral pin configuration, emphasizing that there was no statistically significant difference in clinical and radiographic outcomes between patients treated with lateral entry pinning compared to those treated with crossed pinning, with the former bringing a smaller risk for iatrogenic ulnar nerve injury [24-27].

Contrary to these treatment options, excellent results were achieved in only 36% of the patients treated by closed reduction with cast immobilization, indicating that this is not an adequate treatment method for the treatment of dislocated supracondylar humeral fractures in children. Notwithstanding, some authors, like Hadlow et al. [28], claim that closed manipulation and immobilisation in plaster is suitable for all types of fractures, although open reduction has been increasingly accepted because it entails relatively few complications [29].

Most authors agree that closed reduction with cast immobilization alone is not a satisfactory treatment method for dislocated supracondylar fractures in children. Dislocated fractures of the type-IIa are an exception – they can be treated by closed reduction with cast immobilization, but if there are even the faintest doubts in the stability of reposition or the position of the fragments, the distal fragment should be stabilized by percutaneous fixation with K-wires. O'Hara et al. [30] observed that, even though a good functional and cosmetic result may be obtained with further operative treatment, the initial treatment should be definitive, not only because the reintervention is more difficult to perform, but also because repeat interventions are associated with poorer outcomes.

In our study, both procedures – open and closed reduction with K-wire fixation – were superior to cast immobilization only, and the functional outcome was better in the group of children treated with closed reduction and percutaneous pinning. Our results confirm that the treatment of choice for Gartland type III fractures is closed reduction with percutaneous pinning. In a retrospective review of

189 children, operatively treated during a six-year period at a tertiary care hospital, Skaggs et al. [21] reported high efficacy and good safety of closed reduction with percutaneous pinning in children with supracondylar fractures.

In situations in which it was impossible to achieve an adequate closed reduction, as well as in open fractures, open reduction with K-wire fixation should be the immediate choice of treatment. Open reposition method brings about good treatment results: excellent results were achieved in 65% of our patients. The results from our study, where almost the nine tenth of the subjects, showed good or excellent treatment outcome after closed or open reduction with pinning, confirmed that these procedures are the treatment of choice for Gartland type II and type III displaced supracondylar humeral fractures in children. However, several limitations to this study need to be acknowledged. First, the time of follow-up was relatively short. Second, the initial choice of treatment was based on an expert opinion of a senior orthopaedic surgeon. Third, the investigators were not blinded, and their attitudes for or against an orthopaedic method in an injured child were based on personal experience in interpreting clinical findings (e.g., presence of complications) or available radiographic data.

CONCLUSION

The majority of orthopaedic surgeons accept closed reduction and percutaneous pinning as the initial treatment for a displaced supracondylar fracture of the humerus in children. Based on the results from our single tertiary reference center, we recommend a selective approach to initial treatment of the displaced supracondylar fracture in children based on fracture subtype. Our findings show that manipulation and immobilization in plaster is the least effective option and should be reserved as a definitive mode of treatment only for uncomplicated extension humeral fractures in children (Gartland type IIa). The correct selection of treatment for displaced supracondylar extension-type fractures in children is important, because the right choice of initial management may strongly affect the child's ability to acquire or perform skilled movements with the injured arm. We believe that most pediatric supracondylar humeral fractures can be treated by pinning, either in closed or open reduction.

Our recommendation, formed on the basis of this study, is that closed reduction should always be attempted first. If a satisfactory positioning of the fragment is not achieved after two attempts of closed reduction, open reposition should be employed. However, further investigation and clinical experience is needed to reach a better consensus among orthopaedic surgeons regarding the adequate mode of treatment for displaced supracondylar humeral fractures in children.

NOTE

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Дислоцирани супракондиларни преломи рамене кости код деце: поређење три терапијска приступа

Синиша Дучић[1,2], Марко Бумбаширевић[1,3], Владимир Радловић[2], Петар Никић[4], Зоран Букумирић[5], Радивој Брдар[1,2], Зоран Радојичић[1,2], Бојан Буква[2], Душан Абрамовић[2], Татјана Јарамаз Дучић[4]

[1]Универзитет у Београду, Медицински факултет, Београд, Србија;
[2]Универзитетска дечја клиника, Београд, Србија;
[3]Клинички центар Србије, Београд, Србија;
[4]Специјална болница за цереброваскуларне болести „Св. Сава", Београд, Србија;
[5]Институт за медицинску статистику и информатику, Универзитет у Београду, Медицински факултет, Београд, Србија

КРАТАК САДРЖАЈ

Увод Затворена репозиција с перкутаном фиксацијом је најчешће коришћен начин лечења супракондиларног прелома хумеруса у дечјем узрасту, али и даље не постоји сагласност о најбољој техници код повреда екстензионог типа.

Циљ рада Циљ ове студије је био да се упореде три уобичајене процедуре у лечењу дислоцираних супракондиларних прелома хумеруса екстензионог типа код деце.

Методе рада Урађена је проспективна студија која је обухватила 93 болесника (66 дечака и 27 девојчица) са супракондиларним преломом хумеруса екстензионог типа другог и трећег степена према Гартландовој (*Gartland*) класификацији која су упућена у нашу установу током шестогодишњег периода. На иницијалном прегледу прелом код 48 болесника је класификован као Гартландов прелом тип *II*, а код 45 испитаника као тип *III*. Испитаници су даље сврстани у три групе на основу начина лечења: затворена репозиција с перкутаном фиксацијом, отворена репозиција са фиксацијом Киршнеровим (*Kirschner*) иглама (К-иглама) и затворена репозиција са гипсаном имобилизацијом. Исход лечења и клиничке одлике су поређене међу групама и такође су процењене коришћењем Флинових критеријума.

Резултати Одличан исход лечења је забележен код 70,3% деце лечене затвореном репозицијом с перкутаном фиксацијом, као и код 64,7% деце лечене отвореном репозицијом са фиксацијом К-иглама. Код болесника лечених само затвореном репозицијом и гипсаном имобилизацијом исход лечења је био статистички значајно лошији с обзиром на то да је одличан исход забележен код свега 36,4% испитаника (p=0,011).

Закључак Затворена репозиција с перкутаном фиксацијом је метода избора лечења дислоцираних супракондиларних прелома хумеруса у дечјем узрасту, док је отворена репозиција са фиксацијом К-иглама добра алтернатива у случајевима с јасним индикацијама.

Кључне речи: супракондиларни преломи хумеруса; затворена репозиција; отворена репозиција; перкутана фиксација; компликације лечења; функционални исход

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