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The Comparative Evaluation of Treatment Outcomes in Pediatric Displaced Supracondylar Humerus Fractures Managed with either Open or Closed Reduction and Percutaneous Pinning

Srovnání výsledků léčení suprakondylické zlomeniny u dětí ošetřených otevřenou resp. zavřenou repozicí a perkutánní transfixací K-dráty

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ABSTRACT

PURPOSE OF THE STUDY

The aim of this study was to evaluate comparatively the outcomes of pediatric displaced supracondylar fractures of humerus which were treated with either closed reduction and percutaneous pinning (CRPP) or open reduction and percutaneous pinning (ORPP).

MATERIAL AND METHODS

The study included 100 children with displaced supracondylar fractures of the humerus, who were treated with either CRPP (group 1) or ORPP (group 2); the numbers of subjects in the study groups were equal. The treatment outcomes were assessed clinically and radiologically.

RESULTS

Ninety-six percent excellent or good cosmetic results were achieved in both groups, and 94% / 90% excellent or good functional results were achieved in groups 1 and 2 (respectively). There was no significant difference between Baumann and humero-capitellar angles of intact and operated sides in both groups, but there was an average carrying angle difference of 2,96 degrees in the group 1 and 1,52 degrees in the group 2 and these differences were statistically significant. Five cases (10%) from each group had superficial pin tract infection. Hypertrophic incision scar occurred in 6 (12%) patients performed ORPP.

CONCLUSION

Both CRPP and ORPP are successful treatment methods in the management of non-complicated and non-comminuted displaced supracondylar fractures of the humerus in pediatric ages and their outcomes are similar. Incision scar and the long duration of operation are the disadvantages of open surgery. For fixing the fracture, placement of two K-wires from the medial and lateral aspects which cross each other is enough to achieve a good stability. In ORPP practices, lateral incision is a simple and reliable approach despite of the dissatisfying scar tissue formation.

Key words: supracondylar humerus fracture, open reduction, closed reduction, percutaneous pinning.

INTRODUCTION

Supracondylar fractures of the humerus represent 3% of all fractures in children and a great proportion of 60% of all elbow fractures (9). Inadequate treatments cause undesirable cosmetic results and impair the functionalities of the elbow, hand, wrist and forearm.

In the management of displaced supracondylar fractures of the humerus, different surgical or non-surgical treatment modalities have been implemented until now to achieve the goals of the best reduction, minimal tissue injury, the shortest duration of hospital stay, and minimal rates of complications. Historically, the conservative approaches had been substituted by surgical modalities, and today, fluoroscopy-associated closed reduction-percutaneous pinning (CRPP) and open reduction-percutaneous pinning (ORPP) are accepted as the most popular treatment choices (3, 4, 13, 16, 17, 19, 21–26). In this study, the outcomes of these two treatment modalities implemented in our clinic were assessed by comparing one method with each other to provide guidance to physicians dealing with this issue.

MATERIAL AND METHODS

This study was conducted according to the principles of the Declaration of Helsinki and approved by the local ethics committee. The study included totally 100 patients (two treatment groups, 50 children in each group) with type 3 displaced fracture according to the Gartland classification (8) with relevant radiographs and other data in their hospital records who were presented voluntarily by their families to our clinic in response to the call out of nearly 420 children who were operated by the same surgical team because of supracondylar fracture of the humerus using either CRPP (group 1) or ORPP (group 2) in the period between 1999 and 2006. We excluded the patients with metabolic muscle or bone disorders, those having previous supracondylar fracture, pathologic fracture, open or comminuted fracture of the humerus, the cases with preoperative vascular lesions and those with accompanying bone fractures. Clinical, radiological and demographic data obtained from the hospital files of the patients and during the last visit were recorded.

Clinical evaluation

During the follow-up visits, the carrying angles of both operated and intact elbows were measured with goniometer using McRae method (20) and recorded in degree. The range of motion of the elbow was assessed at both sides using goniometer. Flexion/extension loss at operated side was determined basing on the range of motion measurements of the intact side. Using these data obtained, treatment results were assessed according to the criteria defined by Flynn et al. (6).

The vascular and nerve damages, cubitus varus, surgical site and pin tract infection and other complications developed in early, middle or late postoperative period were tabulated and median values regarding the data were calculated. Comparing the values obtained, it was assessed statistically the advantages and disadvantages of both surgical modalities over each other.

Radiological evaluation

At control visits, antero-posterior and lateral plain radiographs of both operated and intact elbows were taken. The Baumann angle was measured on the antero-posterior radiographs (2, 11) and humero-capitellar angle was measured on the lateral radiographs (2, 11). The changes in humero-capitellar angle (HCA) and Baumann angle at the operated extremity were determined basing on the measurements obtained from the intact counterparts. Afterwards, statistical comparisons were done between median values of two groups.

Surgical technique

All operations were performed under general anesthesia and in the supine position. The fluoroscopy was used during CRPP. When adequate reduction was decided to be achieved, two Kirschner wires were placed traversing each other, one from medial and one from lateral aspect for percutaneous fixing while the elbow was locked in full flexion (Fig.1). For fixation, 1.5 or 2 mm straight Kirschner wires were used. The decision of inserting the first wire from either medial or lateral aspect was made on the displacement of the distal fragment. If the distal fragment was displaced towards posteromedial, the first wire was inserted via the medial epicondyle. For cases having posterolateral displacement, the first wire was inserted via the lateral epicondyle. When inserting the wire at medial aspect, the skin and underlying subcutaneous tissues were pulled towards posterior over the ulnar groove with the help of fingers to take away the ulnar nerve towards posterior. After fixation procedure was completed, peripheral circulation of the extremity was checked, antero-posterior and lateral plain radiographs of the elbow were taken and Baumann and humero-capitellar angles were measured on these radiographic images. These measurements were compared to the values measured on the intact elbow radiographs taken previously. When it was decided that the reduction and fixation were adequate clinically and radiologically, posterior long arm splinting was done while the elbow flexed at 90 degrees and forearm in neutral position.

ORPP technique was performed because of preoperative ulnar nerve injury in 2 (4%) cases, and because of unsuccessful closed reduction or unavailability of fluoroscopy in other cases. Medial incision was used in 2 patients with ulnar nerve injury, lateral incision was performed to other cases. During the operation, the ulnar nerve was observed to be intact in both 2 patients and it was considered as neuropraxia. Kirschner wire fixing and post-fixation procedures were done as in CRPP.

The patients who did not develop any complication were discharged between two and seven days after the operation. The patients were seen again at one week and three weeks after the operation; it was assessed if there was reduction loss and the status of healing of the fracture on the radiographs taken on the day of control. If the patients having sufficient fracture healing, Kirschner wires were removed without giving anesthesia on an average of three weeks after the operation, and active and passive motion of the elbow were allowed. After the removal of Kirschner wires, the patients were followed up clinically and radiologically on monthly visits. The routine follow-up was stopped at the end of the third month. All 5 patients having the ulnar nerve injury that was already present in the preoperative period in two patients and was developed after ORPP in other three cases improved clinically within three months.

Statistical analysis

The data obtained were first assessed separately as the results of ORPP and CRPP methods. Afterwards, statistical comparisons were done between the groups to determine the advantages and disadvantages of both methods over each other. For statistical analyzes, SPSS 11.0 software (SPSS Inc, Chicago, IL, USA) was used. The Student's t-test was used to analyze descriptive statistical data (mean, standard deviation [SD]) and in case comparative data were parametric. The chi-square test was used to compare qualitative data, the results were

Fig. 1. The preoperative (A) and postoperative (B) radiographs of a patient with a displaced supracondylar humerus fracture.

assessed at 95% confidence interval, the significance level of $p<0.05$.

RESULTS

1. General results

The mean age of 100 patients included in the study was 7.04 years; of these patients, 69% were boys and 31% were girls. The mean age of the girls was 6.48 years (SD: 2.97), whilst the mean age of the boys was found to be 7.59 years (SD: 3.47). The ages varied from 1 year to 14 years in both groups; the groups were similar in terms of gender and age ($t = 1.544$, $p = 126$). Ninety-four percent of the cases had extension type fractures, 6% of them had flexion type fractures. The surgery was performed to 96 patients within the first 24 hours, 3 patients underwent operation within the first 48 hours, and one patient on the third day of the injury.

2. The results of the CRPP group

The duration of follow-up was 49.20 months (range, 9–91 months). The length of stay in hospital was 3.92 days (range, 1–12 days), the duration of operation (the time between the beginning and the end of the anesthesia procedure in operation room) was 40.68 minutes (range, 25–70 minutes). Thirty-four patients (68%) had an average flexion loss of 3.14 degrees (SD:4.60) or an average extension loss of 0.72 degrees (SD: 1.74) at the operated elbows in comparison with intact counterparts. The cubitus varus deformity occurred in 2 (4%) patients. According to the criteria defined by Flynn et al., excellent cosmetic results were achieved in 44 patients (88%) and excellent functional results were achieved in 40 patients (80%). Total rate of excellent and good results was 96% on cosmetic evaluation and 94% on functional evaluation (Table 1). There was no statistically significant difference between flexion type and extension type fractures with regard to cosmetic and functional results ($\chi^2 = 0.435$, $p = 0.804$ and $\chi^2 = 1.114$, $p = 0.774$, respectively). On radiological evaluation at the last control visit, there were no statistically significant differences between intact and operated sides with regard to Baumann and humero-capitellar angles, but the difference regarding to the carrying angle was found to be significant (Table 2). The superficial pin tract infection occurred in 5 patients (10%), the infection resolved without causing any further problems with orally administered amoxicillin therapy and removal of the wires after adequate fracture healing.

3. The results of the ORPP group

The follow-up period was 14.12 months (range, 5–56 months). The length of stay in hospital was 4.12 days (range, 1–10 days), the duration of operation was 46.26 minutes (range, 25–70 minutes). Forty-five patients (90%) had an average flexion loss of 4.6 degrees (SD: 3.72) or an average extension loss of 1.3 degrees (SD: 2.21) at the operated elbows in comparison with intact counterparts. The cubitus varus deformity occurred in 1 (2%) patient. According to the criteria defined by Flynn et al., excellent cosmetic results were achieved in 42 patients (84%) and excellent functional results were achieved in 29 patients (58%). Total rate of excellent and good results was 96% on cosmetic evaluation and 90% on functional evaluation (Table 3). There was no statistically significant difference between flexion type and extension type fractures with regard to cosmetic and functional results ($\chi^2 = 0.608$, $p = 0.738$ and $\chi^2 = 0.362$,

p=0.948, respectively). On radiological evaluation at the last control visit, there were no statistically significant differences between intact and operated sides with regard to Baumann and humero-capitellar angles, but the difference found in the carrying angle was significant (Table 4). The superficial pin tract infection occurred in 5 patients (10%), the infection resolved without causing any further problems with orally administered amoxicillin therapy and removal of the wires after adequate fracture healing. Six patients (12%) had hypertrophic incision scar; 28 (56%) patients or their relatives were dissatisfied with the incision scar.

4. The results regarding the comparisons between two groups

The dominant extremity was the right side in 93% of all cases. Of the fractures, 73% were in the left upper extremity and 27% of them occurred in the right upper extremity. Seventy percent of the fractures occurred in the non-dominant extremity. There was no statistically significant difference between the groups regarding to whether the affected extremity was dominant or non-dominant side ($\chi^2 = 0.009$, p = 0923). There was no significant difference between the groups with regard to the length of stay in hospital (t = 0.431, p = 0.667). The average duration of operation was statistically significantly shorter in the CRPP group (t = 2.185, p = 0.031). There were no significant differences between the groups in terms of the elbow flexion loss (t = 1.745, p = 0.084), extension loss (t = 1.460, p = 0.147) and changes in the carrying angle (t = 0.449, p = 0.655), and in humero-capitellar angle (t = 1.047, p = 0.298). According to the criteria defined by Flynn et al., there was no significant difference between the groups with regard to the functional ($\chi^2 = 7.409$, p = 0.060) and cosmetic ($\chi^2 = 0.447$, p = 0.800) results. The pin tract infection occurred in a rate of 10% in each group. Although the cubitus varus deformity was observed in 2 (4%) patients performed CRPP and in 1 (2%) patient performed ORPP, there was no statistically significant difference between the groups in terms of this deformity ($\chi^2 = 0.447$, p = 0.800). The ulnar nerve lesion occurring in 6% of ORPP cases in the postoperative period, which resolved spontaneously within 3 months, was considered as neuropraxia arising from the insertion of Kirschner wires. Since the patients were operated with the elbow lateral incision and the ulnar nerve was not directly contacted during the operation, we did not seek any correlation between the groups in terms of the nerve lesion.

DISCUSSION

At the present time, CRPP and ORPP techniques have been popular in the surgical management of displaced supracondylar fractures of the humerus in childhood period (3, 4, 13, 16, 17, 19, 21–28). Sometimes, surgeons have to choice one of these two techniques because of the characteristics of the fracture, technical availabilities and hospital resources. The CRPP technique requires fluoroscopic assistance and both the patient and the surgical team are exposed to radiation. The ORPP technique can be used for open fractures and fractures associated with vascular injury, when reduction cannot be ensured with closed reduction, if fluoroscopic assistance is unavailable, or as a preference. In the literature, it was reported that open reduction had to be preferred in 1.3–46% of cases (18). Are these two methods successful enough to treat displaced supracondylar fractures of the humerus in pediatric patients and is one of them superior to each other? In this study, we tried to find out the answers to these questions depending on generally accepted assessment criteria.

The functionality and cosmetic appearance of the operated elbow, the changes in Baumann angle and humero-capitellar angle, complications such as nerve-vessel damage, infection, cubitus varus, duration of operation, length of stay in hospital, and duration of fracture healing were taken into consideration to assess treatment outcomes. In addition, it was also evaluated the number and type of insertion of Kirschner wires used for fixation and successfulness of incision options in ORPP cases.

In our cases, the average duration of operation was 40.68 minutes and the length of stay in hospital was 3.92 days in CRPP group; whilst the average duration of operation was 46.26 minutes and the length of stay in hospital was 4.12 days in ORPP group. The length of hospital stay is similar in both groups. However, the duration of operation is statistically significantly shorter in CRPP cases. Although there are studies (23) reporting longer length of stay in hospital for ORPP procedures compared to our data, we think that this parameter is neither a significant advantage nor a disadvantage between CRPP and ORPP in patients having similar fracture type and soft tissue damage characteristics. However, the duration of operation, although it is associated with the experience of the surgical team, is shorter in CPRR technique providing a favorable advantage as observed in both our cases and in other trials (2, 3, 11, 22, 25).

The rate of pin tract infection was 10% in each patient group. This rate is consistent with the literature data (3, 22–24). These infections resolved without any additional problems with the use of oral antibiotics and removal of the fixing wires after adequate bone healing. The surgical site infection was not observed in any patient from ORPP. We think that surgical site infection, which is mentioned as a disadvantage in some studies (9, 29), would not be a problem in case suitable operating room conditions and a good postoperative patient care are provided. In addition, we did not observe any other complications, such as myositis ossificans, osteoarthritis, or nonunion in our cases.

Open reduction can be performed via lateral, medial, anterior, or posterior incisions. It is already controversial which incision should be used. Some researchers recommended the anterior approach since the neurovascular bundle and biceps tendon could be easily recognized and taken away from operation area (1). With posterior approach, gaining the range of motion of the elbow takes long time because the triceps muscle is damaged (9). Some authors claimed that the risk of development of

varus was high with lateral approach since the medial colon could not be controlled, however, medial intervention was favorable because the ulnar nerve could be identified and the medial colon could be controlled (5, 19). We preferred lateral incision, because it is simple and allows to expose easily the fracture line and anterior tissues; considering our treatment outcomes, we think that it is a reliable and simple approach.

Hypertrophic incision scar occurred in 12% of our patients. Fifty-six percent of our cases declared their dissatisfaction with the incision scar. In some other studies, similar results have been reported (5). Incision scar is one of the disadvantages of open surgery.

The iatrogenic ulnar nerve injury was not observed in any patient performed CRPP, whilst it occurred in a rate of 6% among patients undergoing ORPP. The findings of nerve injury resolved spontaneously within 3 months. Iatrogenic vascular damage, radial or median nerve injuries were not observed in any patient groups. Iatrogenic ulnar nerve damage occurs usually during the insertion of Kirschner wire at medial aspect or occasionally during the reduction generally as neuropraxia (2, 11). It was reported in the literature that the rate of iatrogenic ulnar nerve injury varied in a range from 0 to 10.5% (2, 11, 25). Since our patients were performed ORPP through lateral incision, we did not seek any difference between the groups regarding ulnar nerve injury. Several approaches have been proposed to avoid the nerve injury, e.g. the use of medial incision, determination of the nerve trace by stimulating the ulnar nerve during the insertion of wires at medial aspect or exposing the nerve through a small incision (1.5 cm in size) over the medial epicondyle, fixing the bone fragments with multiple wires inserted from the lateral aspect only (13, 14, 16, 17). As is understood, iatrogenic nerve injury may occur in certain rates during both CRPP and ORPP procedures, however, this damage usually manifests as neuropraxia and recovers without trouble. The use of two cross wires inserted at medial and lateral aspects does not seem to be a significant disadvantage with regard to this complication. However, other techniques that potentially reduces further the risk of iatrogenic ulnar nerve injury can be considered.

Another disadvantage of percutaneous pinning is the reduction loss that may result in deformity. It was reported in many trials that the most stable wire configuration was Kirschner wire-model inserted at both medial and lateral aspects (4, 15, 26, 30). None of our patients developed reduction loss. We think that the use of two cross wires inserted at medial and lateral aspects is an adequate and appropriate fixing method to fix the fractures fragments.

The rate of occurrence of cubitus varus was reported to be 1.6–9.52% (4, 22, 23, 25) in CRPP procedures and 0–23% (3, 22, 25) in ORPP procedures. It arose in a rate of 4% in the CRPP group and 2% in the ORPP group. Although there are studies reporting higher incidences of cubitus varus in CRPP patients compared to ORPP cases (10), there was no statistically significant difference between our patient groups with regard to cubitus varus. It was reported that cubitus varus deformity-related ulnar nerve damage might occur in the late period (7). Ulnar nerve damage was not observed in our 3 patients with this deformity during the follow-up period. Given

Table 1. Results of group 1 according to outcome criteria

Cosmetic results				
Loss of carryng angle (results)		**Fracture type**		**Total score**
		Extension	**Flexion**	
0–5° (excellent)	n	41	3	44
	%	82	6	88
5–10° (good)	n	4	0	4
	%	8	0	8
10–15° (fair)	n	0	0	0
	%	0	0	0
>15° (poor)	n	2	0	2
	%	4	0	4
Total score	n	47	3	50
	%	94	6	100

Functional results				
Loss of joint motion (results)		**Fracture type**		**Total score**
		Extension	**Flexion**	
0–5° (excellent)	n	38	2	40
	%	76	4	80
5–10° (good)	n	6	1	7
	%	12	2	14
10–15° (fair)	n	1	0	1
	%	2	0	2
>15° (poor)	n	2	0	2
	%	4	0	4
Total score	n	47	3	50
	%	94	6,0	100

n=number

Table 2. Comparison between angle values of operated and nonoperated sides in group 1

Angles		**Mean values**	**Standard deviation**	**t**	**Significant level**
BA	nonoperated side	69.78	5.55	-1.094	p=0.279
	operated side	70.22	6.08		
CA	nonoperated side	10.80	4.27	4.171	p=0.000
	operated side	7.84	6.28		
HCA	nonoperated side	40.84	6.54	1.414	p=0.164
	operated side	40.16	7.14		

***BA:** Baumann angle, **CA:** Carrying angle, **HCA:** Humerocapitellar angle*

Table 3. Results of group 2 according to outcome criteria

Cosmetic results				
Loss of carryng angle (results		**Fracture type**		**Total score**
		Extension	**Flexion**	
0–5° (excellent)	n	39	3	42
	%	78	6	84
5–10° (good)	n	6	0	6
	%	12	0	12
10–15° (fair)	n	1	0	1
	%	2	0	2
>15° (poor)	n	1	0	1
	%	2	0	2
Total score	n	47	3	50
	%	94	6	100

Functional results				
Loss of joint motion (results)		**Fracture type**		**Total score**
		Extension	**Flexion**	
0–5° (excellent)	n	27	2	29
	%	54	4	58
5–10° (good)	n	15	1	16
	%	30	2	32
10–15° (fair)	n	4	0	4
	%	8	0	8
>15° (poor)	n	1	0	1
	%	2	0	2
Total score	n	47	3	50
	%	94	6	100

n=number

Table 4. Comparison between angle values of operated and nonoperated sides in group 2

Angles		**Mean values**	**Standard deviation**	**t**	**Significant level**
BA	Nonoperated side	68.52	6.29	-0.556	p=0.581
	Operated side	68.80	6.59		
CA	Nonoperated side	10.14	3.76	2.496	p=0.016
	Operated side	8.62	3.94		
HCA	Nonoperated side	43.52	5.84	1.359	p=0.180
	Operated side	42.74	7.12		

***BA**=Baumann angle, **CA**=carrying angle, **HCA**=humerocapitellar angle*

our results, CRPP and ORPP appear to be successful treatment modalities in terms of cubitus varus.

Although there are studies reporting that these treatment modalities did not lead to any significant angular changes in the elbow compared to the intact elbow (23), in our study the changes in Baumann and humero-capitellar angles were found to be statistically insignificant, but the changes in the carrying angle was significant. The carrying angle of the operated elbow reduced by an average of 2.96 degrees in the CRPP group and an average of 1.52 degrees in the ORPP group. The proportion of the cases showing a change of more than 10 degrees in the carrying angle was 4% in each group. The changes in the carrying angle were similar in both groups. As can be seen from these data, both surgical techniques reduces minimally the carrying angle.

CRPP cases had an average flexion loss of 3.14 degrees and an average extension loss of 0.72 degrees; the patients performed ORPP had a flexion loss of 4.6 degrees and an extension loss of 1.3 degrees. Eighty-two percent of CRPP cases and 78% of ORPP cases showed either no change or minimal loss less than 5 degrees in range of motion. The losses of range of motion arisen from any of surgical method were similar. The loss of range of motion more than 5 degrees usually results from insufficient reduction of the humero-capitellar angle (11). Literature data (4, 11, 22, 23, 25) and our results demonstrate that both methods are able to reduce accurately this angle and loss of range of motion of the elbow is at minimal levels. Despite there are studies reporting that open surgery caused much loss of range of motion in the elbow because of wide soft tissue damage (21, 22, 29); as is in our study, comparative studies (21, 22) found the results of both methods to be statistically similar with lesser loss of range of motion in closed method. Since open surgery is generally performed for comminuted fractures, fractures not being reduced by closed reduction attempts, or supracondylar humerus fractures with vessel-nerve damage, these patients are more likely to have loss of range of motion of the elbow. If either of these two methods is used for the fractures showing similar characteristics, as is in our study, the outcomes will be similar.

According to the criteria defined by Flynn et al. excellent and good results were achieved cosmetically in 96% of cases and functionally in 94% of cases in CRPP group; whilst, in ORPP group, excellent and good cosmetic results were achieved in 96% of patients and excellent and good functional results were achieved in 90% of cases. Our study showed that both surgical methods provided successful and alike cosmetic and functional outcomes. In other studies, it was also reported that successful results were achieved with both methods in the majority of patients (3, 4, 6, 12, 19, 22, 23, 27). Among these trials, there are studies reporting that the outcomes of these methods were similar, and there are also studies claiming that one of these two methods was superior to each other. There are studies reporting that closed reduction was more challenging and had worse outcomes in flexion-type fractures compared to extension-type fractures (11). In our series, although the proportion of flexion-type fractures was as low as 6%, treatment outcomes are successful and these two methods can be considered as reliable for both type of fractures.

CONCLUSION

If the surgical team has enough experience, CRPP and ORPP are successful treatment methods in the management of non-complicated and non-comminuted displaced supracondylar fractures of the humerus in pediatric ages and the treatment outcomes of these methods are alike. Incision scar and the long duration of operation are the disadvantages of open surgery. Considering the risk of exposure to radiation for the patient and surgical team, CRPP can be perform preferably in the centers having proper facilities. In the centers where suitable imaging resources can not be provided, ORPP method allows similar results. For fixing the fracture, insertion of two K-wires from the medial and lateral aspects which cross each other is enough to achieve a good stability. In ORPP practices, lateral incision is a simple and reliable approach despite of the dissatisfying scar tissue formation.

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