ORIGINAL ARTICLE

Does rotational deformity cause poor outcomes after pediatric supracondylar humerus fractures?

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ABSTRACT

BACKGROUND: We aimed to show the effect of rotational deformity on the development of cubitus varus deformity (CVD) complication after supracondylar humerus fracture surgery.

METHODS: Patients with Gartland type II, and more severe fractures treated with Closed reduction and percutaneous pinning alone were included in the study. Rotational deformity was assessed with the formula described by Henderson et al. Patients with rotational deformity >10° were included in Group 1, and patients with deformity <10° in Group 2. In terms of CVD development, patients were evaluated with the Baumann angle measurements made on the carrying angle and final follow-up radiographs. Patients who developed CVD were divided into two groups: Group A included patients who developed CVD and Group B included patients who did not develop CVD. The cosmetic and functional results were evaluated using Flynn criteria.

RESULTS: Eighty-eight patients who met the inclusion criteria were enrolled in the study, 32 were female and 56 were male. The mean age at the time of surgery was 6.0±2.8 years and the mean follow-up time was 5.1±2.5 years. Based on measurements, Group 1 had 13 patients and Group 2 had 75 patients. Only four of the 88 had developed CVD. Three of these patients had a rotational deformity of ≥20°. The mean age of patients in group A was 2.1 years and the mean carrying angle was 5.7°±1.5° varus (P<0.001). According to the Flynn cosmetic criteria, Group A and Group 1 had significantly worse outcomes (P<0.001).

CONCLUSION: In conclusion, fixation of the distal fragment in rotation may be associated with CVD and intraoperative assessment is of great value to avoid long-term deformity and cosmetic degradation.

Keywords: Closed reduction percutan pinning; cubitus varus deformity; pediatric; rotational deformity; supracondylar humerus fracture.

INTRODUCTION

Supracondylar humerus fractures (SCHF) are common in children due to a weak distal humeral metaphysis.[1] SCHF occupies an important place in pediatric orthopedic practice because it can lead to serious acute and chronic complications. While neurovascular injury and compartment syndrome may occur in the acute phase, long-term deformity of the elbow, ulnar nerve palsy, and limitation of motion may occur.[2,3]

The goal of SCHF treatment is to fully restore elbow mobility, maintain a cosmetically normal elbow, and protect the patient from potential neurovascular complications. Closed reduction and percutaneous pinning (CRPP) have become the preferred treatment modality in the management of SCHF.[3-5] The nature of the fracture and, accordingly, the degree of instability at the fracture line may complicate anatomic reduction.[1] The remodeling capacity of the distal part of the humerus in the coronal plane is quite low.[6,7] Therefore, it is important to achieve anatomic reduction. In the long term, cubitus varus deformity (CVD) may occur after SCHF, espe-

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cially if an anatomic reduction in the coronal plane cannot be achieved.[8,9] CVD is the most commonly reported long-term complication after SCHF.[8,10]

Although the relationship between developing CVD and fixation of the fracture in the rotation is well known, few studies have been performed to determine the presence of rotation in the initial period after fixation of the fracture. The most recent study on this topic is an experimental study published by Henderson et al.[8] in 2007. They obtained radiographs after creating a fracture model and fixing it with 5° rotations between fragments. Later, the authors determined the degree of rotational deformity by inserting the measurement results obtained from the radiographs into a mathematical formula. In earlier studies, a definite degree could not be obtained, and the authors reported their results as percentages.[5,11]

When the literature was reviewed, we saw that the methods described for rotational deformity measurements were not applied to patient groups. In our study, we aimed to show the effect of the presence of rotational deformity on the development of cubitus varus after SCHF surgery.

MATERIALS AND METHODS

Institutional review board approval was obtained from the clinical research ethics committee before starting the study (19-KAEK-247). Patients who underwent surgery for SCHF at our hospital between 2011 and 2019 were reviewed retrospectively. We included patients with incomplete distal humeral ossification, Gartland Type II, and more severe fractures treated with CRPP alone. We excluded patients with flexion-type SCHF fractures, open fractures, who underwent open reduction during surgery for any reason, with <1 year of follow-up, with metabolic bone disease, and with a history of fracture of the same elbow.

Demographic data were scanned from the archive and patients who met the criteria were called for final control. In the last examination; carrying angle measurement, joint range of motion, and current elbow X-rays were evaluated.

The rotational deformity measurements of the patients were made on the anteroposterior (AP) and lateral radiographs taken during the surgery using the formula defined by Henderson et al.[8] (Fig. 1). In that study, Henderson et al. reported that the presence of a rotational deformity of <10° may not be noticed; therefore in our study; patients with a deformity of more than 10° were called Group 1 and patients with a deformity of <10° were called Group 2.

Carrying angle measurements of the patients were performed using the method described by McRae.[12] To determine the CVD radiologically, Baumann angles were measured on comparative AP elbow radiographs taken in the presence of an independent orthopedic specialist. According to the measurements conducted, the patients were divided into two groups in terms of CVD presence. Patients who developed CVD were called Group A and patients who did not develop were called Group B.

The clinical results of the patients were evaluated using the functional and cosmetic criteria defined by Flynn et al.[13] Flynn cosmetic criteria is a classification based on the change in carrying angle. The carry angle change is evaluated as excellent if it is between 0° and 5°, good if it is between 6° and 10°, moderate if it is between 11° and 15°, and bad when it is more than 15°. All complications observed in the early postoperative period and at the last examination were recorded and the evaluation was completed.

In all patients, reduction was performed under general anesthesia by forced flexion of the elbow in extension and pronation of the forearm after axial traction. Medial or lateral compression was applied depending on the direction of displacement of the distal fragment. After assessing the reduction of the medial and lateral columns of the distal humerus

Table 1. Demographic data and features of patients

Age (year)	6.03±2.88
Gender (female/male)	32/56
Follow-up period (years)	5.15±2.55
Fractured limb (right/left)	37/51
Baumann's angle (°)	21.38±4.02
Time to surgery (min)	9.1±12.05
Operation time (min)	53.58±26.02
Carrying angle (°)	7.2±3.13
Gartland classification	
Type IIa	23
Type IIb	15
Type III	39
Type IV	11
Pin number	
2	48
>2	40
Pin configuration (L/M)	
1+1	48
2+1	33
2+2	7
Flynn cosmetic criteria	
Excellent	80
Good	5
Fair	3
Flynn functional criteria	
Excellent	81
Good	7

Data presented as mean±SD and median (IQR); SD: Standard deviation; IQR: Interquartile range.

with the oblique views and the sagittal plane with the hourglass sign in the lateral view, osteosynthesis was performed with crossed Kirschner wires (K-wires) inserted from the medial and lateral sides under fluoroscopic control. To increase the stability of the fracture fixation, additional K-wires were inserted according to the width of the medullary canal. Postoperatively, a long-arm splint was applied to all patients, with the elbow flexed 90°, and the forearm maintained in neutral rotation.

Statistical Methods

We evaluated the patient's age at the time of fracture, sex, the time elapsed after surgery, sides of the fractured limb, the type of fracture, the number of K-wires used during surgery, the carrying angle, the Flynn cosmetic and functional criteria, measurements of rotational deformity on early post-operative radiographs, duration of surgery, and time to surgery. We analyzed the data using SPSS Statistics Software (version 23.0, IBM Corp, Armonk, NY, USA.). We analyzed the categorical data with the Pearson's Chi-square, Fisher's exact, and the Fisher-Freeman-Halton tests. For the other data, we assessed the distribution of the data with the Kolmogorov-Smirnov test. We evaluated parametric and non-parametric data with Student's t-test and the Mann-Whitney U test, respectively. We evaluated the dependent groups (for nonnormally distributed data) with the Wilcoxon test. We considered $P<0.05$ to be statistically significant in all the tests.

RESULTS

Eighty-eight patients who met the inclusion criteria were enrolled in the study, 32 were female and 56 were male. The mean age at the time of surgery was 6.0±2.8 years and the mean ± standard deviation follow-up time was 5.1±2.5 years. Demographic data of the patients who participated in our

Table 2. Evaluation of our patients with regard to the development of rotational deformity

	Group I (n=13)	Group II (n=75)	P-value
Age (year)	5.5±3.35	6.12±2.8	0.477
Gender (female/male)	5/8	27/48	0.865
Follow-up period (years)	4.58±2.23	5.25±2.61	0.381
Fractured limb (right/left)	9/4	28/47	0.031
Baumann's angle (°)	19.08±4.09	21.77±3.9	0.025
Time to surgery (min)	8.62±8.32	9.19±12.63	0.876
Operation time (min)	54.62±28.97	53.4±25.68	0.877
Carrying angle (°)	6.23±5.51	7.37±2.52	0.226
Cubitus varus occurred	3	1	
Gartland classification			
Type IIa	4	19	0.931
Type IIb	2	13	
Type III	6	33	
Type IV	1	10	
Pin number			
2	6	42	0.510
>2	7	33	
Pin configuration (L/M)			
1+1	6	42	0.287
2+1	7	26	
2+2	-	7	
Flynn cosmetic criteria			
Excellent	9	71	<0.001
Good	1	4	
Fair	3	-	
Flynn functional criteria			
Excellent	11	70	0.284
Good	2	5	

Data presented as mean±SD and median (IQR); SD: Standard deviation; IQR: Interquartile range.

study are given in Table 1.

Based on the measurements, there were 13 patients in Group 1 and 75 patients in Group 2. It was observed that CVD developed in three patients in Group 1 (P=0.010) and they had significantly worse results in Flynn cosmetic criteria (P<0.001). There were no other significant differences between the groups in age, sex, carrying angle, follow-up time, time to surgery, surgery time, the number of pins, and configurations (Table 2). The characteristics of the patients with rotational deformity are presented in Table 3.

When the patients participating in our study were examined in terms of CVD presence, it was observed that CVD was present in four of our patients. Three of these patients had more than 20° of rotational deformity. The mean age of patients in group A was 2.1±1 years and the mean carrying angle was 5.7±1.5 varus. The mean age of our patient in group B was 6.2±2.8 years, while the mean carrying angle was 7.7±1.7 valgus. The mean age (P=0.005) and carrying angle (P=0.001) were found to be significantly lower in Group A. Based on the Flynn cosmetic criteria, two of the patients in Group A were rated as moderate and one was rated as good; the patient in Group B had significantly worse results (P<0.001). Although the Baumann angle was lower in group a, it was not statistically significant (P=0.672) (Table 4).

There was no neurovascular deficit at the last examination of the patients. A review of the patient records revealed that distal pulses were undetectable in four of our patients at the time of enrollment but recovered spontaneously after surgery. Ulnar nerve paralysis developed postoperatively in one of our patients, and the ulnar nerve palsy disappeared after removal of the medial K-wire. Three of our patients who had two K-wires sent laterally developed an infection at the insertion site. Two of these patients healed with dressing control, while one patient required oral antibiotic therapy and one wire had to be removed during the initial period.

DISCUSSION

After SCHF, it is possible to achieve anatomical reduction without ignoring the rotational deformity at surgery and to prevent the development of CVD in the late phase. Alignment of these fractures does need to be monitored closely for achieve and maintain adequate reduction and preventing loss of reduction, deformities that develop in the coronal plane usually occur after inadequate reduction because the remodeling capacity in this plane is low.[4,7,14] Moraleda et al.[15] examined untreated Type II SCHF fractures and reported that the incidence of CVD development was 26.1% and the most effective method to avoid this situation was to provide anatomical reduction to mimic the healthy side. We measured rotational deformity and found that the presence of rotational ≥10° in the early period was associated with worse cosmetic Flynn results and greater CVD development.

There have been a limited number of studies in the literature investigating the presence of rotational deformity after

Table 3. Demographic characteristics of patients with rotational deformity

	Patient												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Age (years)	1	3	1.5	8	6	9	1	6	8	5	7	12	4
Gender	Boy	Girl	Boy	Girl	Boy	Girl	Girl	Boy	Boy	Boy	Boy	Boy	Girl
Fractured limb	Sağ	Sağ	Sol	Sağ	Sağ	Sağ	Sağ	Sol	Sağ	Sağ	Sağ	Sol	Sol
Follow-up time (years)	4	4	3	5	4	3	8	4	2	9	1.5	5	7
Gartland type	IIb	IIb	III	III	III	IIa	III	IIa	IIa	IIa	III	IV	III
Pin configuration	LL + M	LL + M	LL + M	L + M	LL + M	LL + M	LL + M	L + M	LL + M	L + M	LL + M	L + M	L + M
Rotational deformity (°)	20	30	30	20	20	20	20	10	10	10	10	10	10
Fractrured limb carrying angle (°)	−8	−3	−8	−4	8	9	10	7	7	8	8	10	10
Nonfractrured limb carrying angle (°)	5	8	5	11	8	8	10	7	7	8	8	7	12
Flynn cosmetic criteria	Fair	Good	Fair	Fair	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Flynn functional criteria	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Good

L + M: One K-wire from the lateral and one from the medial; LL + M: Two K-wires from the lateral and one from the medial.

Table 4. Evaluation of our patients with regard to the development of cubitus varus deformity

	Group A (n=4)	Group B (n=84)	P-value
Age (years)	2.1±1	6.2±2.8	0.005γ
Gender (female/male)	1/3	31/53	>0.999
Fractured limb (right/left)	1/3	36/48	0.636
Fractured extremity carrying angle (°)	−5.7±1.5	7.7±1.7	0.001
Baumann angle (°)	19.7±4.0	21.4±4.0	0.672
Gartland classfication			
IIa	-	23	0.280*
IIb	2	14	
III	2	36	
IV	-	11	
Pin configuration (lateral + medial)			
1+1	1	47	0.213*
2+1	2	30	
2+2	1	7	
Flynn cosmetic criteria			
Excellent	-	80	<0.001*
Good	1	4	
Fair	3	-	

*Fisher-Freeman-Halton tests were used; γ: Student's-t-test was used. Data presented as mean±SD and median (IQR); SD: Standard deviation; IQR: Interquartile range.

SCHF. The first study on this subject was published in 1962 by Lonroth[5] in a series of 13 patients. The authors evaluated the detectability of the presence of rotation by applying 5° rotations, and they recommended performed the reduction again if there was >5° rotation when comparing two elbows. In a study using the lateral rotational percentage calculation method by measuring the amount of displacement to the length of the distal fragment, the authors examined 138 patients and reported that the probability of the development of rotational deformity is higher, especially in the detection of type 3 fractures, and that CVD may develop accordingly.[11]

In subsequent studies, the net degree of rotational deformity was calculated and a fracture model was used by Henderson et al.[8] The authors showed that after measuring the proximal and distal metaphyseal parts of the fracture fragment in the AP and lateral planes on the acquired radiographs, the degree of rotation could clearly be determined by trigonometric calculation. The authors also stated that rotational deformity <10° cannot be calculated and that the method they described gives the most accurate results for deformities between 15 and 55°.[8] Based on this information and these methods, we divided our patients into two groups based on the measurements from radiographs taken immediately after surgery. We found that 13 of our patients were fixed in rotation.

Two patients who had developed CVD had rotational deformity of 30°, one patient had rotational deformity of 20°, and one patient did not develop rotational deformity. Two of our patients with rotational deformity were operated on for Gartland type IIb fractures and one patient was operated on for a Gartland type III fracture. Our patient without rotational deformity was operated on for a Gartland type III fracture. Based on the literature, Gartland type IIb and type III fractures predispose individuals to develop CVD.[7] CVD can also be observed in the late phase of Gartland Type I fractures associated with medial collapse and fragmentation.[7]

Takahara et al.[16] reported that a malrotation of 30–45° at the elbow is acceptable. In contrast, Prabhakar et al.[1] reported that this level of malrotation is unacceptable. We found that CVD occurred in patients with fractures detected at a rotation angle of ≥20°. However, we had a patient with no rotational deformity on early radiographs but who still developed CVD. Unlike the other three patients who had developed CVD, osteosynthesis was achieved by inserting two K-wires from the medial and lateral sides. The previous studies have found that growth disturbances due to medial arrest or lateral stimulation can lead to deformities, and in rare cases, trochlear necrosis causes the development of CVD.[17-20] Moreover, the vessels supplying nutrients to the trochlea arise from the anastomoses in the posterior part, enter the bone from the periphery of the trochlea, and supply it by diffusion.[7,21] These vessels can be damaged during trauma and manipulation, causing avascular necrosis. Although no rotational deformity was seen on the radiograph taken during surgery, we believe that the repeated manipulations to achieve reduction and sending two K-wires to preserve the reduction led to the development of CVD.

In an experimental study conducted to determine whether there is a relationship between rotational deformity and CVD development, the authors performed varus angulation, internal rotation, posterior angulation, flexion contracture, and combinations of these conditions. The authors reported that the deformity most commonly associated with the development of CVD is fixation in varus, while the second most common fixation is in internal rotation and flexion contracture.[22] Similarly, Dowd and Hopcroft[23] reported that 40% of patients with internal rotation fixation developed CVD, and these patients also had varus and flexion contractures. We found that 23% of our patients with rotational deformity developed CVD, and the Baumann angle of these patients was lower compared with patients without CVD.

When we examined the characteristics of our patients with CVD, we found that they were significantly younger than the patients who did not develop CVD. However, we could not find any publication comparing age and CVD. When comparing groups A and B, the low mean age of group A patients, although not significant, suggests that there may be a relationship between reduction problems and young age. Therefore, extreme caution should be used when reducing fractures in young children. Avoiding repetitive manipulation can prevent iatrogenic injuries that could lead to CVD.

The results of our patients enrolled in the study were significantly worse according to Flynn's cosmetic criteria in patients with rotational deformity and CVD. We attribute the fact that the results were significantly worse according to the Flynn cosmetic criteria, although there was no significant difference in the change in carrying angle in this group, to the fact that cubitus varus is more common in patients with rotational deformity. In addition, in two studies of the changes in the carrying angle in the pediatric age group, the authors reported an annual increase of 0.42° in boys and 0.6° in girls up to the age of 15 years.[24,25] We think that the better bearing angle and indirectly the cosmetic results according to Flynn criteria in the groups without deformities are due to the higher average age of the patients in this group.

It has been reported that the use of crossed K-wires in fracture fixation in SCHF treatment is a more biomechanically robust configuration than other methods.[26,27] In a study published by Diri et al. to increase stability to protect fracture reduction, it was reported that more stable fixation was achieved when a third wire was added in addition to the crossed K-wire.[26] Turgut et al. reported in their study that loss of reduction is more common in Gartland Type III and IV fractures due to fragmentation and deterioration of periosteal integrity.[28] In our study, we used the same method to increase stability. Although we had patients with rotational deformity in our post-operative follow-up and evaluations, there were no patients who required reoperation due to loss of reduction. Yıldırım et al. observed more loss of reduction in Gartland type IIa and type IIb patients with oblique and type IIa fractures that they treated conservatively.[29] The authors attributed this result to the possibility that the contact area and stability of oblique fractures were worse affected by these fractures and that reduction loss was less in type IIb fractures and more attention was paid to reduction in these patients.[29] Considering the results of our study, we attribute the very rare occurrence of rotational deformity and cubitus varus in Gartland type 4 patients, similar to the authors, to more careful management during treatment.

This study contributes to literature with an experimental approach to measure rotational deformity in a group of patients, and to establish a clinical evaluation. And also this study includes a series of patients operated on with the same surgical technique in a single center and with a long follow-up period. The limitations of our study are that it is retrospective, the operations were performed by surgeons with different experiences, the fractures were of different severity and, accordingly, different pin configurations were used, and there were no control groups.

Conclusion

Rotational deformities that may occur during fixation of SCHF can be determined by measurements taken before surgery is completed. Because fixation of the distal fragment in rotation may be associated with CVD, intraoperative assessment is of great value to avoid long-term deformity and cosmetic degradation.

Ethics Committee Approval: This study was approved by the Gaziosmanpasa University School of Medicine Clinical Research Ethics Committee (Date: 05.12.2019, Decision No: 83116987-233).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Pediatrik suprakondiler humerus kırıklarından sonra rotasyonel deformite kötü sonuçlara neden olur mu?

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AMAÇ: Bu çalışmada, suprakondiler humerus kırığı (SKHK) cerrahisi sonrası rotasyonel deformitenin kübitus varus deformitesi (KVD) komplikasyonu gelişimine etkisini göstermeyi amaçladık.
GEREÇ VE YÖNTEM: Distal humerus ossifikasyonu tamamlanmamış, Gartland Tip II ve daha ciddi kırığı olan ve kapalı redüksiyon perkütan pinleme (KRPP) ile tedavi edilen hastalar çalışmaya dahil edildi. Hastaların değerlendirilmesinde demografik veriler ve ameliyat sırasında çekilen radyografiler tarandı. Rotasyonel deformite ölçümü, Henderson ve ark. tarafından tanımlanan yönteme göre yapıldı. Rotasyonel deformitesi >10° olan hastalar grup 1'e, deformitesi <10° olan hastalar grup 2'ye alındı. KVD gelişimi açısından hastalar taşıma açısında yapılan Baumann açı ölçümleri ve son kontrol grafileri ile değerlendirildi. KVD gelişen hastalar iki gruba ayrıldı; Grup A, KVD gelişen hastaları, grup B ise KVD gelişmeyen hastaları içermektedir. Kozmetik ve fonksiyonel sonuçlar Flynn kriterleri kullanılarak değerlendirildi.
BULGULAR: Kabul edilme kriterlerini karşılayan 88 hasta çalışmaya alındı, 32'si kadın, 56'sı erkekti. Ameliyat anındaki ortalama yaş 6.0±2.8, ortalama takip süresi 5.1±2.5 yıldı. Ölçümlere göre grup 1'de 13 hasta, grup 2'de 75 hasta vardı. 88 kişiden sadece dördünde KVD gelişmişti. Bu hastaların üçünde ≥20° rotasyonel deformite vardı. Grup A'daki hastaların ortalama yaşı 2.1 ve ortalama taşıma açısı 5.7°±1.5 varus idi (p<0,001). Flynn kozmetik kriterlerine göre, grup A ve grup 1 önemli ölçüde daha kötü sonuçlara sahipti (p<0.001).
TARTIŞMA: Sonuç olarak, distal fragmanın rotasyonda sabitlenmesi KVD ile ilişkili olabilir, intraoperatif değerlendirme, uzun süreli deformite ve kozmetik bozulmayı önlemek için büyük değer taşır.
Anahtar sözcükler: Cubitus varus deformitesi; kapalı redüksiyon perkütan çivileme; pediatrik; rotasyonel deformite; suprakondiler humerus kırığı.

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