Original Article

Prognosis and Risk Factors of Nerve Injuries in Displaced Pediatric Supracondylar Humerus Fractures

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ABSTRACT

Background: Supracondylar humerus (SCH) fractures are serious injuries due to the neighborhood of critical neural and vascular structures. One of the most devastating complications of SCH fractures is neurological damage, since it may cause permanent disability. The aim of this study is to categorize neurological complications, to report long-term functional outcomes, and to determine risk factors associated with childhood SCH fractures. **Methods:** The records of 375 children were reviewed retrospectively. Data about amount and direction of displacement, the shape of the fracture, age at the time of fracture, gender, time from impaction to surgery, time of surgery, type of neurological injury, and recovery time were recorded. **Results:** Neurological complications were seen in 37 (9.85%) children. Thirteen (35.1%) of the children had an iatrogenic nerve injury. All iatrogenic injuries were fully recovered in this study. However, 2 children who had combined neurological injury of radial, ulnar, and median nerves did not recover. Nearly 95% of all children who had neurological injury recovered fully. An anterior long and sharp bone fragment (spike) was observed in most of the children with neurological injury, and this spike was seen in 14 (58.3%) patients who had a trauma-related injury (n = 24). **Conclusion:** The prognosis of these nerve injuries is excellent, especially the iatrogenic ones. A long and sharp bone fragment (spike) may be responsible for nerve injuries in some children. Surgical exploration is not necessary after an iatrogenic nerve injury when there is no neurotmesis. Patience and care are utmost needed to handle neurological complications.

KEYWORDS: *Cross-pinning, iatrogenic nerve injury, neurological injury, prognosis, supracondylar fracture*

BACKGROUND

Fractures around the elbow constitute about 5–10% of all childhood fractures, and two-thirds of these fractures are supracondylar humerus (SCH) fractures.[1,2] SCH fractures cause serious injuries due to the proximity of critical neural and vascular structures, increased risk of compartment syndrome, and difficulties in reduction[1]; therefore SCH fractures represent an orthopedic emergency.[3]

One of the most devastating complications of SCH fractures is neurological damage, since it may cause permanent disability. The incidence of neurological complications varies from 5% to 19% in the literature.[4-6]

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Nerve injuries can happen as a primary lesion at the time of initial impact due to stretching, entrapment, and disruption of nerve in fracture site; or they can occur as an iatrogenic injury during treatment period mostly due to medial pinning of the fracture.[7] Excessive manipulation, immobilization in hyperflexion, swelling, and edema may also cause nerve dysfunction during the treatment period.[8]

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Most symptoms are local hypoesthesia or minor motor dysfunction, and they quickly recover spontaneously after the fracture.[4-6] However, there is still no consensus in the literature about the treatment of neurological complications after SCH fractures.

The aim of this study is to categorize neurological complications and to report long-term functional outcomes associated with childhood SCH fractures.

Methods

Approval was obtained from the institutional ethics committee, and the data of the patients were collected retrospectively. Approval date was 07.09.2016. The children who were treated due to SCH fracture were included in the study. Gartland type-1 nondisplaced fractures,[9] intraarticular fractures, patients older than 12 years of age, the patients who had a neurological injury due to cervical spine or brachial plexus injury, and the patients who were treated conservatively were excluded from the study. Data about fracture classification according to Gartland classification,[9] amount and direction of displacement, age at the time of fracture, gender, time from injury to surgery, type of surgery, time of surgery, open fractures, type of neurological injury, and recovery time were recorded.

All the patients had either open or closed reduction, with two crossed pins. The ulnar nerve was pushed back with the thumb of the surgeon to minimize the risk of iatrogenic ulnar nerve injury.[10] The patients who had nerve injury were followed up monthly until full recovery of neurological damage.

Statistical analysis was performed with IBM SPSS Statistics for Windows Version 19.0. (Armonk, NY: Released 2010). One sample Kolmogorov-Smirnov test was used to evaluate the suitability of quantitative data to the normal distribution. Mann Whitney-U test and Kruskal-Wallis variance analysis were used for the comparisons between the groups when the data was not suitable for normal distribution.

Fisher's exact test, continuity to correction, and Kolmogorov-Smirnov two-sample tests were used for qualitative data. Numbers, percentages, median (minimum-maximum) values, and mean values ± standard deviation (±SD) were used for descriptive statistics. A P value < 0.05 was considered statistically significant for all statistical analyses.

Results

The records of 375 children were available for review. There were 226 (60.3%) boys and 149 (39.7%) girls. The mean age was 5.8 ± 2.5 (median 5.5; minimum: 1, maximum: 12). There were 356 (94.9%) extension type III Gartland injuries and 19 (5.1%) flexion type III Gartland injuries.

Open reduction and cross-pinning (ORCP) was required in 128 (34.1%) children, and 247 (65.9%) children were treated by closed reduction and percutaneous cross-pinning (CRCP). The main reason for the open reduction was an unacceptable reduction (n = 109, 85.1%).

The children who had neurological injury were followed up until complete recovery of the nerve and mean follow-up time was 13.1 months. No improvement was observed in 2 children. One of them had a trauma-related radial nerve injury, and the other had an iatrogenic combined ulnar and radial nerves injury.

The time between the injury and surgery was calculated for each patient and called the surgical delay. The children with neurological injury were compared with the ones who had no neurological damage regarding the surgical delay, and the difference was statistically insignificant (P = 0.376).

Neurological complications were seen in 37 (9.85%) children, and they were summarized in Table 1. Around 13 (35.1%) children had an iatrogenic nerve injury, and they were summarized in Table 2. Seven of the children who had iatrogenic injury were treated with ORCP and six of them have been addressed with CRCP. The difference was statistically insignificant (P = 0.171).

When Table 2 was observed it was recognized that 12 (92%) of the iatrogenic nerve injuries were ulnar nerve injuries. Iatrogenic and noniatrogenic nerve injuries were compared statistically, and it was observed that the incidence of ulnar nerve injury was statistically higher in iatrogenic injury group (P = 0.023). On the other hand, all iatrogenic injuries recovered in a mean time of 4.6 months (one patient who had persistent injury was removed in the calculation of mean).

Nine of the patients with neurological injury were explored surgically. The findings were summarized in Table 3.

Furthermore, girls and boys were compared for the incidence of neurological injury. The incidence of neurological injury was 10.6% (n = 13) for boys and 8.7% for girls. The difference was insignificant (P = 0.671).

The relationship between age and neurological injury was also investigated, and a statistically significant difference was found. The mean age of the children who had neurological injury was higher than the children who had no damage (P < 0.001) [Table 1].

Table 1: Demographic and fracture data

General	Neurological injury	*P*	
No# of cases	375	37 (9.85%)	
Age	5.8±2.5	8.5±2.5	
(median 5.5; min: 1, max: 12)		(median 8; min: 3, Max: 12)	<0.001
Male/Female ratio	1.5	1.8	0.671
Nerve injured			
Median	0.8%	8.1% (*n*=3)	
Radial	2.1%	21.7% (*n*=8)	
Ulnar	5.3%	54% (*n*=20)	
Combined	1.6%	16.2% (*n*=6)	
Direction of translational displacement			
Gartland Type-2[9]	20 (5.3%)	1 (2.7%)-1*	
Posteromedial	181 (48.4%)	19 (51.4%)-6*	>0.05**
Posterolateral	98 (26.1%)	11 (29.7%)-5*	>0.05**
Posterior	57 (15.2%)	3 (8.1%)-1*	>0.05**
Anterior	19 (5%)	3 (8.1%)	>0.05**
Amount of translational displacement		0.013**	
Gartland Type-2[9]	20 (5.3%)	1 (2.7%)-1*	
25%	102 (27.2%)	5-(13.5%)-1*	
50%	54 (14.4)	5-(13.5%)-1*	
75%	38 (10.1%)	4-(10.8%)-1*	
100%	161 (43%)	22-(59.5%)-9*	

*iatrogenic injury, **(iatrogenic injuries removed)

Table 2: Characteristics of nerve injuries

Nerve	Iatrogenic		Noniatrogenic
	OR	CR	
Ulnar	6	6	8
Radial	0	0	8
Median	0	0	3
Combined	1	0	5
Total	13		24
	P=0.023		*P*>0.05

OR: Open reduction, CR: Closed reduction

Table 3: Exploration of nerves and findings

Nerve	Iatrogeneic	Finding	Recovery
Ulnar	Yes	Intact	2 months
Ulnar	Yes	Intact	4 months
Ulnar	Yes	Intact	6 months
Ulnar	No	Trapped	12 months
Ulnar	Yes	Trapped	6 months
Ulnar	Yes	Trapped	2 months
Ulnar	Yes	Contusion	8 months
Median	No	Trapped	5 months
Radial	No	Contusion	No healing

Mean operation time was 109 min, and it was 86 min for the ones who had an iatrogenic neurological injury. Although the operation time was shorter in iatrogenic injury group, this difference was nonsignificant (*P* = 0.913).

Around 35 (94.5%) children who had neurological injury recovered fully. Mean recovery times for each nerve were summarized in Table 4. No statistically significant difference was observed between the recovery times of each nerve (*P* = 0.07).

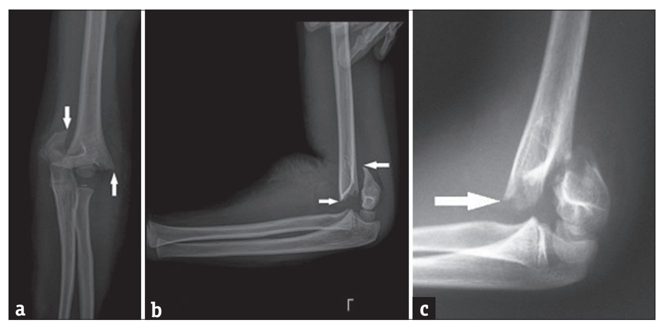

Figure 1: Anterior-posterior view of long and sharp fracture in a Gartland type III SCH fracture (a), Lateral view of long and sharp fracture in a Gartland type III SCH fracture (b), Lateral view of long and sharp fracture in a Gartland type III SCH fracture (c)

Mean recovery time was 4.92 ± 2.4 months (median: 6, min: 1, max: 8) for iatrogenic and 6.3 ± 3.8 months (median: 6, min: 1, max: 15) for noniatrogenic nerve injuries. Although the recovery of iatrogenic nerve injuries was faster than the fracture-related injuries, the difference was statistically nonsignificant (*P* = 0.286).

The relationship between the amount of displacement and the neurological injury was statistically significant (*P* = 0.013) [Table 1]. The incidence of neurological injury increased as the amount of displacement increased in this study.

Table 4: Recovery of injured nerves*

Nerve	*n*	Recovery time (months)				
		Mean	Stand. dev.°	Median	Minimum	Maximum
Ulnar	20	5.15	3.04	6	1	12
Radial	7	6.37	3.92	7	3	12
Median	3	4.33	2.08	5	2	6
Combined	5	8.25	7.65	9	2	15

*The two patients who had no signs of recovery were removed. *n*=Number of children. °Standart deviation

The direction of displacement of children who had neurological injury was compared with the direction of displacement of patients who had no neurological injury, and no statistically significant difference was observed [Table 1].

There were 19 flexion type and 356 extension type injuries according to Gartland classification. These two types of injuries were compared for the development of neurological injury [Table 1]. Three (15.7%) neurological injuries were seen in the flexion group and 34 (9.6%) neurological injuries were seen in the extension group. The difference was insignificant ($P = 0.621$).

During radiological evaluations, an anterior long and sharp bone fragment (spike) was observed in most of the children with neurological injury, and it was also investigated [Figure 1]. This spike was seen in 14 (58.3%) patients who had a trauma-related neurological injury ($n = 24$). The spike was observed only in 12 (3.4%) patients who had no neurological injury after the trauma ($n = 351$). The difference was statistically significant ($P = 0.017$).

Discussion

Fracture related or iatrogenic neurological injuries are among the most frequent complications in the treatment of SCH fractures. The incidence of neurological complications has been reported to be as high as 49%.[11] However, it ranged from 5% to 19%.[4-6] The overall incidence of neurological injury in this study was, 9.85% and this incidence were comparable with the literature.

Moreover, boys (60.3%) were more susceptible to SCH fractures than girls (39.7%). Hence, neurological injuries were seen more frequently in boys. Male/female ratio was 1.5:1 for the whole patient population however it was 1.8:1 for the children who had a neurological injury. Although males suffer neurological injury more frequently than females, the difference was statistically insignificant.

Mean follow-up time was 5.3 months and this time is relatively short, and this is one of the limitations of this study. The children who had neurological injury were followed up until complete recovery of the nerve and mean follow-up time was 13.1 months for these kids (the two that did not recover were exceptions).

One of the controversial subjects is the timing of surgery. Schmid *et al.*[12] reported that delay of treatment did not have a significant influence on rates of open reduction and complications. The surgical delay did not also affect neurological complications in this study. Therefore, elective treatment can be reasonable for children who had no signs of compartment syndrome to avoid complications.

The incidence of neurological injury was 9.5% in this study. This incidence was comparable with the literature (5%–20%).[4-6,13,14] Regarding the incidence of each nerve, McGraw *et al.*[5] found the median nerve to be most frequently damaged (53%), followed by the ulnar and radial nerve injury (23.5% each). Brown and Zinar[4] reported the radial nerve injury to be most prevalent (61%), followed by the median nerve (28%) and ulnar nerve (11%). In this study, the most frequently injured nerve was ulnar nerve (54%), followed by the radial nerve (21.7%) and median nerve (8.1%). The incidence of ulnar nerve injury in this study was higher than those reported in the literature. However, 57% of ulnar nerve injuries were iatrogenic injuries. There was no statistical difference in the incidence of nerve injuries when iatrogenic injuries were removed. Therefore, it cannot be reported that the ulnar nerve is the most frequently injured nerve in pediatric SCH fractures in this study. We also observed that more than one nerve was found to be injured in 6 cases (16.3%), which is not infrequent, since van Vugt *et al.*[6] had reported similar findings in almost 50% of the cases.

Iatrogenic nerve injury is a common postoperative complication in the treatment of pediatric SCH fractures.[15] It was reported as high as 3.3%–14%[15-17] in the literature. One-third of the children who had neurological injury had iatrogenic injuries in this study, and the incidence was 3.5%. The results were comparable with the literature. Joiner *et al.*[15] mentioned that the two main reasons for the development of iatrogenic nerve injury are reduction and cross-pinning. Brauer *et al.*[18] found that iatrogenic nerve injury occurred in 3.5% of the patients with cross pinning and 1.9% in lateral pinning. Lyons *et al.*[19] observed iatrogenic ulnar nerve injury up to 20% of the children who were treated with cross pins. In a meta-analysis, the most common nerve involved in iatrogenic nerve injury was ulnar nerve (3.2% of all cases).[20] In this study, all patients were treated with cross pinning, and 92% of the iatrogenic nerve injuries were ulnar nerve injuries. Seven of the children in this study who had iatrogenic injury were treated with ORCP, and six of them were treated with CRCP. The difference was statistically insignificant (P = 0.171). Mean operation time was 109 min, and it was 86 min for the ones who had an iatrogenic neurological injury. Although the operation time was shorter in iatrogenic injury group, this difference was not significant (P = 0.913).

Nevertheless, cross pinning can be the leading cause of iatrogenic nerve injuries due to medial pin irritation of the ulnar nerve. Dekker *et al.*[21] found the overall incidence of persistent ulnar nerve-related complaints as 3.5/1000. Therefore, it is suggested that cross pinning can still be used with more attention in the treatment of pediatric SCH fractures if you are familiar with this method.

Khademolhosseine *et al.*[17] had 18% nerve damage in their series and exploration was applied to five children. They observed complete resolution of all injuries and did not suggest immediate nerve exploration. Rasool *et al.*[22] reported that the pin rarely pierced the nerve in their patients with operative exploration. Several studies have suggested that 85–100% of neurological injury is neuropraxia and they resolve in 2–3 months.[4,11,14,19] Routine surgical exploration is not recommended in the literature.[4,11,23] In contrast, some authors recommend surgical exploration in selected cases. Culp *et al.*[13] surgically explored nine children who had no signs of recovery in electromyography and reported one case with complete laceration of the radial nerve. In this study, nine patients were explored surgically and no severe damage by the pin was observed. No additional benefit was obtained with exploration in this study. It is unnecessary surgery and may cause increased morbidity; therefore, we do not also recommend surgical exploration when a nerve injury is associated with closed fracture, especially in children with iatrogenic ulnar nerve injury.

It is recommended to wait about 6 months before any diagnostic test is performed like electromyography.[4] It is believed that motor function returns in about 6–12 weeks, however, the return of sensorial deficit can be delayed up to 6 months.[24,25] Brown and Zinar[4] reported average recovery time for the median, radial, and ulnar nerve injuries as 1.0, 1.8, and 3.6 months. Moreover, it was observed that the average ulnar nerve recovery is longer than other nerves in the literature. In this study, 95% of the children who had neurological injury recovered fully, and our results are comparable with the literature.[7] The ulnar nerve was the most frequently injured nerve and recovered in about a mean time of 5.15 months. Median nerve injury was observed in 8% of the cases but they recovered more quickly (4.33 months). The number of radial nerve injuries was eight and the mean recovery time was 6.37 months. One child with radial nerve injury was surgically explored, and a contused but intact nerve was observed. This patient did not recover in 30 months of time and was lost to follow-up. No statistically significant difference was found between the recovery times of each nerve (P = 0.07). Average recovery times for each nerve in this study is longer than those reported in the literature. There were six combined injuries, and five of them recovered in 2 to 15 months. One child with a combined injury of ulnar and radial nerves did not also recover in 12 months follow-up, and this patient refused exploration. When we compare all injuries combined injuries healed more slowly but the difference was not significant. We suggest that surgical exploration can be postponed up to 12–15 months in combined injuries when there are no signs and symptoms of recovery.

Mean recovery times for iatrogenic and fracture-related injuries was compared and it was observed that iatrogenic injuries recovered faster but the difference was not significant.

Whether or not there is a relationship between the nerve-injured and the direction and amount of displacement remains controversial in the literature. Mc Graw *et al.*[5] reported that posterolateral displacement was only associated with median nerve injury, on the other hand, posteromedial displacement was equally related to radial, median, and ulnar nerve injuries. In this study, no statistically significant relationship was observed between the nerve-injured and direction of displacement. Most of the injuries were associated with posteromedial displacement (three ulnar, one median, six radial, and three combined). There were six injuries related to posterolateral displacement (three ulnar, two median, and one combined). Pure posterior displacement was associated with two radial nerve injuries, and anterior displacement (flexion type injury) was related to two ulnar nerve and one combined injury. Our results did not support current literature findings. It was thought that the direction of force and displacement at the time of impaction are the primary determinants of nerve damage, rather than damage due to displaced bone.

It was also thought that the amount of displacement might affect soft tissue damage rather than the direction of displacement. There is no data related to this subject in the literature. The relationship between the amount of displacement and nerve injury was investigated, and a statistically significant relationship was found. The incidence of neurological injury was higher in displaced fractures. Therefore, it can be suggested that an increased amount of displacement is associated with an increased incidence of neurological injury according to the findings of this study.

Traditionally, it is thought that flexion type injuries cause neurological complications more frequently (mostly ulnar injury).[7] There is not much data about this subject in the literature. In their series, Valencia *et al*. reported only one case of ulnar nerve injury associated with flexion type injuries. In this study three (15.7%) neurological injuries were seen in the flexion group (two ulnar, one combined) and 34 (9.6%) neurological injuries were seen in an extension group. The difference was not significant ($P = 0.621$). It cannot be mentioned that flexion type injuries are associated with more neurological complications according to the findings of this study.

During radiological evaluations, an anterior long and sharp bone fragment (spike) was observed in most of the children with neurological injury [Figures 1 and 2]. This spike was seen in 58.3% of the children who had a trauma-related neurological injury, on the other hand, it was observed only in 3.4% of the children who had no neurological injury after the trauma. The difference was statistically significant ($P = 0.017$). It was thought that this spike is one of the leading causes of neurological injury in SCH fractures in children, due to compression, contusion, or direct laceration. Therefore, the shape of the fracture is one of the leading causes of neurological injury in SHF in children.

The major limitation of this paper was the retrospective nature of the study. Mean follow-up time was also short (5.3 months) however, these children recovered quickly, and therefore longer follow-up was not needed in most cases. The children who had neurological injury were followed up until complete recovery (except the two that did not recover) and this time was 13.1 months. Prospective studies with huge numbers are needed for more precise results.

Conclusions

Neurological injury after SCH fractures in children is a depressing complication for both the surgeon and the family. The parents feel very anxious. However, the prognosis of these injuries is excellent, especially the iatrogenic ones. This information must be given to the family appropriately. Besides, patience is needed to handle neurological complications while explorations and reoperations are not helpful. If there is a sharp bone fragment, the surgeon must be alerted for neurological complication.

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Conflicts of interest

There are no conflicts of interest.

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