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Functional outcomes of Gartland III supracondylar humerus fractures with early neurovascular complications in children

A retrospective observational study

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Abstract

This was a retrospective observational study. The aim of this study was to evaluate functional outcomes in children treated for Gartland III supracondylar humerus (SCH) fracture with neurovascular (NV) injuries using validated outcome measures. A secondary goal was to determine whether clinical parameters such as age at injury, sex, weight, fracture site, and/or direction of displacement could predict NV injury at the time of fracture or long-term functional outcomes in these patients.

One hundred fifty-four patients of Gartland III SCH fractures between March 2004 and May 2013 were studied retrospectively. The patients were divided into 2 groups according to the presence of NV injury. Medical records and radiographs were reviewed to assess several parameters, including age, sex, weight, treatment intervention, the extremity involved, direction of fracture displacement, and NV injury. Functional outcome was assessed on final follow-up using the Pediatric Outcomes Data Collection Instrument (PODCI) and Quick Disabilities of the Arm, Shoulder, and Hand (Quick DASH) outcome measures. Statistical analysis was used to determine the relationship between NV injury and functional outcomes.

There were 33 cases with Gartland III SCH fracture associated with NV injuries (10 cases of vascular compromise, 14 cases of neural injury, and 9 cases involving both vascular compromise and neural injury). There were significant differences between the 2 groups in age ($P = .048$), weight ($P = .009$), and direction of displacement ($P = .004$). Vascular compromise and median nerve injury were most common in fractures with posterolateral displacement, and radial nerve injuries were common in fractures with posteromedial displacement. The mean global function score in the PODCI was 91.4 points, and the mean Quick DASH score was 11.7 points, with excellent functional outcomes. No differences in outcomes were identified based upon age, fracture site, sex, weight, direction of displacement, or operative technique in NV injury patients ($P > .05$).

The majority of patients with Gartland III SCH fractures associated with NV injuries returned to a high functioning level after treatment of their injuries. NV injury does not appear to influence functional outcomes. Good functional results can be expected regardless of age, fracture site, sex, weight, direction of displacement, and operative technique.

Abbreviations: CR = closed reduction, NV = neurovascular, OR = open reduction, PODCI = Pediatric Outcomes Data Collection Instrument, Quick DASH = Quick Disabilities of the Arm, SCH = supracondylar humerus, Shoulder, and Hand.

Keywords: children, functional outcome, humerus, neurovascular injury, supracondylar fracture

1. Introduction

Supracondylar humerus (SCH) fractures are common injuries in children and represent a surgical emergency because of the possibility of associated neurovascular (NV) injury.[1] The incidence of neural injuries associated with this type of fracture has been reported to range from 5% to 19%.[2–4] Vascular compromise has been reported in association with 2% to 10% of displaced SCH fractures.[5–7] Most NV injuries occur after the initial energy impact and displacement of the fracture, which causes stretching, entrapment, or disruption of NV structure. Orthopedic surgeons treating these injuries are frequently faced with questions related to long-term outcomes, including upper

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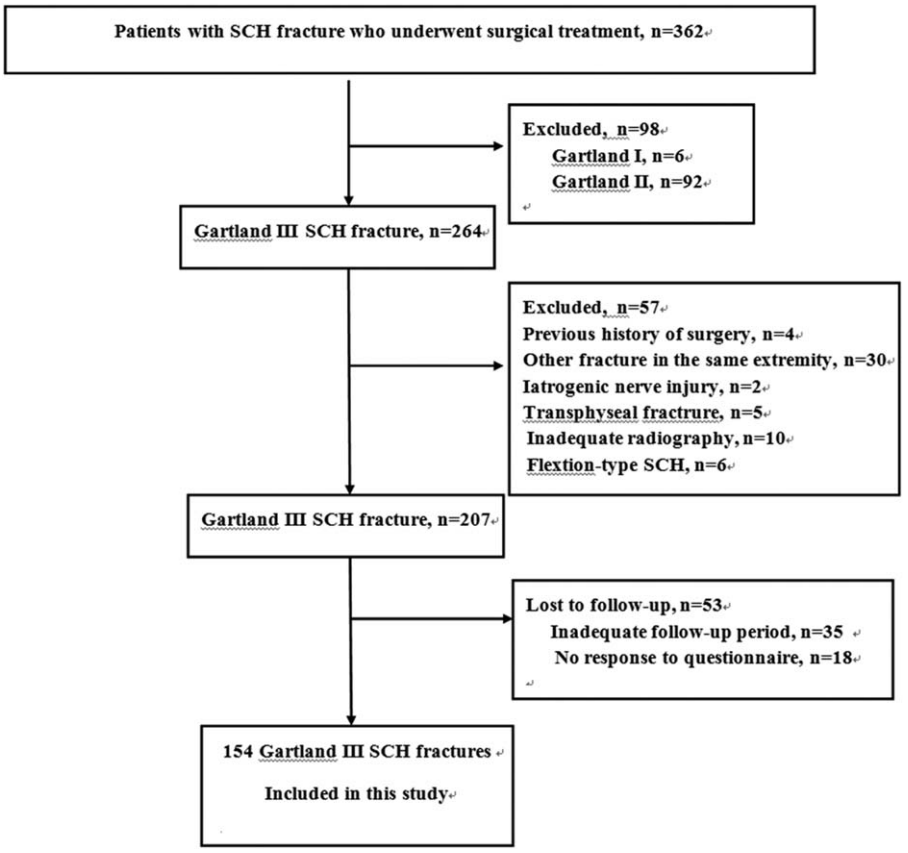

Figure 1. Flow diagram of eligible patients. SCH = supracondylar humerus.

extremity function, quality of life, and the ability to return to sports and physical activities, from patients and their parents. Functional outcomes have been reported previously using the Quick DASH questionnaire,[8] a specific standardized functional outcome tool for injuries of the elbow region, but this questionnaire has limitations in evaluation of pediatric musculoskeletal conditions with regard to validation. Meanwhile, the Pediatric Outcomes Data Collection Instrument (PODCI) has been subjected to rigorous validation testing in a broad range of pediatric musculoskeletal conditions and has consistently demonstrated high reliability, validity, and sensitivity to clinically relevant changes.[9–11] To the best of our knowledge, no formal measurement of outcome function has previously been conducted using the Quick DASH and PODCI in children with SCH fractures associated with NV injuries. The purpose of the present study was to evaluate the functional outcomes of children treated for Gartland III SCH fracture with NV injuries using validated outcome measures. A secondary goal was to determine whether clinical parameters such as age at injury, sex, weight, fracture site, and direction of displacement could predict long-term functional outcomes of these patients.

2. Patients and methods

2.1. Study design and patients

This was a retrospective observational study that was approved by the Ethical Review Boards of Chonbuk National University Hospital (No. CUH 2017-02-019-002). All patients provided written informed consent. Medical records and radiographs of 362 patients with SCH fracture who underwent surgical treatment between March 2004 and May 2013 were reviewed. The inclusion criteria were as follows: isolated Gartland III fractures[12] in patients younger than 13 years at the time of injury; at least 18 months of follow-up; and functional outcomes assessed using the PODCI and Quick DASH at the final follow-up. Exclusion criteria were Gartland I and II fractures, a history of surgery, other fractures in the same extremity, iatrogenic neural injury, transphyseal fractures that had been reported as SCH fractures, flexion-type SCH, inadequate radiographs or follow-up period, and omitted replies in the questionnaires. On the basis of these criteria, 154 patients were included in the study (Fig. 1). Patients who were lost to follow-up had a similar distribution in terms of the presence of NV injury compared with our study group (Table 1). The patients were divided into 2 groups according to the presence of NV injury. Their charts were reviewed for collection of data, including age, sex, body mass index (BMI), NV injury, operative technique, and complications. Age was stratified into 4 age classes: <3 years, 3 to 6 years, 7 to 10 years, and >10 years. BMI was also categorized into 4 classes for evaluation: underweight (<18), normal (18–23), overweight (23–25), and obese (>25). We also assessed the direction of

Table 1

Distribution of Gartland III suprascondylar elbow fracture.

	Study group (n = 154)	Loss to follow-up (n = 53)	*P*
NV intact	121 (78.5%)	44 (83%)	.64*
NV injury	33 (21.5%)	9 (17%)	

NV = neurovascular.
* Chi-square test.

Table 2

Demographic data for the patients with supracondylar fractures.

	Group A (n=121)	Group B (n=33)	P
Age at the time of fracture, y	6.1±2.3	7.3±2.3	
<3	8 (6.6%)	0 (0)	.048*
3–6	58 (47.9%)	13 (39.4%)	
7–10	49 (40.5%)	15 (45.5%)	
>10	6 (5%)	5 (15.1%)	
Left/right	94/27	22/11	.142*
Male/female	86/35	25/8	.917*
Weight (BMI)	20.3±2.7	21.5±1.8	
<18 (underweight)	29 (23.9%)	2 (6.1%)	.009*
18 –23 (normal)	72 (59.5%)	20 (60.6%)	
23–25 (overweight)	20 (16.6%)	9 (27.2%)	
>25 (obese)	0 (0)	2 (6.1%)	
Direction of displacement			
Posteromedial	87 (71.9%)	14 (42.5%)	.004*
Posterolateral	34 (28.1%)	19 (57.5%)	

Group A, neurovascular intact group; Group B, neurovascular injury group.
BMI=body mass index.
* Logistic regression analysis.

fracture displacement (extension or flexion, posteromedial or posterolateral) using the anteroposterior and lateral radiographs taken at the time of injury, and these data were assessed to investigate the associations between NV injury, direction of fracture, and other factors. Functional outcomes were assessed by the operating surgeon on the last visiting day at the outpatient clinic using the PODCI and Quick DASH questionnaires. These questionnaires were administered by the parents of the patients with the child present; patients who were old enough to complete the questionnaire themselves did so under a parent's supervision.

2.2. Neurovascular examination

Each child with a suspected SCH fracture had a NV examination at the time of emergency room presentation, pre- and postoperatively by the operating surgeon. The motor function of the median, radial, ulnar, and anterior interosseous nerve was assessed using the "okay" sign and "thumbs-up" sign. The sensory distributions of the each nerve were assessed for light touch, comparing to the contralateral side.[13] Vascular injuries were diagnosed by palpating the radial and ulnar arteries and observing the color, temperature, and capillary refill time of the fingers. After the fracture is reduced, if no palpable pulse was present, the Doppler examination was performed to find the radial pulse.

2.3. Operative technique

All completely displaced supracondylar fractures were treated surgically. Patients who were managed operatively underwent closed reduction (CR) and percutaneous pinning with Kirschner wires under fluoroscopy. If reduction could not be obtained via CR, open reduction (OR) was performed. If nerve injury was suspected, exploration was performed when neural recovery was not observed after 4 to 6 months of observation or when electromyography showed signs of nerve damage. For cases involving vascular compromise, exploration was immediately performed when the radial artery was not palpated after reduction, when fingers were white and cold, or when compartment syndrome was suspected. After reduction and fixation of the fracture, a cast was applied with the elbow flexed at about 80°.

Table 3

Relationship between neurovascular injury and direction of displacement.

	Posteromedial (n=14)	Posterolateral (n=19)	Total (n=33)
Median nerve injury	1	7	8
Radial nerve injury	7	2	9
AIN injury	2	2	4
Ulnar nerve injury	1	2	3
Brachial artery injury	4	15	19

AIN=anterior interosseous nerve.

2.4. Statistical analysis

Unpaired *t* tests were used to determine the statistical significance of differences in functional outcome data between patients with and without NV injury. Comparisons of categorical data were performed using the Chi-square test. Logistic regression analysis was conducted to evaluate whether clinical parameters such as age, fracture site, sex, weight, and direction of fracture displacement predicted the presence of NV injury at the time of fracture. Multiple linear regression analysis also was used to determine whether clinical parameters could predict long-term functional outcomes in NV injury patients. All categorical variables with 2 or more classes were dummy-coded for these analyses. For all logistic regression and multiple linear regression analyses, $P<.1$ was used as the cut-off for significance, and for all other analysis, $P<.05$ was considered significant. SPSS version 18.0 (SPSS Inc., Chicago, IL) was used for all analyses.

3. Results

3.1. Patients characteristics

A total of 154 patients were included in the study; 111 patients (72%) were boys and 43 (28%) were girls. Mean patient age was 6.4 years (range: 1–13 years), and mean follow-up duration was 38.2 months (range: 18–150 months). The patients were divided into 2 groups according to the absence (Group A) or presence (Group B) of NV injury. There were 33 cases of Gartland III SCH fracture associated with NV injury. Logistic regression analysis was performed to determine the significance of the clinical parameters as they related to the NV injury at that time of fracture. Table 2 summarizes that the constituent proportions of fracture site ($P=.142$) and sex ($P=.917$) were consistent between the 2 groups with no significant differences. However, significant differences existed in age at the time of fracture ($P=.048$), weight ($P=.009$), and direction of fracture displacement ($P=.004$).

Table 3 summarizes that in Group B (n=33), 23 cases involved neural injury (14.4%) and 19 cases involved vascular compromise (11.9%); 9 of these 33 cases presented with both neural injury and vascular compromise. With regard to the relationship between NV injury and the direction of displacement, median nerve injury was common in posterolateral displacement, and radial nerve injury was common in posteromedial displacement. Vascular compromise was common in posterolateral displacement.

3.2. Functional outcomes

The average PODCI global functioning score and Quick DASH scores were 91.4 and 11.7, respectively, which both indicated excellent function (Table 4). In the PODCI questionnaire, the 2 groups did not differ significantly in global function ($P=.53$), happiness ($P=.10$), pain/comfort ($P=.42$), sports and function

Table 4

Comparative analysis of outcomes scores based on neurovascular injury.

	PODCI global function	PODCI happiness	PODCI pain and comfort	PODCI sports and function	PODCI transfer and mobility	PODCI upper extremity	Quick DASH
Group A	91.6±1.9	98.1±4.9	90.0±3.7	98.4±5.0	90.3±3.5	98.6±3.3	11.4±1.1
Group B	91.4±1.8	96.6±4.1	89.4±4.7	96.8±4.1	89.9±4.0	98.0±2.5	11.7±1.7
P^*	.530	.101	.428	.095	.529	.317	.228

Group A, neurovascular intact group; Group B, neurovascular injury group.

PODCI = Pediatric Outcomes Data Collection Instrument, Quick DASH = Quick Disabilities of the Arm, Shoulder, and Hand.

* Unpaired *t* test.

($P=.09$), transfer and mobility ($P=.52$), or upper extremity ($P=.31$). There were also no significant differences in Quick DASH scores between the 2 groups ($P=.22$) (Table 4). Multiple linear regression analysis was performed to determine the significance of the clinical parameters of NV injury patients in relation to the PODCI global functioning score. There were no significant differences in functional outcomes using the PODCI global functioning score regardless of age at injury ($P=.74$), right or left extremity ($P=.85$), sex ($P=.28$), weight ($P=.15$), direction of displacement ($P=.58$), or operative technique ($P=.80$) (Table 5). Using the Quick DASH score, there were no significant differences in functional outcome regardless of these clinical parameters (Table 6).

3.3. Complications

Three cases in the NV injury group developed compartment syndrome. Therefore, fasciotomy was performed simultaneously.

4. Discussion

The relationship between NV injury and the clinical parameters such as sex, age, weight, or direction of displacement remains controversial in SCH fracture. In a previously reported study, age at the time of SCF was 6.5±4.7 years in the general group and 7.7±2.5 years in the neurological injury group.[14] Seeley et al[15] reported that obese and overweight children are at an increased risk for more complex SCH fractures, as well as preoperative and postoperative nerve palsy. In the current study, age and weight at the time of fracture significantly differed in the NV injury group, presumably because older or overweight children may incur more complex injuries when they fall on an outstretched hand.

Regarding the incidence of injury of each nerve, Brown and Zinar[2] found the radial nerve to be the most frequently damaged (61%), followed by the median nerve (28%) and the ulnar nerve (11%). McGraw et al[3] reported median nerve injury to be the most prevalent (53%). In contrast, Crammer et al[16] reported anterior interosseous nerve palsy to be the most prevalent (66.7%). Campbell et al[17] reported that displacement in extension-type fractures occurs posteromedially most often, and is associated with radial nerve injury, whereas posterolateral displacement is more likely to cause median nerve injury.

In our study, the incidence of radial and median nerve injury was very similar, at 39% (9 patients) and 34.7% (8 patients), respectively, and the incidence of anterior interosseous nerve

Table 5

Multiple linear regression analysis of PODCI global function in neurovascular injury group.

	Mean PODCI scores±SD	*P*
Age at the time of fracture, y		
3–6	91.3±0.8	.746*
7–10	91.4±2.5	
>10	90.8±0.9	
Extremity		
Right elbow	91.1±0.8	.857*
Left elbow	91.3±2.1	
Sex		
Male	91.1±1.8	.284*
Female	92.0±1.8	
Weight (BMI)		
<18 (Underweight)	91.0±1.3	.151*
18–23 (Normal)	90.9±1.5	
23–25 (Overweight)	92.0±2.4	
>25 (Obese)	91.8±0.2	
Direction of displacement		
Posteromedial	91.0±2.3	.585*
Posterolateral	91.5±1.3	
Operative technique		
Closed reduction	91.0±0.8	.809*
Open reduction	91.4±2.0	

BMI = body mass index, PODCI = Pediatric Outcomes Data Collection Instrument, SD = standard deviation.

* Multiple linear regression analysis.

Table 6

Multiple linear regression analysis of Quick DASH outcome in neurovascular injury group.

	Mean DASH scores±SD	*P*
Age at the time of fracture, y		
3–6	12.0±2.5	.668*
7–10	11.3±0.6	
>10	12.4±1.1	
Extremity		
Right elbow	11.4±0.7	.708*
Left elbow	11.5±1.0	
Sex		
Male	12.0±1.8	.324*
Female	11.1±1.1	
Weight (BMI)		
<18 (Underweight)	15.5±6.3	.128*
18–23 (Normal)	11.4±1.0	
23–25 (Overweight)	11.7±0.8	
>25 (Obese)	11.5±0.7	
Direction of displacement		
Posteromedial	11.5±1.2	.690*
Posterolateral	11.7±1.0	
Operative technique		
Closed reduction	11.7±1.0	.878*
Open reduction	11.8±1.9	

BMI = body mass index, Quick DASH = Quick Disabilities of the Arm, Shoulder, and Hand, SD = standard deviation.

* Multiple linear regression analysis.

injury was 17.4% (4 patients). We also found posterolateral displacement to be more frequently associated with median nerve injury and vascular compromise, while posteromedial displacement was more frequently associated with radial nerve injury. The high frequency of median nerve and vascular injuries in our series compared with previous studies was attributed to the significantly greater posterolateral displacement of the distal fragment in the NV injury group than those without NV injury.

The PODCI is a validated scoring system designed to evaluate physical and psychosocial health in the pediatric population.[9–11] It has been tested in the evaluation of many orthopedic conditions and has minimal floor and ceiling effects compared with other outcomes measures.[18,19] Scannell et al[20] demonstrated that patients with perfused, pulseless SCH fractures have high PODCI scores after CR, pinning, and observation of their vascular status. The Quick DASH is a questionnaire that is routinely used in research involving upper extremity musculoskeletal disorders. Isa et al[21] classified 94 pediatric patients with SCH fractures into type 1 (53 cases), type 2 (26 cases), and type 3 (15 cases) based on Gartland classification and assessed their functional outcomes using DASH. The patients showed no statistically significant differences in sex, side of injury (left or right), body weight, treatment modality, or age at injury.

In the present study, there were no significant differences in functional outcomes between patients with NV injury and those without NV injury as assessed by these validated outcome measures, with excellent outcomes. This does not mean that presence of NV injury is not important in the management of pediatric SCH fracture. We speculate that the NV injury group had good functional outcomes because most nerve damage healed spontaneously, and isolated vascular injury and vascular injury associated compartment syndrome were treated with fasciotomy when necessary, preventing the development of additional complications. We also found that good functional results can be expected regardless of age, fracture site, sex, weight, direction of displacement, and operative technique.

The limitations of this study include its retrospective design, small sample size, and that parents filled out the questionnaires based on their perceptions of their children's functioning. There is also a possibility that data were skewed by the loss of 53 patients to follow-up. Given our small sample size, a difference in the PODCI and DASH scores among groups could have been missed. However, despite the small number of patients at follow-up, we reviewed the charts of all 154 patients who were included in the study to identify any adverse outcomes or need for further therapy; none were identified from this chart review. We also reviewed the surgeon's notes at subsequent follow-up visits. Our study further provides a longitudinal evaluation of functional outcomes in children treated for Gartland III SCH fracture with NV injury using the PODCI and DASH as standardized outcome measures. In future studies, more cases should be assessed and objectivity should be improved by monitoring changes in functional outcomes over time instead of performing one-time assessments.

5. Conclusion

The majority of patients with Gartland III SCH fractures with NV injuries returned to a high functioning level after treatment of their injuries. NV injury does not appear to influence functional outcomes. Good functional results can be expected regardless of age, fracture site, sex, weight, direction of displacement, and operative technique.

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