Clinical Characteristics of Severe Supracondylar Humerus Fractures in Children

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Background: The safety of delayed surgical treatment of severe supracondylar elbow fractures in children remains debated. No large studies have evaluated complications of injury and surgery evaluating only type 3 fractures. Our aim was to review the results of our experience treating children with severe supracondylar elbow fractures at various time points after injury.

Methods: All children treated operatively for supracondylar humerus fractures from 2004 to 2007 at a single pediatric trauma center were identified. A total of 1296 children had operative treatment, of which 872 had type 3 fractures. Clinical records were reviewed to identify time to surgery from presentation at our institution. Patients were grouped into 4 cohorts [< 6 h (n = 325), 6 to 12 h (n = 224), 12 to 24 h (n = 295), and > 24 h (n = 28)]. Emergency, operative, inpatient, and outpatient records were reviewed to determine morbidity at presentation as well as operative and postoperative complications.

Results: There was no difference in sex, age, or energy mechanism between children in the various time groups. An absent pulse was found in 54 children (6%) at presentation, of which only 5 ultimately required a vascular intervention. Nerve injury occurred in 105 patients (12%). Use of a medial entry pin was not associated with ulnar nerve injury. Increased time from presentation to surgery was not associated with increased morbidity from the injury or treatment complications. In contrast, there was a trend to steady decrease in morbidity and complication rates with increased time to surgery.

Conclusions: This is the largest single-center study of severe supracondylar humerus fractures and describes rates of vascular compromise, nerve injury, infection, and other complications of these injuries. Most children with type 3 supracondylar humerus fractures can be treated safely in a delayed manner. Appropriate clinical judgment is imperative to optimize outcomes.

Level of Evidence: Level III—retrospective comparative study.

Key Words: supracondylar humerus fracture, complication, type 3, delay, surgery

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The reported complication rates for supracondylar humerus fractures in children are variable; with the rate of nerve injuries, for example, varying from 2% to 35% in different case series. Moreover, in many of these studies, the results of type 2 and 3 injuries are frequently pooled which will affect injury rates.[1]

Many surgeons now delay the treatment of supracondylar fractures, reducing and pinning supracondylar humerus fractures urgently (within 24 h of injury) as opposed to emergently (as soon as possible after presentation). Several studies support delayed surgical treatment of supracondylar humerus fractures.[2–8]

Several of these studies report on a combined cohort of type 2 and 3 fracture. As the degree of soft-tissue injury is quite different between these injuries, and given that multiple studies demonstrate low morbidity in patients with type 2 fractures, it is more appropriate to report the safety of nonemergent reduction and pinning of type 3 fractures as a separate cohort.[2,4,5,7,9]

The practice at our institution has been to treat most type 3 fractures on an urgent rather than emergent basis. The primary goal of this study is to determine whether there are increased complications when the treatment of these severe injuries is undertaken on an urgent versus emergent basis. A secondary goal is to describe the overall morbidity and complication rates for severe supracondylar humerus fractures at a high-volume trauma center over a recent 4-year period.

METHODS

After obtaining institutional review board approval, a query of the operative records of the hospital for current procedural terminology code 24538 and 24545 (closed and open treatment of supracondylar humerus fracture) yielded a total of 1385 patients who had

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operative treatment between 2004 and 2007. Clinical records were reviewed by one of the first 6 authors. Patients were followed until fracture union. Eighty-nine patients were excluded because of incorrect diagnosis or lost to follow-up before fracture union, leaving 1296 patients. None of the reviewers were involved with the clinical care of the patients.

Time of injury was recorded using a variety of means. Family report, emergency medical services report, and emergency room/orthopaedic documentation were used in that order to establish time of injury and the time to surgery was calculated. As many patients were transferred from other health care facilities, time from presentation at our institution to surgery was also calculated. The latter measure is more relevant for the treating surgeon as it has the potential to be under his or her control. Mechanism of injury was classified as low—fall from standing height, medium—fall from nonmotorized device (eg, bicycle, scooter) or fall from playground apparatus, and high—motorized vehicle injury.

Physical examination notes were used to establish rates of vascular compromise. Presence or absence of wrist pulses was noted, as well as Doppler examination of pulses if carried out. Consistent data on quality of Doppler signal (eg, monophasic, biphasic, triphasic) was not recorded and therefore we elected to classify Doppler signal only as "present" or "absent." Perfusion of the extremity was also noted from the initial examination based on color, warmth, and capillary refill time. Nerve injury was recorded based on the examination at presentation. If no examination could be obtained due to child's age or temperament this was noted.

Fracture classification was determined based on the intraoperative documentation of the attending surgeon. A total of 872 patients had type 3 fractures based on the Gartland classification. The intraobserver and interobserver reliability of this classification system has been established.[10–12] A standardized operative note for all providers was used in the majority of cases and detailed the Gartland classification. If this was absent, or any discrepancy was noted in the documentation, the radiographs were reviewed to determine classification.

All surgery was performed by fellowship-trained pediatric orthopaedic surgeons. All children received prophylactic antibiotics before pin placement.

Complications and morbidity of the injury and/or treatment were strictly defined. These included absence of radial pulse by palpation, absent perfusion to the hand by clinical exam, need for vascular surgery, nerve injury (preoperative or postoperative), loss of fixation, broken implants, refracture within 1 year, concomitant upper extremity fracture at another location, open fracture, infection requiring antibiotic treatment, infection requiring operative irrigation and debridement, referral to physical therapy for stiffness, and reoperation for any other reason. Any new postoperatively identified nerve palsy with a normal documented preoperative exam was classified as iatrogenic, presumably from intraoperative manipulation or implant related. Because of the multiple providers and inconsistent range of motion measurements at postoperative visits, we used referral to outpatient physical therapy as a surrogate marker for clinically significant postoperative stiffness.

The list of adverse events listed in the prior paragraph represents both effects of the trauma as well as from operative treatment. Our results describe each of these individually to present a full representation of the consequences of this injury. Analysis will also look at these events as a whole in the population to evaluate the effect of surgical timing.

Recall bias has the potential to affect the data regarding exact time from injury to treatment, therefore to reduce this effect we broke the cohort into 4 groups as opposed to analyzing time to surgery as a continuous variable (Table 1).

For comparing ≥ 2 rates, standard χ^2 contingency table methods were used. For comparing 2 means, we used the 2-sample Student t test, assuming unequal variances in the 2 groups. When comparing ≥ 3 means, we used a standard 1-way analysis of variance methods; if a significant overall result was seen, then Tukey multiple comparisons were used to elicit the significant differences between the means. For those variables with grossly unequal variances within the 4 time groups, we took the common logarithm of those values and used them in the analysis of variance or t test.

A posthoc analysis was not favored by our statistician (R.H.B.) due to the limitations of applying a power analysis; nonsignificance is not automatically the result of an underpowered study. A study with 80% power will still return a nonsignificant result 20% of the time, even though the alternative hypothesis is true. Statistical theory has shown that a nonsignificant result will automatically return a low value of power; therefore, a posthoc power analysis is rarely informative.[13]

All analysis was carried out using SAS version 9.2 (Cary, NC).

RESULTS

A total of 1296 children were treated operatively for supracondylar humerus fractures over a 4-year period at our institution. A total of 399 (31%) had type 2 fractures, 872 (67%) had type 3 fractures, and 25 (2%) had flexion type fractures. The 872 children with type 3 fractures comprised the study cohort. The distribution of these patients treated at the various time points after presentation are shown in Table 1.

Table 2 shows demographic and fracture characteristics of the various groups based on delay to surgery from presentation. Children with an ipsilateral distal radius fracture were more likely to have surgery <6 hours from presentation. A medial pin was utilized slightly more frequently in children who had surgery >12 hours from presentation. Length of time pins were retained was not different between groups.

There was no palpable wrist pulse in 54 patients (6%) at presentation. Twenty patients (37%) had a

TABLE 1. Distribution of 872 Type III Fracture Patients Based on Hours From Presentation to Surgery

	# of Patients	# Absent Radial Pulse (%)	# Nerve Palsy (%)	# Open Reduction (%)
< 6 h	325	42 (36)	53 (46)	10 (5)
6-12 h	224	5 (2)	19 (7)	2 (1)
12-24 h	295	7 (2)	23 (8)	8 (2)
> 24 h	28	0 (0)	0 (0)	0 (0)

documented Dopplerable pulse and a pink, perfused hand after closed reduction but the wrist pulses remained nonpalpable. These patients were observed in the hospital for signs of ischemia, and 1 patient did require vascular repair after developing a cool, pale hand approximately 9 hours after pin fixation; the other 19 observed did not undergo vascular exploration and regained a palpable pulse before discharge or by the first postoperative visit. Twenty-six patients (48%) had restoration of a palpable wrist pulse following fracture. The vascular examination postoperatively was not noted in 4 patients, none of whom had vascular exploration. In total, 5 children underwent vascular exploration because of poor perfusion and all had a vascular injury needing repair. Three patients who required a vascular procedure had surgery within 6 hours of presentation and the other 2 had surgery between 6 and 12 hours after presentation.

Nerve palsy was identified in 105 children (12%). Of these, 75 (71%) had nerve palsy identified preoperatively and 30 (29%) had nerve injury first identified postoperatively. The median nerve/anterior interosseus nerve (AIN) was the most frequently injured. Ninety-four patients had a median nerve/AIN palsy of which 24 were identified postoperatively. Twenty-seven patients had a radial nerve palsy of which 12 were identified postoperatively. Ulnar nerve injury was the least frequent, identified in only 16 patients of which 9 were identified postoperatively. There was no increased rate of ulnar nerve palsy with use of a medial pin. Seven of 335 patients with a medial pin developed an ulnar nerve palsy (5 identified postoperatively) and 9 of 537 patients without a medial pin developed a ulnar nerve palsy (4 identified postoperatively) ($P > 0.5$).

Unfortunately, only 68 (65%) patients maintained regular follow-up to nerve palsy resolution; the remainder were lost to follow-up before recovery and their status is unknown. Average time to resolution was 64 days in the group with preoperatively identified palsy and 89 days in the group with postoperatively identified palsy, this was not significantly different. Given the poor follow-up, however, conclusions or prognostic recommendations cannot be made based on our data.

Infection occurred in 18 patients (2%) of which 9 had deep infections/septic arthritis requiring operative debridement and 9 had superficial infections that responded to local wound care and antibiotics. Open fracture occurred in 15 patients (2%). None developed osteomyelitis. Ipsilateral forearm or wrist fractures were present in 49 patients (6%).

Open reduction was required in 20 patients. Open reduction was performed if acceptable closed reduction could not be achieved or in cases of open fracture.

One patient developed a compartment syndrome requiring open fasciotomy despite being taken to the operating room 8.5 hours after injury and < 5 hours after presentation to our center.

Time from injury to surgical treatment averaged 16.3 hours (range, 0.9 to 322 h, 99th percentile 133 h), and 11.5 hours (range, 0.5 to 217 h, 99th percentile 38 h) from time of presentation at our center to surgery. There was no increased rate of morbidity or complications with increased lengths of time from presentation to surgery (Figs. 1, 2).

All patients included in the cohort were followed at minimum to fracture union and pin removal. Union was defined based on documentation of new periosteal bone formation around the fracture site on radiographs and absence of pain at the fracture site. Seventy-one patients (8%) were referred to outpatient physical therapy due to elbow stiffness. The refracture rate was low, with only 8 patients (1%) having a repeat supracondylar humerus fracture on the same side within 1 year after the initial injury based on the available records.

TABLE 2. Demographic and Fracture Characteristics Based on Hours from Presentation to Surgery

	< 6 h	6-12 h	12-24 h	> 24 h	*P*
Sex, number (%)					
Male	184 (57%)	113 (50%)	165 (56%)	14 (50%)	0.4678
Female	141 (44%)	111 (50%)	130 (44%)	14 (50%)	
Age (mean)	4.4	5.6	5.7	6.1	0.1637
Energy mechanism, number (%)					
Low	109 (34%)	95 (43%)	106 (36%)	12 (44%)	0.2173
Medium	193 (61%)	122 (55%)	172 (59%)	13 (48%)	
High	15 (5%)	4 (2%)	13 (4%)	12 (7%)	
Ipsilateral distal radius fracture, number (%)	27 (8%)	10 (4%)	10 (3%)	2 (7%)	0.0486
Medial pin placement, number (%)	101 (31%)	82 (37%)	141 (48%)	11 (39%)	0.0003
Days until pins removed (mean)	24.0	24.5	23.9	23.0	0.4484

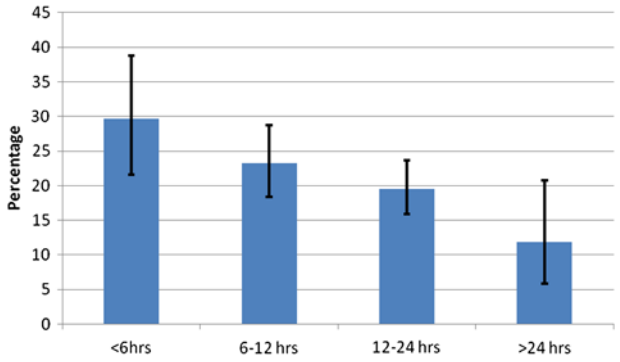

FIGURE 1. Complication rates based on increasing time from presentation to surgery.

Analysis of morbidity and complication rates based on time to surgery after presentation at our center was also done *excluding* patients who had preoperatively identified nerve palsy, open fracture, and/or absent radial pulse. This demonstrated no difference in overall morbidity or complication rates based on delay to surgery looking at both 6- and 12-hour time points (Table 3).

DISCUSSION

Despite being among the most common surgically treated pediatric orthopaedic injuries, there is limited high-quality literature on the incidence of neurological and vascular morbidity of supracondylar elbow fractures, and oftentimes type 2 and 3 fractures are reported together.[9,14–25] It is the authors' belief these are distinct injury patterns with dramatically different morbidities and therefore should be reported separately. This study is the largest consecutive case series of operatively treated severe supracondylar elbow fractures at a single institution.

Overall incidence of vascular compromise (6%) and nerve palsy (12%) for severe supracondylar humerus fractures is described for our institution over a 4-year period. As a retrospective review we were not able to grade quality of the pulse or Doppler signal but rather

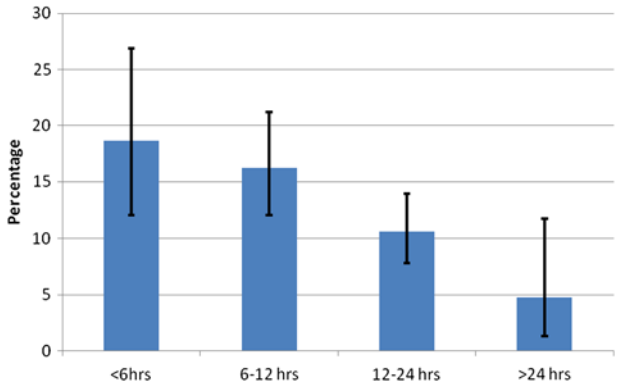

FIGURE 2. Complication rates base on increasing time from presentation to surgery excluding physical therapy referrals.

TABLE 3. Complication Rates Based on Hours from Presentation to Surgery, Excluding Patients With Preoperative Nerve Palsy, Absent Radial Pulse, and/or Open Fracture (n = 761)

	< 6 h	> 6 h	*P*
All complications, number (%)	31 (12%)	64 (13%)	0.1776
Excluding physical therapy referral, number (%)	11 (3%)	20 (4%)	0.8341
	< 12 h	**> 12 h**	***P***
All complications, number (%)	54 (10%)	34 (4%)	0.7438
Excluding physical therapy referral, number (%)	21 (4%)	10 (3%)	0.5744

relied on simple presence or absence of palpable pulse as our marker for vascular injury. This definition is broad and by excluding Doppler signal may be an overestimation of vascular compromise. In clinical application, however, having a palpable pulse and brisk capillary refill is consistent with adequate perfusion of the hand.

Two recent papers had differing conclusions regarding the management of the pulseless extremity following supracondylar elbow fractures.[26,27] Our experience echoes that described by Choi et al.[27] Children with clinically perfused limbs despite absent palpable or Doppler pulse were observed clinically. All children had restoration of a palpable pulse by their first postoperative visit. Consideration should be made for 24-hour observation following treatment of type III and flexion fracture to capture patients who deteriorate as described in 1 case in this cohort. Long-term data on vascular function and symptoms are not available for this patient cohort.

Our series echoes the recent meta-analysis of 5154 fractures that showed a nerve palsy rate of 11.3%.[1] The median nerve/AIN was the most frequently injured nerve with radial and ulnar nerve palsy occurring less frequently. The rate of iatrogenic nerve injury (28%) was also higher than we had anticipated. We suspect that this may represent injury to an already traumatized nerve from intraoperative manipulation of the fracture. Use of a medial pin was not associated with a higher rate of postoperative ulnar nerve injury and should be considered if needed to enhance stability.

Recent literature has focused heavily on pin configuration and evaluating the effect of surgical delay on outcomes.[2–8,19–25,28–31] Our focus was to evaluate the effect on time from presentation to our facility to surgery and clinical morbidity of the injury and its treatment. The latter has not been emphasized in prior case series.[2,4–8,28,30,32] No adverse effect was identified with longer times to surgery in our patient cohort of severe supracondylar humerus fractures. Overall complication rates were equivalent at all time points from presentation.

Breaking the sample into more or less than 6 and more or less than 12 hours from presentation did establish statistically significant decreases in complications with later surgery (Table 4). We believe that this finding of increased morbidity with early surgery represents selection bias with the treating physicians expeditiously

TABLE 4. Complication Rates Based on Hours from Presentation to Surgery, All Patients (n = 872)

	< 6 h	> 6 h	*P*
All complications, number (%)	41 (13%)	68 (12%)	0.9367
Excluding physical therapy referral, number (%)	17 (5%)	21 (4%)	0.3304
	< 12 h	**> 12 h**	***P***
All complications, number (%)	69 (13%)	40 (13%)	0.9366
Excluding physical therapy referral, number (%)	28 (5%)	10 (3%)	0.1615

treating more severe fractures. The need for open reduction in patients taken to surgery within 6 hours of presentation was significantly higher than those taken >6 hours after presentation. This is another example of selection bias in our data based on the surgeons taking more severe injuries clinically to surgery in an expedited manner. Figures 1 to 3 demonstrate the effect of this selection bias showing a steady trend towards decreased morbidity and complications with increasing time to surgery. There is no statistically significant difference between the groups.

Analysis *excluding* patients with absent pulse, nerve injury, and open fracture did not demonstrate any difference in need for open reduction based on time from presentation to surgery (Table 3). Similarly, analysis *excluding* these patients also showed no differences in rates of need for reoperation, infection, or physical therapy referral rates based on time from presentation to surgery. A deficit to this type of revision analysis, however, is lack of clinical scaling of soft-tissue injury which also may have prompted certain patients to have earlier surgery than others.

When deciding on urgency of surgical treatment of patients with severe supracondylar elbow fractures

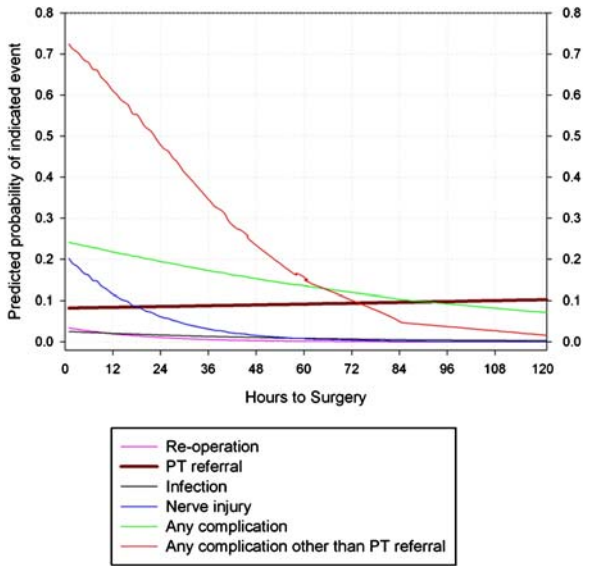

FIGURE 3. Logistic regression estimates of probabilities as a function of hours to surgery.

clinical judgment remains of utmost importance. Each child's injury should be assessed independently. In our practice, children with absent pulse or nerve palsy are taken for reduction and pinning in an expedited manner. Cases with less severe injury are treated in an urgent manner during daylight hours. No increased risk of morbidity was demonstrated with this protocol in our recent experience. Only 28 of 872 patients were treated >24 hours after presentation and we continue to practice and recommend surgery within 24 hours of presentation for type 3 and supracondylar elbow fractures.

In conclusion, this series can serve as a reference point for health care providers regarding the incidence of a host of morbidities associated with severe supracondylar elbow fractures. Further work will focus on long-term outcomes in patients with vascular injury, better surveillance for patients with nerve palsy, and prospective evaluation of treatment and outcomes using functional measures.

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