Copyright © 2025 by The Journal of Bone and Joint Surgery, Incorporated

A commentary by Pablo Castañeda, MD, is linked to the online version of this article.

Nerve Recovery in Pediatric Supracondylar Humeral Fractures

Assessing the Impact of Time to Surgery

Akbar N. Syed, MD, David Isaacs, BA, Leta Ashebo, BA, Divya Talwar, PhD, MPH, BDS, Jason B. Anari, MD, and J. Todd R. Lawrence, MD, PhD

Investigation performed at the Division of Orthopaedics, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania

Background: Nerve injuries in pediatric supracondylar humeral (SCH) fractures occur in 2% to 35% of patients. Previous research has suggested that isolated anterior interosseous nerve injuries are not influenced by the time to surgery; however, little is known about other nerve injuries or mixed, motor, and sensory injuries. With this study, we aimed to examine the impact of time to surgery on nerve recovery in patients with traumatic nerve injuries associated with SCH fractures.

Methods: Patients <18 years of age with SCH fractures stabilized using percutaneous pins during the period of January 2009 to June 2022 were retrospectively reviewed. Patients presenting with any traumatic nerve injury noted preoperatively were included, while those with iatrogenic or postoperative nerve injuries and incomplete documentation were excluded. Demographic data, injury characteristics, time to surgery, and number of days to nerve recovery were collected. Comparisons of nerve recovery time by anatomic distribution and functional deficit using an 8-hour time-to-surgery cutoff were made in bivariate and multivariate analyses.

Results: A total of 2,753 patients with SCH fractures were identified, with 214 of the patients having an associated nerve injury. Documentation of nerve recovery was available for 197 patients (180 patients with complete recovery) with an overall mean age of 6.8 ± 2.1 years. Time to recovery differed significantly when comparing the motor, sensory, and mixed-deficit cohorts ($p < 0.001$). Early surgery (≤8 hours from injury to surgery) was significantly associated with shorter overall time to nerve recovery ($p = 0.002$), recovery of multiple nerve distributions ($p = 0.011$), and recovery of mixed motor and sensory deficits ($p = 0.007$). On multivariable analysis, mixed nerve deficits (hazard ratio [HR], 0.537 [95% CI, 0.396 to 0.728]; $p < 0.001$) and time from injury to treatment of >8 hours (HR, 0.542 [95% CI, 0.373 to 0.786]; $p = 0.001$) were significantly associated with delayed nerve recovery.

Conclusions: Surgical timing impacts the time to recovery of complex nerve injuries. Early surgical management of patients with mixed motor-sensory deficits may help to reduce the time to complete nerve recovery.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Neurological impairment is the most common complication associated with pediatric supracondylar humeral (SCH) fractures, with reported rates ranging from 2% to 35%[1]. Anatomically, the median nerve is the most commonly implicated nerve, accounting for 52% to 62% of nerve injuries in SCH fractures, and is associated with posterolateral displacement[1-4]. Most of these nerve injuries with SCH fractures are neurapraxic injuries demonstrating full spontaneous recovery by 4 to 6 months[5-7].

SCH fractures with associated nerve palsies are usually initially managed with closed reduction and pinning of the fracture, but few studies have evaluated the implications of the timeliness of the reduction on the duration of neurological symptoms. Prior studies have examined perioperative and postoperative complications associated with the timing of treatment, noting no increase in complications with treatment at various cutoffs (8, 12, and 18 hours)[3,8,9]. One multicenter prospective study of 35 patients with an isolated anterior interosseous nerve injury suggested that nerve

Disclosure: No external funding was received for this work. The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJS/I449).

recovery is not related to surgical delay[10]. There is very little known about the effect of surgical delay on the recovery of nerve deficits in other anatomic nerve distributions, or by functionality when classified into sensory, motor, or mixed deficits. As the time to the operating room for this fracture pattern has become an important metric to departments and hospital systems, understanding the impact of surgical timing on outcomes has become even more imperative[8].

Therefore, the purpose of this study was to investigate the impact of surgical timing on nerve recovery following surgical pinning of SCH fractures presenting with nerve palsies in pediatric patients. We hypothesized that longer recovery times would be associated with a delay in surgery and complex nerve injuries (multiple nerve distributions affected or with combined motor and sensory deficits) noted preoperatively.

Materials and Methods

This retrospective study received institutional review board approval and was conducted over a period of 13 years (January 2009 to June 2022) at a tertiary care pediatric hospital. Using the appropriate Current Procedural Terminology codes, we identified patients <18 years of age who presented with an SCH fracture that was stabilized with percutaneously placed pins. Patients presenting with nerve deficits at the time of injury were included in this study. We excluded patients who underwent nonoperative management or open reduction and internal fixation with plates or interfragmentary screws for SCH fractures, those with iatrogenic or postoperative nerve injuries, and patients lost to follow-up or with inadequate medical record documentation. All procedures and postoperative clinical assessments were performed by 1 of 17 board-certified, fellowship-trained pediatric orthopaedic surgeons. All patients were seen for follow-up at our institution at 3 to 4 weeks postoperatively for pin removal, followed by clinical assessments at approximately 8 weeks, 3 months, and 6 months postoperatively. Further follow-up was conducted at the surgeon's discretion based on the patient's recovery.

Medical records were reviewed to collect demographic characteristics (age, sex, race, and ethnicity), injury characteristics (mechanism, fracture classification, fracture type, preoperative vascularity, anatomic nerve distribution, and functional nerve deficit), reduction method (open versus closed), surgeon experience, distance from patient residence/injury location to hospital, time to surgery (assessed as the number of hours from the time of injury to surgery, which was very reliably recorded by the emergency department staff), and number of days to recovery of the neurological deficit. Nerve deficits were recorded and assessed under 2 distinct categories: anatomic distribution of the nerve deficit (radial, median, or ulnar) and functional deficit of the nerve (isolated motor deficit, isolated sensory deficit, or mixed deficit). The anatomic nerve distribution was assessed on the basis of isolated radial, median, or ulnar nerve symptoms or involvement of multiple nerve distributions, irrespective of the functional nerve deficit. Functional nerve deficits were classified as isolated motor, isolated sensory, or mixed deficits and included sensory and/or motor deficits from a single anatomic nerve distribution or multiple nerve distributions. Time to surgery was calculated from the time of injury to when the patient entered the operating room. Timing was separated into ≤8 hours (early) versus >8 hours from injury (late). The 8-hour split was based on the preoperative fasting guidelines at our institution, which use a cutoff of 8 hours for needing to note clinical urgency in order to justify performing the case prior to this time, i.e., before the recommended fasting period is completed. Nerve recovery was defined as complete or partial resolution of the nerve deficit, depending on the type of preoperative neurological deficit.

Statistical Analysis

Descriptive statistics were used to summarize patient, injury, and treatment characteristics, and the Kolmogorov-Smirnov test was used to assess for normality. Continuous variables were assessed using the Mann-Whitney U test and Kruskal-Wallis test. An analysis was conducted to compare the time to surgery from injury and the time to nerve recovery among the various cohorts. Further analysis was performed to compare the time to nerve recovery for those operated on early versus late. The log-rank test and Kaplan-Meier estimate curves (1-minus curves) were used to compare nerve recovery at various time intervals, while time-to-event multivariable analysis was performed using Cox regression, censoring for patients achieving partial recovery. Data were analyzed using IBM SPSS Statistics for Windows (version 29). A p value of <0.05 was defined as significant.

Results

We identified a total of 2,753 patients with SCH fractures, with 214 of the patients having an associated nerve injury (7.7%, 214 of 2,753). There was inadequate documentation for 17 patients (8.0%, 17 of 214). Neurological recovery was documented for the remaining 197 patients, of whom 17 had partial recovery and were included. Among the 197 patients, the mean age at the time of injury (and standard deviation) was 6.8 ± 2.1 years, and there was nearly equal distribution by sex (51.3% male and 48.7% female). The majority of patients were White (70.1%; 138/197), followed by African American (7.1%, 14/197), Asian (4.6%, 9/197), Indian (2.0%, 4/197), and American Indian (0.5%, 1/197), with race reported as Other/Unknown for 15.7% (31/197). The majority of patients were of non-Hispanic or Latino ethnicity (89.3%; 176/197). A fall at the playground (33.0%, 65 of 197) was the most common mechanism of injury, with the majority of the fractures being closed (96.4%, 190 of 197 patients) and extension Gartland Type 3 (84.3%, 166 of 197). Vascularity was preserved in most cases, with palpable pulses present in 72.6% (143 of 197) and a well perfused hand in 98.0% (193 of 197). Most patients had deficits in a single nerve distribution (82.2%, 162 of 197), with the most common being median nerve involvement (66.0%, 130 of 197). From a functional deficit standpoint, 45.2% (89 of 197) of the patients had isolated motor deficits, whereas 42.1% (83 of 197) were noted to have mixed motor and sensory deficits. Isolated sensory deficits were only noted in 12.7% (25 of 197) of the patients. Of the 197 patients, 2 had a neurolysis while 3 patients had decompression performed. A detailed distribution of patient characteristics is shown in Table I.

TABLE I Patient Characteristics (N = 197)*

Age† (yr)	6.8 ± 2.1
Sex	
Male	101 (51.3%)
Female	96 (48.7%)
Mechanism of injury	
Fall at playground	65 (33.0%)
Fall from trampoline	19 (9.6%)
Fall from standing	35 (17.8%)
Fall from height	47 (23.9%)
Fall from personal transport	9 (4.6%)
Sport	18 (9.1%)
Other	4 (2.0%)
Fracture classification	
Extension Gartland Type 2	7 (3.6%)
Extension Gartland Type 3	166 (84.3%)
Extension Gartland Type 4	17 (8.6%)
Flexion	7 (3.6%)
Fracture type	
Closed	190 (96.4%)
Open	7 (3.6%)
Palpable radial pulse	
Present	143 (72.6%)
Diminished	36 (18.3%)
Absent	18 (9.1%)
Hand perfusion	
Perfused (pink)	193 (98.0%)
Not perfused (white)	4 (2.0%)
Anatomic nerve distribution	
Median nerve	130 (66.0%)
Ulnar nerve	13 (6.6%)
Radial nerve	19 (9.6%)
Multiple nerves‡	35 (17.8%)
Functional nerve deficit§	
Isolated motor deficit	89 (45.2%)
Isolated sensory deficit	25 (12.7%)
Mixed deficit	83 (42.1%)
Reduction	
Closed	176 (89.3%)
Open	21 (10.7%)
Nerve recovery	
Complete	180 (91.4%)
Partial	17 (8.6%)
Time from injury to surgery# *(hr)*	13.5 [8.9-17.6]
Distance from injury location/residence to hospital# ** *(miles)*	26.9 [18.5-39.9]
Surgeon experience# *(yr)*	8.0 [3-12.5]
Time to recovery *(days)*	56.0 [25-99.5]

*The values are given as the number, with the percentage in parentheses, except where otherwise noted. †The values are given as the mean and standard deviation. ‡Includes patients with ≥2 distinct nerve distributions. §Includes patients with deficits from a single nerve distribution or multiple nerve distributions. #The values are given as the median, with the interquartile range in square brackets. **1 mile = 1.6 kilometers.

Overall, the median time to nerve recovery was 56 days (interquartile range [IQR], 25 to 99.5 days). Comparing the time to recovery among the anatomic nerve distributions, the median time to nerve recovery did not differ ($p = 0.759$). However, nerve recovery time differed significantly among the different (motor, sensory, or mixed) functional-deficit cohorts ($p < 0.001$). The median time to recovery was the longest for mixed motor and sensory deficits, at 85 days (IQR, 34.0 to 128.0 days), and shortest for isolated sensory deficits, at 11 days (IQR, 8.0 to 30.0 days), while isolated motor deficits took an intermediate time to recover (median, 50 days [IQR, 26.0 to 87.5 days]). Details of nerve recovery characteristics are shown in Table II.

Time to surgery was assessed as the time from injury to surgery, with an overall median time of 13.5 hours (IQR, 8.9 to 17.6 hours). A similar median time to surgery was noted among the cohorts on the basis of anatomic nerve distribution ($p = 0.177$) and functional deficits ($p = 0.166$). However, a shorter median time to surgery was noted for patients with deficits in multiple nerve distributions and for patients with mixed motor and sensory deficits, at 11.3 hours (IQR, 7.3 to 17.0 hours) and 13.0 hours (IQR, 8.6 to 17.3 hours), respectively. Details of time from injury to surgery are presented in Table III.

To examine the role of surgical timing on time to nerve recovery, the time to the resolution of nerve-related symptoms was compared between patients treated ≤8 or >8 hours from injury. Overall, fractures surgically treated early had a faster nerve recovery than those treated late: median, 30 days (IQR, 9.0 to 62.5 days) versus 61 days (IQR, 28.0 to 105.5 days), respectively ($p = 0.002$). On the basis of the anatomic nerve distribution, the difference in nerve recovery time between early and late treatment did not reach significance for isolated, single-nerve injuries ($p = 0.056$), while injuries with symptoms in multiple nerve distributions that were treated early had a faster recovery than those treated late: median, 9.5 days (IQR, 7.7 to 42.0 days) compared with 86 days (IQR, 43.5 to 117.5 days), respectively ($p = 0.011$). On the basis of the initial functional deficit, the timing of treatment did not have a significant effect on recovery time for patients with isolated motor deficits ($p = 0.112$) or isolated sensory deficits ($p = 0.733$). However, patients with mixed motor and sensory deficits treated early had a significantly faster nerve recovery than those treated late: median, 44.5 days (IQR, 7.7 to 81.7 days) versus 91.0 days (IQR, 48.5 to 133.5 days), respectively ($p = 0.007$). We also compared patient age ($p = 0.155$), surgeon experience ($p = 0.477$), and distance from the hospital ($p < 0.001$) on the basis of early or late treatment, with only distance from the hospital showing a significant effect on nerve recovery. The effect of early versus late surgery on nerve recovery is detailed in Table IV.

Following bivariate analysis, multivariable analysis was performed. After adjusting with Cox regression, mixed nerve deficits (hazard ratio [HR], 0.537 [95% confidence interval [CI], 0.396 to 0.728]; $p < 0.001$) and time from injury to treatment of >8 hours (HR, 0.542 [95% CI, 0.373 to 0.786]; $p = 0.001$) were significantly associated with delayed nerve recovery. However,

TABLE II Nerve Injury Recovery Characteristics

Nerve Characteristics	N	Median Time (IQR) to Recovery *(days)*	P Value
Anatomic nerve distribution			0.759
Median nerve	130	56.0 (28.0, 99.0)	
Ulnar nerve	13	27.0 (12.0, 148.5)	
Radial nerve	19	55.0 (25.0, 91.0)	
Multiple nerves*	35	83.0 (9.0, 109.0)	
Functional deficit†			**<0.001**
Isolated motor deficit	89	50.0 (26.0, 87.5)	
Isolated sensory deficit	25	11.0 (8.0, 30.0)	
Mixed deficit	83	85.0 (34.0, 128.0)	

*Includes patients with ≥2 distinct nerve distributions. †Includes patients with deficits from a single nerve distribution or multiple nerve distributions.

multiple anatomic nerve distributions (HR, 0.968 [95% CI, 0.661 to 1.416]; p = 0.865) were not significantly associated with delayed nerve recovery after adjustment in the regression model.

To see whether a time threshold for treatment could be identified, we also performed further investigation into the timing of complete nerve recovery at various surgical treatment time points. For the comparisons of ≤6 versus >6 hours and ≤7 versus >7 hours from injury to surgery, significant differences in overall nerve recovery time were found, with a faster recovery time for the lower cutoffs (≤6 versus >6 hours: median, 25 days [IQR, 9 to 70.5] versus 57 days [IQR, 28 to 101 days], respectively; p = 0.039; and ≤7 versus >7 hours: median, 28.5 days [IQR, 9 to 78 days] versus 56 days [IQR, 27 to 109 days], respectively; p = 0.017) (Fig. 1). All surgical time points above 8 hours, analyzed at hourly increments (i.e., 9, 10, 11, and 12 hours), were not significant (p ≥ 0.05) for differences in overall nerve recovery between those treated up to versus later than the given cut-off. The results of the Kaplan-Meier analysis with 1-minus curves, showing the proportion of patients with nerve recovery (overall) categorized by time from injury to surgery at different time intervals (0 to <6 hours, 6 to <8 hours, 8 to <10 hours, 10 to <12 hours, and ≥12 hours), are shown in Figure 2. Early time intervals to surgery showed faster recovery times (p = 0.009).

Discussion

Practice recommendations regarding the timing of surgical management of pediatric patients with an SCH fracture and an associated motor or sensory nerve palsy are lacking despite extensive literature noting the high incidence of nerve palsies in these patients. Although most of these injuries are simply a neurapraxia and will thus have a very high rate of recovery, these children and their parents may experience notable physical or psychological morbidity until the symptoms have resolved, especially in cases of an extended time to full recovery. The current literature reporting on the impact of surgical delay presents a limited perspective without encompassing the broader context of other nerve injuries[10]. Our study builds on the work of Barrett et al.[10] on the effect of surgical delay on the time to nerve recovery over 13 years in a large cohort of patients with SCH fractures. The main new finding of our study is that patients treated within 8 hours of injury (early) showed

TABLE III Time from Injury to Surgery

Nerve Characteristics	N	Median (IQR) Time to Surgery *(hr)*	P Value
Anatomic nerve distribution			0.177
Median nerve	130	13.2 (9.0, 17.4)	
Ulnar nerve	13	17.3 (10.5, 22.3)	
Radial nerve	19	14.3 (11.2, 18.2)	
Multiple nerves*	35	11.3 (7.3, 17.0)	
Functional nerve deficit†			0.166
Isolated motor deficit	89	13.4 (9.0, 17.1)	
Isolated sensory deficit	25	16.0 (9.9, 18.9)	
Mixed deficit	83	13.0 (8.6, 17.3)	

*Includes patients with ≥2 distinct nerve distributions. †Includes patients with deficits from a single nerve distribution or multiple nerve distributions.

TABLE IV Effect of Time to Surgery (Injury to Operating Room) on Nerve Recovery

	Early: ≤8 Hr		Late: >8 Hr		
	N	Value*	N	Value*	P Value
Overall time to recovery *(days)*	37	30.0 (9.0, 62.5)	160	61.0 (28.0, 105.5)	**0.002**
Age *(yr)*	37	6.2 (5.3, 6.9)	160	6.2 (5.3, 8.4)	0.155
Surgeon experience *(yr)*	37	7.0 (3.5, 11.0)	160	9.0 (3.0, 13.0)	0.477
Distance from hospital§ *(miles)*	37	19.2 (6.9, 28.7)	160	29.8 (20.9, 44.1)	**<0.001**
Recovery by anatomic nerve distribution *(days)*					
Isolated single nerve	27	34.0 (13.0, 63.0)	135	56.0 (28.0, 101.0)	0.056
Multiple nerves†	10	9.5 (7.7, 42.0)	25	86.0 (43.5, 117.5)	**0.011**
Recovery by functional nerve deficit‡ *(days)*					
Isolated motor deficit	18	33.0 (10.5, 68.7)	71	54.0 (28.0, 91.0)	0.112
Isolated sensory deficit	5	10.0 (8.5, 30.0)	20	17.0 (7.2, 44.0)	0.733
Mixed deficit	14	44.5 (7.7, 81.7)	69	91.0 (48.5, 133.5)	**0.007**

*The values are given as the median, with the interquartile range (IQR) in parentheses. §1 mile = 1.6 kilometers. †Includes patients with ≥2 distinct nerve distributions. ‡Includes patients with deficits from a single nerve distribution or multiple nerve distributions.

faster recovery times than those treated later. This effect was especially notable among patients presenting with mixed motor and sensory deficits, where the recovery time was approximately twice as long if the treatment was performed >8 hours after the injury.

Our patient characteristics were similar to those reported in the current literature. The mean age of patients presenting with SCH fractures and neurological deficits has been reported to be between 6 and 7.5 years, which is in line with our average age of 6.8 years[6,7,10,11]. Also similar to the current literature, the majority of fractures in our study were closed, extension Gartland Type-3 fractures treated with closed reduction and pinning, and the majority of nerve injuries presented as single, isolated nerve injuries in the distribution of the median nerve[1,6,7,10,11]. However, our study is the first to examine nerve deficits on the basis of the noted functional deficits, namely motor, sensory, or mixed deficits. We observed that the most common deficits were isolated motor deficits (45.2% of the patients), followed closely by mixed deficits (42.1%), while isolated sensory deficits were noted only in 12.7% of the patients.

The overall median time to nerve recovery in the current study was 56.0 days, or 1.9 months, which is comparable with those reported by Shore et al. (2.3 months) and Louahem et al.

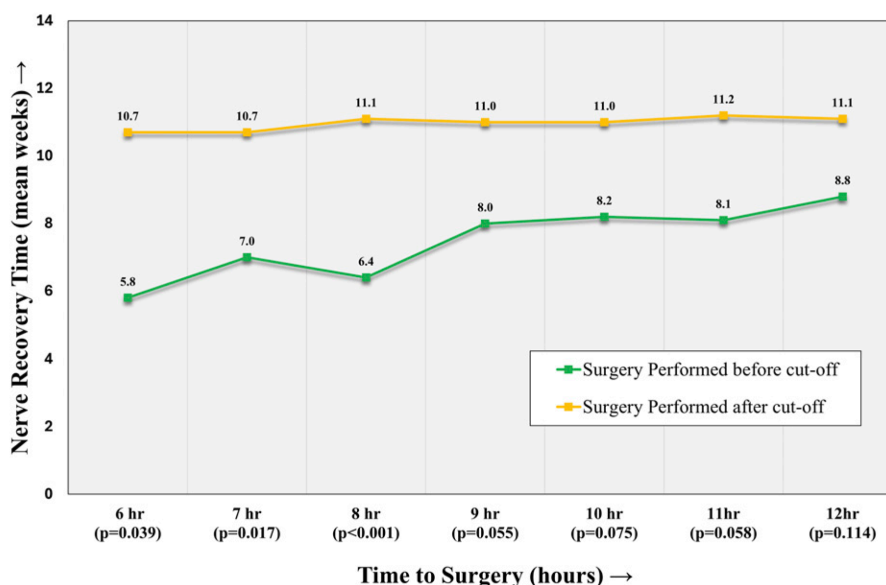

Fig. 1
Overall mean recovery time for patients with complete recovery compared by surgical time before (up to) and after various time points; $p < 0.05$ = significant.

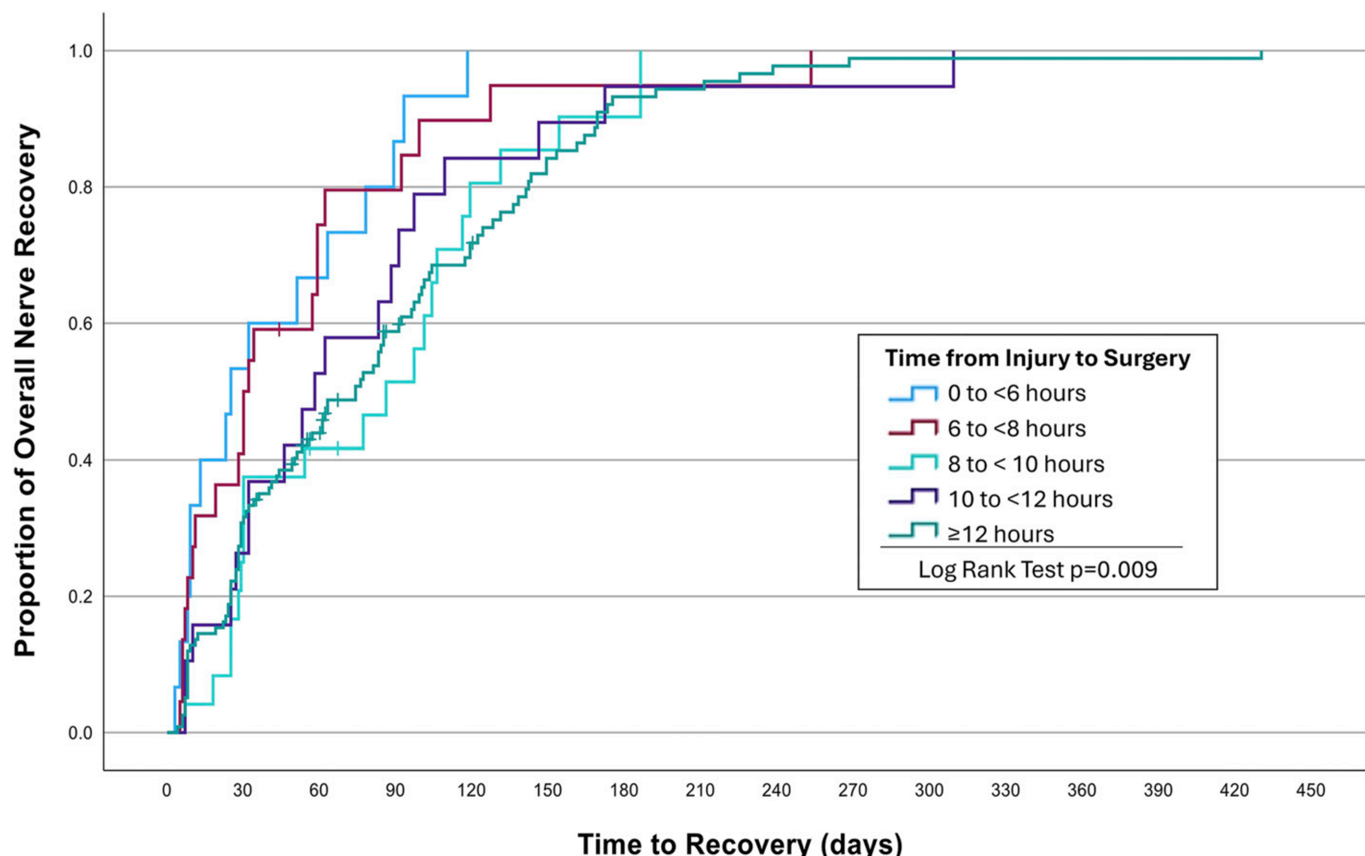

Fig. 2

Kaplan-Meier 1-minus curves showing the proportion of patients with nerve recovery at various intervals of time from injury to surgery, with censoring (+) for partial recovery.

(3.3 months)[6,7]. Shore et al. noted that multiple nerve injuries took 54% longer to recover than isolated median nerve injuries, when controlling for fracture severity. Similarly, in our study, multiple nerve injuries took the longest to recover, but the difference in recovery time on the basis of anatomic nerve distribution was not significant. However, nerve recovery times increased significantly with increased levels of initial functional deficits (isolated sensory, 1 to 2 weeks; isolated motor, approximately 7 weeks; mixed motor and sensory, >12 weeks), likely indicating greater initial trauma to the nerve and potentially more substantial ongoing pathophysiology.

Our findings add to the growing body of literature that the nature of the injury and the duration of the pathophysiological mechanism or nerve ischemia contribute to the severity of nerve palsy at presentation and the timing and completeness of subsequent nerve recovery[12-16]. Nerve injury or ischemia has been shown to increase in a time-sensitive manner with the prolonged use of a tourniquet or in a patient with compartment syndrome[17]. Similarly with respect to fractures, the severity of nerve palsy has been shown to be related to the severity of the initial injury, which may be exacerbated secondary to an increase in the time to surgery as a result of an increase in nerve compression and/or ischemia time[18]. In the current study, using an 8-hour cutoff, we found that early reduction of the fracture halved the time to nerve recovery in SCH fractures among patients with evidence of more severe nerve injuries, namely those with mixed motor and sensory deficits. These data suggest that there may be ongoing nerve damage in SCH fracture cases with complex nerve injuries that can be relieved by early surgical management and thus accelerate the recovery time. These data suggest that consideration should be given to both the anatomic and functional characteristics of the nerve palsy when deciding on the timing of surgery for SCH fractures.

There were several limitations to this study. As a retrospective study, it may be subject to selection and treatment bias. Assessment of nerve recovery is physician-dependent, variable, and often assessed and recorded only by the resident physician. Two-point discrimination in light-touch sensation was not routinely assessed in the emergency room, and we may have missed some sensory deficits in the setting of nerve palsy and a supracondylar humeral fracture. In this light, one might criticize the study for not truly reflecting a more detailed neurological examination that may have been performed by a "more qualified" physician. However, clinical decisions are often based on the examination performed by the emergency room physician or orthopaedic trainee of an often less-than-cooperative child in pain, thus bolstering the real-world applicability of the findings. Time to nerve recovery may be influenced by the duration and

frequency of subsequent follow-up, as recovery may have occurred prior to the physician's documentation. The finding that the noted differences are much longer than the average follow-up interval argues against this effect changing the ultimate result of the analysis, but different follow-up time patterns at different institutions may result in slightly different assessed recovery times. Lastly, we were not able to examine or comment on the recovery of individual branches for each distribution, or to adjust for the fracture type (Gartland type, flexion versus extension, closed versus open) and multiple surgeries because of the sample size. This, by extension, limits the generalizability of these findings in terms of recommendations for isolated nerve injuries, by fracture type or secondary procedures.

Nevertheless, these data strongly suggest that surgical timing impacts the time to neurological recovery in SCH fractures with complex nerve injuries, especially those presenting with both motor and sensory deficits, which may take twice as long to recover if treatment is delayed >8 hours. We found that nerve recovery was the longest when both sensory and motor deficits were demonstrated at the time of injury. When feasible, surgeons may consider more expeditious surgical management of patients with supracondylar humeral fractures with dense motor and sensory palsies at presentation, to help reduce the duration of neurological symptoms in the postoperative period. ■

Akbar N. Syed, MD[1]
David Isaacs, BA[2]
Leta Ashebo, BA[1]
Divya Talwar, PhD, MPH, BDS[1,2]
Jason B. Anari, MD[1,2]
J. Todd R. Lawrence, MD, PhD[1,2]

[1]Division of Orthopaedics, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania

[2]Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pennsylvania

Email for corresponding author: lawrencej@chop.edu

References

1. Babal JC, Mehlman CT, Klein G. Nerve injuries associated with pediatric supracondylar humeral fractures: a meta-analysis. J Pediatr Orthop. 2010 Apr-May;30(3):253-63.
2. Campbell CC, Waters PM, Emans JB, Kasser JR, Millis MB. Neurovascular injury and displacement in type III supracondylar humerus fractures. J Pediatr Orthop. 1995 Jan-Feb;15(1):47-52.
3. Gupta N, Kay RM, Leitch K, Femino JD, Tolo VT, Skaggs DL. Effect of surgical delay on perioperative complications and need for open reduction in supracondylar humerus fractures in children. J Pediatr Orthop. 2004 May-Jun;24(3):245-8.
4. Vaquero-Picado A, González-Morán G, Moraleda L. Management of supracondylar fractures of the humerus in children. EFORT Open Rev. 2018 Oct 1;3(10):526-40.
5. Graff C, Dounas GD, Todd MRLC, Sung J, Kumawat M. Management of Traumatic Nerve Palsies in Paediatric Supracondylar Humerus Fractures: A Systematic Review. Children (Basel). 2023 Nov 27;10(12):1862.
6. Shore BJ, Gillespie BT, Miller PE, Bae DS, Waters PM. Recovery of Motor Nerve Injuries Associated With Displaced, Extension-type Pediatric Supracondylar Humerus Fractures. J Pediatr Orthop. 2019 Oct;39(9):e652-6.
7. Louahem DM, Nebunescu A, Canavese F, Dimeglio A. Neurovascular complications and severe displacement in supracondylar humerus fractures in children: defensive or offensive strategy? J Pediatr Orthop B. 2006 Jan;15(1):51-7.
8. Sullivan MH, Wahlig BD, Broida SE, Larson AN, Shaughnessy WJ, Stans AA, Milbrandt TA. Does Shorter Time to Treatment of Pediatric Supracondylar Humerus Fractures Impact Clinical Outcomes? J Pediatr Orthop. 2023 Jul 1;43(6):350-4.
9. Mehlman CT, Strub WM, Roy DR, Wall EJ, Crawford AH. The effect of surgical timing on the perioperative complications of treatment of supracondylar humeral fractures in children. J Bone Joint Surg Am. 2001 Mar;83(3):323-7.
10. Barrett KK, Skaggs DL, Sawyer JR, Andras L, Moisan A, Goodbody C, Flynn JM. Supracondylar humeral fractures with isolated anterior interosseous nerve injuries: is urgent treatment necessary? J Bone Joint Surg Am. 2014 Nov 5;96(21):1793-7.
11. Kwok IHY, Silk ZM, Quick TJ, Sinisi M, MacQuillan A, Fox M. Nerve injuries associated with supracondylar fractures of the humerus in children: our experience in a specialist peripheral nerve injury unit. Bone Joint J. 2016 Jun;98-B(6):851-6.
12. Hewson DW, Bedforth NM, Hardman JG. Peripheral nerve injury arising in anaesthesia practice. Anaesthesia. 2018 Jan;73(S1)(Suppl 1):51-60.
13. Nitz AJ, Matulionis DH. Ultrastructural changes in rat peripheral nerve following pneumatic tourniquet compression. J Neurosurg. 1982 Nov;57(5):660-6.
14. Azad A, Sager B, Gupta S, Ayalon O, Paksima N. Reducing Tourniquet Pressures in Hand Surgery: Are Lower Pressures as Effective? J Wrist Surg. 2022 Sep 26;12(3):205-10.
15. Burnett MG, Zager EL. Pathophysiology of peripheral nerve injury: a brief review. Neurosurg Focus. 2004 May 15;16(5):E1.
16. Menorca RMG, Fussell TS, Elfar JC. Nerve physiology: mechanisms of injury and recovery. Hand Clin. 2013 Aug;29(3):317-30.
17. Broadhurst PK, Robinson LR. Compartment syndrome: Neuromuscular complications and electrodiagnosis. Muscle Nerve. 2020 Sep;62(3):300-8.
18. Mohler LR, Hanel DP. Closed fractures complicated by peripheral nerve injury. J Am Acad Orthop Surg. 2006 Jan;14(1):32-7.