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Sex-based differences in pediatric supracondylar humerus fractures

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Abstract

Supracondylar humerus (SCH) fractures are reported to be approximately twice as common among boys as among girls. Little is known about sex-associated differences in fracture patterns and complications. We compared the incidence of pediatric SCH fractures, injury mechanism (high-energy or low-energy), fracture subtypes, associated neurologic injuries, and treatment types by patient sex.

We reviewed 1231 pediatric SCH fractures treated at 1 center from 2008 to 2017, analyzing sex distributions overall and by year and fracture subtype. We noted patient demographic characteristics, injury mechanisms, neurologic injuries, and treatments (nonoperative or operative). Binomial 2-tailed, chi-squared, and Student's *t* tests were used for analysis. Multiple logistic regression was performed to assess associations between sex, age, and injury mechanism. Alpha = 0.05.

We found no significant difference in the distribution of girls (52%) vs boys (48%) in our sample compared with a binomial distribution ($P = .11$). Annual percentages of fractures occurring in girls ranged from 46% to 63%, and sex distribution did not change significantly over time. The mean (± standard deviation) age at injury was significantly younger for girls (5.5 ± 2.5 years) than for boys (6.1 ± 2.5 years) ($P < .001$). High-energy injury mechanism was associated with older age (odds ratio [OR], 1.05; 95% confidence interval [CI], 1.03–1.06) but not male sex (OR, 1.04; 95% CI, 0.98–1.1). The overall incidence of neurologic injury was 9.5% but boys did not have greater odds of sustaining neurologic injury (OR, 1.03; 95% CI, 1.0–1.1). We found no sex-associated differences in the distribution of Gartland fracture subtypes ($P = .13$) or treatment type ($P = .39$).

Compared with boys, girls sustain SCH fractures at a younger age. SCH fractures were distributed equally among girls and boys in our sample. Patient sex was not associated with fracture subtype, injury mechanism, neurologic injury, or operative treatment. These findings challenge the perception that SCH fracture is more common in boys than girls.

Level III, retrospective study.

Abbreviations: AIN = anterior interosseous nerve, SCH = supracondylar humerus.

Keywords: complications, incidence, sex, supracondylar humerus fracture

1. Introduction

Supracondylar humerus (SCH) fractures are classically associated with falls from playground equipment onto an outstretched, nondominant hand, and are believed to be more common among boys than among girls.[1–3] SCH fractures often occur between the ages of 4 and 8 years,[2,3] when elbows are thought to be vulnerable because of increased bone remodeling and thin cortical bone.[4–6] Incidence of SCH fractures has been reported to increase during school breaks and during the spring and summer.[7,8] Most fractures are treated nonoperatively; closed reduction and percutaneous pinning is preferred for displaced fractures. Neurologic injuries are commonly associated with SCH fractures, with a reported incidence of 7% to 18%.[9–11] Neurologic injuries can be caused by fracture displacement or fracture manipulation.[12,13]

Studies have reported that boys are 1.5 to 2.5 times as likely as girls to sustain SCH fractures.[3,14] The higher incidence of SCH fractures among boys has been suggested to be related to boys' more active and aggressive style of play compared with that of girls.[1] Epidemiologic studies in developing countries continue to suggest that boys have a higher incidence of SCH fracture than girls.[14,15] The number of girls participating in sports in the United States has increased by nearly 1000% since 1973, however, with a concomitant increase in sports injuries among girls.[16] Other authors have reported that SCH fracture incidence is higher among girls.[2,17] Recent studies in the United States have suggested that there may be no sex-based difference in incidence of SCH fractures.[8,18]

To the best of our knowledge, no study has comprehensively analyzed the associations between patient sex and SCH fracture

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characteristics, such as differences in mechanism of injury, subtype of fracture, treatment, or complications. We sought to compare the number of pediatric SCH fractures, mechanisms of injury (high-energy or low-energy), fracture subtypes, associated neurologic injuries, and treatment types by patient sex over time. We hypothesized that the incidence of SCH fractures would increase over time because of increasing participation in sports, particularly among girls. We also hypothesized that mechanisms of injury, fracture subtypes, and neurologic complication rates would be similar between girls and boys.

2. Methods

2.1. Study population

After institutional review board approval, we reviewed data from our pediatric fracture and musculoskeletal injury database for all patients presenting to our academic medical center with fractures between January 2008 and June 2017. A total of 1253 patients <18 years old had primary SCH fractures. We excluded 22 patients with unknown fracture subtypes, leaving 1231 patients for analysis.

2.2. Data collection

We extracted data on patient sex, age, mechanism of injury, Gartland type, extension vs flexion type, presence and type of neurologic injury, and operative vs nonoperative treatment. Mechanism of injury was determined by medical record review. Mechanisms of injury were classified as high-energy or low-energy mechanisms. Falls from a height >3 feet, contact injuries, and high-velocity mechanisms involving a bicycle or motor vehicle were considered high-energy mechanisms; all other mechanisms were considered low-energy mechanisms. Gartland types were defined as follows: type I, nondisplaced; type II, displaced with a posterior cortical hinge, with or without rotation; type III, displaced without a cortical hinge; and type IV, multidirectional instability without a periosteal hinge.[19] Neurologic injury was defined as any deficit in the upper extremity at presentation or during the perioperative period. Neurologic injuries were categorized as motor, sensory, or mixed lesions. Motor lesions exhibited deficits in motor function only. Sensory lesions were dysesthesias, paresthesias, or sensation deficits. Mixed lesions were those involving both motor and sensory deficits. All patients underwent preoperative and postoperative physical examination to test motor function and sensory function via detection of light touch. Neurologic injury was established clinically, without the use of electromyography or nerve conduction studies. Operative vs nonoperative treatment was determined by medical record review. Operative reports were examined to determine whether the patient underwent closed reduction and percutaneous pinning, open reduction and internal fixation, or open reduction and percutaneous pinning.

2.3. Statistical analysis

We analyzed the incidence of SCH fracture by patient sex using a 2-tailed binomial test. We compared the incidence of Gartland fracture subtype and energy of injury mechanism between sexes using chi-squared tests. For each Gartland fracture subtype, we compared age at injury between sexes using Student's *t* tests. We used multivariate logistic regression to analyze the relationship between patient sex and energy of injury mechanism while adjusting for age, race, neurologic injury, and fracture subtype. We also used multivariate logistic regressions to analyze the relationship between patient sex and both neurologic injury and treatment while adjusting for age, race, energy of injury mechanism, and fracture subtype. $P < .05$ was considered statistically significant. All analyses were performed using RStudio software, version 1.0.136 (RStudio, Boston, MA).

3. Results

3.1. SCH fracture incidence

A larger proportion of fractures were sustained by girls (52%) than boys during the study period, but this difference was not significant (Fig. 1; Tables 1 and 2; $P = .11$). However, girls were significantly younger than boys at the time of fracture across all fracture types ($P < .001$; Table 2). The annual number of SCH fractures increased steadily from 2008 to 2016 (Fig. 2) among patients of both sexes. The annual percentages of girls with SCH fractures ranged from 46% to 63%.

3.2. Gartland subtypes

The most frequently observed fracture pattern was a Gartland type-III fracture (42%; Table 1). Boys and girls who had Gartland type-II and type-III fractures were significantly older than those with type-I or type-II fractures ($P = .02$) (Table 2). The distribution of Gartland fracture subtypes was not significantly different between boys and girls ($P = .13$).

3.3. Mechanism of injury

Low and high-energy injuries occurred at similar rates (47% vs 50%, respectively), with no significant differences between sexes (Table 3). Among specific mechanisms, climbing bars were the most common, again with no difference between sexes. High-energy mechanisms were not associated with patient sex (odds ratio [OR], 1.04; 95% confidence interval [CI], 0.98–1.1). However, they were associated with older age (OR per year of age, 1.05; 95% CI, 1.03–1.06) and more often associated with Gartland type-III and Gartland type-IV fractures than with type-I fractures ($P < .01$) (Table 4).

3.4. Neurologic injury

The incidence of neurologic injury during the study period was 9.5% (117/1231). Motor lesions (79/117) occurred more frequently than sensory (31/117) or mixed lesions (7/117). The anterior interosseous nerve (AIN) was the most common nerve injured (43/117). AIN injury was associated with male sex ($P < .01$). Posterior interosseous nerve palsies occurred less frequently (8/117), and their incidence did not differ by patient sex ($P = .40$) (Table 5). Neurologic injury was not associated with patient sex ($P = .05$). However, it was associated with older patient age, and with Gartland type-III and type-IV fractures (both, $P < .001$). Neurologic injury was not associated with high-energy mechanisms of injury ($P = .93$) (Table 6).

3.5. Treatment

Of the 1231 SCH fractures, 838 (68%) were treated operatively (Table 1). Most patients whose fractures were treated operatively (97%) underwent closed reduction and percutaneous pinning,

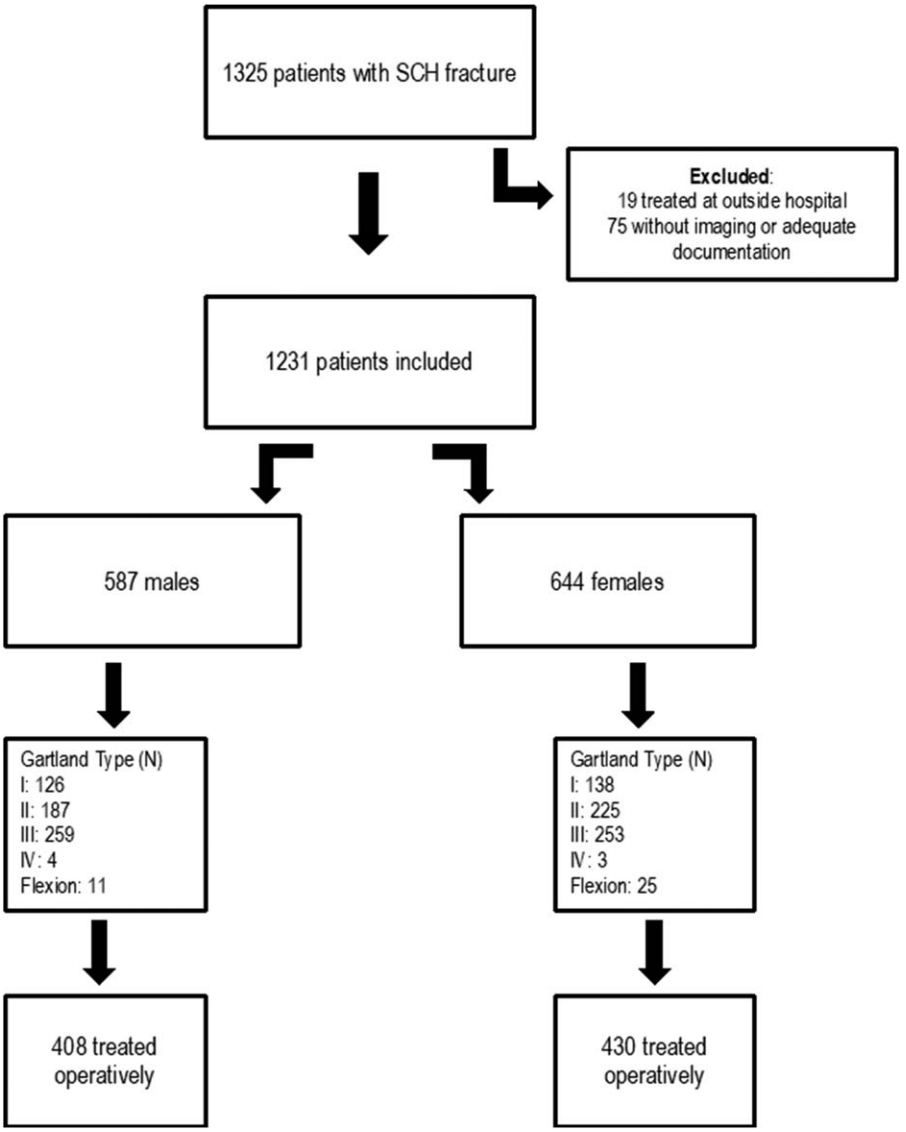

Figure 1. Flow chart of patient characteristics, clinical features, and exclusion criteria (SCH = supracondylar humerus).

with very few patients undergoing open reduction and internal fixation or open reduction and percutaneous pinning. Gartland type-I fractures accounted for 67% of nonoperatively treated fractures. Nonoperative treatment consisted of placement of a long arm cast and closed reduction and placement of a long arm cast for select type-II fractures. We found no significant difference in treatment type between sexes ($P = .39$). However, higher odds of operative treatment were found for older patients, those of white race, and those with Gartland type-II, type-III, or type-IV fractures, as well as flexion fractures (all $P < .001$; Table 6).

4. Discussion

SCH fracture is one of the most common pediatric upper extremity fractures and can cause substantial morbidity. Although previous studies reported that boys were more likely than girls to sustain SCH fractures, recent studies have reported that girls sustain SCH fractures at equal or higher rates than do boys.[8,17] During a 10-year study period, we found no difference in the numbers of boys vs girls treated for SCH fracture at 1 major US metropolitan healthcare center, contrary to previous findings and common beliefs. These findings suggest an evolution in the epidemiology of pediatric SCH fractures during the past several decades.

Consistent with one aspect of our hypothesis, we observed an increase in the number of SCH fractures during the study period, which was similar between girls and boys. However, these findings from a single center contrast recent reports of the incidence of SCH fractures in the United States. Using the US Nationwide Emergency Department Sample database, Holt et al[8] found a stable annual incidence of 60 to 72 SCH fractures per 100,000 children between 2006 and 2011. Although it is possible that our findings indicate an absolute increase in the incidence of SCH fractures, these results may also simply reflect changing referral patterns. Kasser[20] suggested that the success of surgical treatment in reducing complications (e.g.,

Table 1

Characteristics of 1231 pediatric patients with supracondylar humerus fractures treated at 1 center, 2008 to 2017.

Characteristic	N (%)	
	All patients	Operatively treated patients
Sex		
Female	644 (52)	430 (67)
Male	587 (48)	408 (70)
Treatment		
Operative	838 (68)	
CRPP	812 (97)	
ORIF	24 (2.9)	
ORPP	2 (0.24)	
Nonoperative	393 (32)	
Fracture type		
Gartland type		
I	264 (21)	2 (0.76)
II	412 (33)	287 (70)
III	512 (42)	509 (99)
IV	7 (0.57)	7 (100)
Flexion	36 (2.9)	33 (92)

CRPP = closed reduction and percutaneous pinning, ORIF = open reduction and internal fixation, ORPP = open reduction and percutaneous pinning.

cubitus varus) has caused an increase in referrals to pediatric orthopaedic centers for children whose SCH fractures would have been treated in community clinics in the past. Reports regarding SCH fracture characteristics between boys and girls offer conflicting information. Barr[7] reported a higher ratio of boys to girls sustaining Gartland type-II and -III fractures, but an almost equal proportion of girls (53%) to boys when analyzing all SCH fractures. In 209 patients with SCH fractures, Houshian et al[17] found no differences by Gartland type or patient sex. Similarly, we found no significant differences in the frequencies of Gartland types by patient sex, indicating that SCH fractures have similar characteristics among boys and girls. However, we did identify a positive association between flexion-type injuries and female sex. Kim et al[21] also found that flexion-type injuries were positively associated with female sex and older age. The incidence of flexion-type SCH fractures in our study was 2.9%, which is similar to previous reports.[6,22]

Girls were, on average, 6 months younger than boys at the time of SCH fracture. This finding could be attributable to the difference in skeletal maturation between girls and boys. Patel et al[23] described the appearance of elbow ossification centers by analyzing elbow radiographs. They found that the appearance and subsequent fusion of ossification centers in the elbow occurred at younger ages in girls than in boys. Conversely, it has been suggested that both sexes undergo cortical remodeling between 6 and 7 years of age, when a thinned cortex in the olecranon fossa is susceptible to fracture.[6] A larger series and further evaluation of the ossification difference between girls and boys is needed to clarify this finding.

We found no associations between sex, Gartland types, or high-energy mechanism of injury. Additionally, we found no association between sex and neurologic injuries. Previous studies have evaluated the correlation between patient sex and mechanism of injury. Abbott et al[24] found that older patients and boys were more likely to sustain complications after Gartland type-III fractures compared with younger patients and girls, respectively. They postulated that boys may be at greater risk of complications because of a difference in high-energy mechanisms of injury. Fletcher et al[25] evaluated association of high-energy mechanisms of injury. They retrospectively analyzed Gartland type-III SCH fractures and stratified patients into 2 groups according to age at time of injury (<8 years or >8 years). Without analyzing patients by sex, Fletcher et al[25] found that older age was positively associated with high-energy mechanisms of injury. In contrast to Abbott's finding, we found no association between sex and Gartland types, but similar to Fletcher et al,[25] we found that older age was significantly associated with high-energy mechanisms of injury. In terms of neurologic injury, we found no significant association between neurologic injury and high-energy injury mechanism ($P = .07$). The 9.5% incidence of neurologic injuries during our study period is consistent with previously reported rates, which range from 7% to 18%.[2,9,10,26] Similar to previous studies, the most commonly injured nerve was the AIN, and injury of the AIN was associated with male sex,[27] but we did not find greater odds of neurologic injury on the basis of patient sex.[28,29]

Treatment of SCH fractures depends on patient presentation and degree of fracture displacement. Most Gartland type-I fractures are treated nonoperatively, whereas Gartland type-III fractures are treated surgically.[30] Similar to past reports, we found that 0.76% of type-I and 99% of type-III fractures were treated operatively. Our "surgically treated" type-I fractures required operative intervention for ipsilateral injuries, which, if absent, would have allowed nonoperative fracture treatment with casting. Opel et al[31] used the National Trauma Data Bank to study the association between sex and surgical treatment of humeral shaft fractures and found that girls were less likely than boys to be treated surgically. Conversely, among patients presenting to the emergency department with SCH fractures, Holt et al[8] found no significant association between patient sex and rate of operative treatment. Similarly, we found that most patients (68%) underwent surgical treatment for SCH fractures, with no difference in rates by patient sex.

Our findings suggest that the epidemiology of SCH fractures has changed over time. We found no sex-based differences in SCH fracture rates, although girls sustained SCH fractures at younger ages. Additionally, patient sex was not associated with high-energy mechanisms, but was associated with older age. We found no sex-based difference in operative treatment. Our study, along with others, should challenge the misconception that SCH fractures are more common in boys, who are involved in rougher play/activity, and who thus require more surgical intervention. SCH fractures occur at similar rates in boys and girls; mechanism of injury is associated with age and not sex; and both girls and boys undergo surgery at similar rates.

5. Limitations

Limitations of our study include its retrospective design, with inherent variability in data documentation. Though this may result in underreporting of some variables (e.g., neurologic injuries), electronic medical records are likely to be accurate for most study variables, such as sex, age, and operative treatment. Also, we analyzed patients from one, level-1 trauma, tertiary referral center in a large US metropolitan area, and thus have a large operative management group. Although our findings may not be generalizable to smaller community settings in the United States or centers in other countries, they would likely correlate with other large tertiary care centers in the United States. An

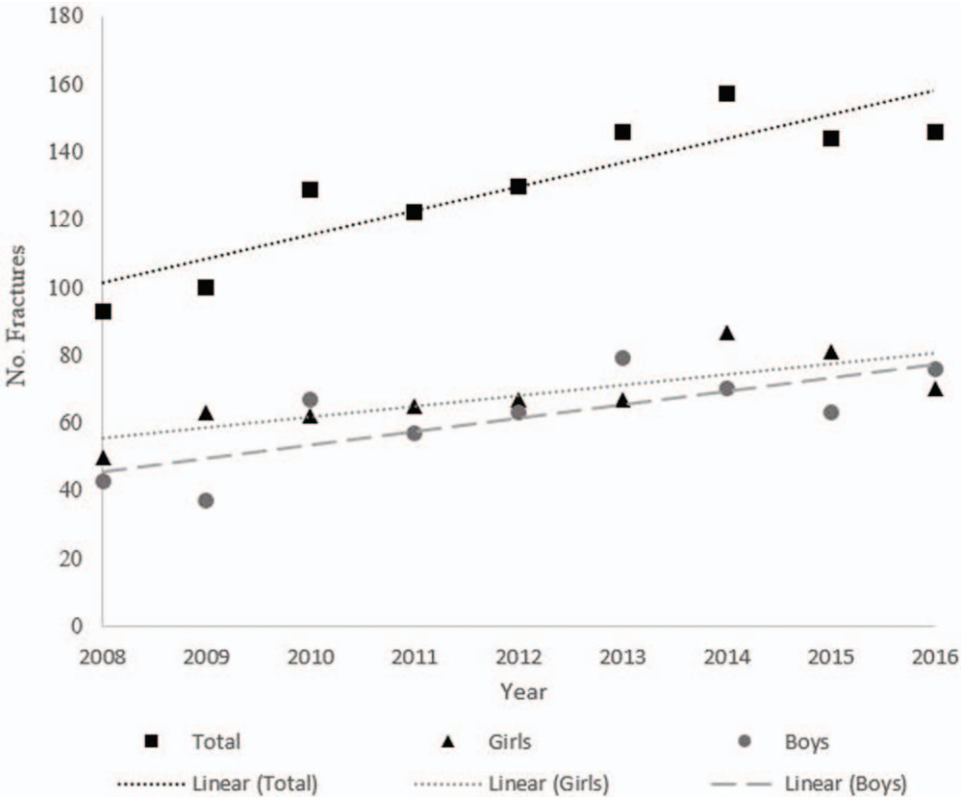

Figure 2. Number of pediatric supracondylar humerus fractures treated at 1 center from 2008 to 2016. Only 6 months of data were available for 2017, so that year was excluded.

inherent limitation in the pediatric population is the ability to detect neurologic deficits, especially in the youngest patients, using reported and subjective examination findings. Thus, neurologic injuries are likely underreported. This is a limitation of similar studies and is a reasonable method for detecting clinically relevant neurologic deficits. Furthermore, we may have underestimated the number of high-energy mechanisms because of a lack of specific injury details. However, previous studies[9,25] have used similar criteria for categorizing mechanisms of injury.

6. Future directions

The misconception that boys sustain SCH fractures more frequently than girls and are at greater risk for complications is often described in the literature. We hypothesize that the higher incidence found in boys in previous studies is attributable to cultural differences, such as a societal belief that boys play "rougher" than girls. Future research should be undertaken to determine whether outcomes after SCH fracture differ on the basis of patient sex.

Table 2

Frequency of supracondylar humerus fractures by sex and fracture type in 1231 patients treated at 1 center, 2008 to 2017.

	Fracture type											
			Gartland type									
			I		II		III		IV		Flexion	
Patient sex	N	Mean (±SD) age, year	N	Mean (±SD) age, year	N	Mean (±SD) age, year	N	Mean (±SD) age, year	N	Mean (±SD) age, year	N	Mean (±SD) age, year
Male	587	6.1±2.5	126	5.5±2.5	187	5.7±2.3	259	6.6±2.5	4	4.4±1.2	11	7.7±3.3
Female	644	5.5±2.5	138	5.0±2.7	225	5.2±2.5	253	6.1±2.4	3	4.5±2.5	25	7.0±1.5
All	1231	5.8±2.5	264	5.2±2.6	412	5.4±2.5	512	6.3±2.4	7	4.5±1.7	36	7.2±2.2
P	.11*	<.001†		.19†		.02†		.02†		.97†		.47†
						.13‡						

SD = standard deviation.
* From binomial probability test.
† From 2-tailed Student's *t* test, for difference by patient sex.
‡ From chi-squared test, for difference in Gartland types by sex.

Table 3

Most common mechanisms of injury among 1231 pediatric supracondylar humerus fractures treated at 1 center, 2008 to 2017.

Variable	N (%)	Girl:boy ratio	P*
Mechanism†			
High-energy	571 (46)	0.97	.74
Low-energy	615 (50)	1.2	
Event‡			
Climbing bars	180 (15)	1.4	.03
Playing sports	110 (8.9)	0.5	<.001
Playground	106 (8.6)	0.8	.38
Fall off bed	82 (6.7)	1.6	.04
Fall on outstretched hand	61 (5.0)	1.1	.80

* From chi-squared test, for difference by patient sex.
† Forty-five patients were excluded from this analysis because of unknown injury mechanism.
‡ From binomial probability test.

Table 4

Odds of sustaining a high-energy injury mechanism in 1186* patients with pediatric supracondylar humerus fractures treated at 1 center, 2008 to 2017.

Variable	OR (95% CI)	SE	P
Male sex	1.04 (0.98–1.1)	0.03	.20
Age	1.05 (1.03–1.06)	0.006	<.001
White race	1.07 (1.01–1.13)	0.03	.02
Neurologic injury	1.0 (0.92–1.11)	0.05	.85
Fracture subtype†			
Gartland II	1.07 (0.99–1.15)	0.04	.10
Gartland III	1.12 (1.04–1.21)	0.04	.002
Gartland IV‡	1.64 (1.14–2.36)	0.19	.008
Flexion	1.11 (0.94–1.32)	0.09	.23

CI = confidence interval, OR = odds ratio, SE = standard error.
* Forty-five patients were excluded from this analysis because of unknown injury mechanism.
† Referent, Gartland type-I fracture.
‡ The OR for the Gartland type-IV fracture group should be interpreted with caution because of the small number of patients in this subgroup (n = 7).

7. Conclusions

We found no association between patient sex and the number of pediatric SCH fractures treated at our center, nor any sex-based differences in the distribution of Gartland types. Girls presented with fractures at a younger mean age than that of boys, and both sexes had equal odds of sustaining neurologic injury. We recommend family education about common mechanisms of injury in SCH fractures, the ages when children are at greatest risk, and that children of both sexes are equally likely to sustain SCH fracture. These findings both contrast and complement those of previous studies and challenge the common belief that the incidence of SCH fracture is higher among boys than girls.

Table 5

Neurologic injury by patient sex and fracture type in 117 patients with supracondylar humerus fractures treated at 1 center, 2008–2017.

	No. of injuries					
	AIN injury		PIN injury		Other neurologic injury*	
Fracture type	Female	Male	Female	Male	Female	Male
Gartland type						
I	0	0	0	0	1	0
II	1	0	0	0	4	5
III	12	29	3	5	22	27
IV	1	0	0	0	0	2
Flexion	0	0	0	0	4	1
Total	14	29	3	5	31	35
P†	<.01		.40		.37	
P† overall vs sex	.01					

AIN = anterior interosseous nerve, PIN = posterior interosseous nerve.
* Includes injury to multiple nerves and other isolated nerve injuries (e.g., median, ulnar, radial).
† From chi-squared test, for difference by patient sex and neurologic injury.

Table 6

Odds of experiencing a neurologic injury or being treated operatively in 1231 patients with pediatric supracondylar humerus fractures treated at 1 center, 2008 to 2017.

	Neurologic injury			Treatment		
Variable	OR (95% CI)	SE	P	OR (95% CI)	SE	P
Male sex	1.03 (1.0–1.1)	0.02	.05	1.01 (0.98–1.05)	0.02	.39
Age	1.01 (1.0–1.02)	0.003	<.001	1.01 (1.00–1.02)	0.003	.04
White race	1.02 (0.98–1.05)	0.02	.30	1.04 (0.98–1.07)	0.02	.03
High-energy mechanism	1.0 (0.92–1.09)	0.04	.93	0.98 (0.90–1.06)	0.04	.59
Fracture subtype*						
Gartland II	1.02 (0.97–1.06)	0.02	.43	1.99 (1.91–2.08)	0.02	<.001
Gartland III	1.19 (1.13–1.24)	0.02	<.001	2.66 (2.55–2.77)	0.02	<.001
Gartland IV†	1.53 (1.24–1.89)	0.11	<.001	2.68 (2.18–3.30)	0.11	<.001
Flexion	1.12 (1.01–1.23)	0.05	.03	2.44 (2.21–2.69)	0.05	<.001

CI = confidence interval, OR = odds ratio, SE = standard error.
* Referent, Gartland type-I fracture.
† ORs for Gartland type-IV fractures should be interpreted with caution because of the small number of patients in this subgroup (n = 7).

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