

# Radiographic assessments of pediatric supracondylar fractures and mid-term patient-reported outcomes

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## Abstract

Radiographic parameters are commonly used to determine the need for surgical supracondylar humeral (SCH) fracture reduction and the postoperative quality of reduction. We studied whether such parameters are correlated with mid-term patient-reported outcome (PRO) scores in pediatric patients.

We retrospectively reviewed data from 213 patients (104 girls) treated surgically for Gartland type-II (n=84) or type-III (n=129) SCH fractures from 2008–2016. Mean ( $\pm$  standard deviation) age at surgery was  $5.1 \pm 2.1$  years. Mean time from initial treatment to outcome survey completion was  $5.0 \pm 2.1$  years (range, 2.0–10 years). We evaluated preoperative radiographs for coronal/sagittal fracture displacement, presence of impaction/comminution, Gartland classification, and rotation. Patients, parents were asked via telephone to complete the QuickDASH (Quick Disability of the Arm, Shoulder, and Hand) and PROMIS (Patient-Reported Outcomes Measurement Information System) Strength Impact, Upper Extremity, and Pain Interference questionnaires. Parents were also asked whether the previously fractured arm appeared normal or abnormal. We evaluated postoperative radiographs for coronal/sagittal deformity, Baumann angle, and rotation and classified reductions as near complete/complete or incomplete. Anterior humeral line through the capitellum, Baumann angle in the 7.5th to 92.5th percentile of the sample, or rotation ratio between 0.85 and 1.15 were considered near complete/complete reductions; all others were considered incomplete. Bivariate analysis was used to determine whether radiographic parameters and arm appearance were associated with QuickDASH and PROMIS scores.

Patients with Gartland type-III fractures had significantly greater disability on the QuickDASH at follow-up compared with those with Gartland type-II fractures ( $P < .01$ ). It is unknown if this statistical difference translates to clinical relevance. No other preoperative or postoperative radiographic parameter was significantly associated with PRO scores. There was no association between fractured arm appearance at follow-up and PRO scores.

Radiographic parameters that are used to evaluate the need for and quality of pediatric SCH fracture reduction are not significantly associated with mid-term PROMIS and QuickDASH scores.

LOE: Prognostic Level III.

**Abbreviations:** AHL = anterior humeral line, CRPP = closed reduction and percutaneous pinning, PRO = patient-reported outcome, PROMIS = Patient-Reported Outcomes Measurement Information System, QuickDASH = Quick Disability of the Arm, Shoulder, and Hand, SCH = supracondylar humeral, SD = standard deviation.

**Keywords:** children, pain interference, patient-reported outcome measures, PROMIS, QuickDASH, strength impact, supracondylar humerus fractures, upper extremity

## 1. Introduction

Supracondylar humeral (SCH) fractures are the most common elbow fractures in children,<sup>[1,2]</sup> with an annual incidence of approximately 70 fractures per 100,000 children.<sup>[3,4]</sup> Few studies have investigated outcomes of surgical treatment of SCH fractures

using validated patient-reported outcome (PRO) measures.<sup>[5–9]</sup> Furthermore, despite the widespread use of radiographic criteria to determine the need for fracture reduction and evaluate the postoperative quality of reduction, little is known about associations between these criteria and long-term PROs.

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PRO measures are patient-centered metrics of satisfaction and success. The Patient-Reported Outcomes Measurement Information System (PROMIS) is widely available, precise, reliable, and broad in scope.<sup>[10]</sup> PROMIS has been used to assess outcomes in several orthopedic conditions, including those of the foot and ankle, upper extremity, and spine, but not in SCH fractures.<sup>[11–15]</sup> The QuickDASH is a concise measure of physical function and symptoms in patients with musculoskeletal disorders of the upper extremities. It has been used to assess outcomes in pediatric SCH fractures, suggesting that excellent functional results are achieved regardless of neurological complications, direction of fracture displacement, and Gartland classification.<sup>[9,16]</sup>

To our knowledge, no study has investigated associations between mid-term PROMIS and QuickDASH scores and pre- and postoperative radiographic parameters in pediatric SCH fractures. Our aim was to determine whether 1) radiographic parameters commonly used in the evaluation of SCH fracture and subsequent fracture reduction, and 2) arm appearance at mid-term follow-up were associated with mid-term functional outcomes according to validated PRO measures.

## 2. Materials and methods

This study was approved by our institutional review board, and verbal consent was attained before survey administration.

### 2.1. Patient selection

Using the database of our tertiary care hospital, we retrospectively identified pediatric patients who were treated surgically for isolated Gartland type-II or type-III SCH fractures from January 2008 through July 2016. We included patients for whom preoperative and postoperative radiographs were available and who were 5 to 17 years of age at the time of telephone interviews in 2018, the range for which the Pediatric and Parent Proxy PROMIS measures have been validated. We excluded patients for whom 2 years had not yet elapsed since surgery or who did not complete the telephone interview.

### 2.2. Patient sample

Of the 617 eligible patients, 213 patient families (35%) responded to the telephone-based survey and constituted our convenience sample (Table 1). The mean patient age at surgery was 5.1 years (range, 1–11 years), and the mean age at survey was 10 years (range, 5–17 years). The mean ( $\pm$  standard deviation [SD]) duration from injury to survey was  $5.0 \pm 2.1$  years. The sample was racially diverse, with white patients representing a small majority ( $n = 118$ , 55%). Most patients ( $n = 129$ , 61%) had Gartland type-III fractures, and the remaining ( $n = 84$ , 39%) had Gartland type-II fractures. Most fractures ( $n = 205$ , 96%) were reduced with closed reduction and percutaneous pinning (CRPP).

**2.2.1. Preoperative factors.** Preoperative radiographs were evaluated for 4 factors. First, we classified fractures according to the Gartland system as type II (hinged with an intact posterior cortex) or type III (complete fracture without an osseous hinge).<sup>[3]</sup> Second, we evaluated the degree of displacement. Coronal plane displacement was categorized as absent, posterolateral, or posteromedial. Sagittal plane displacement was determined as a percentage of fracture width and categorized as 100% or <100%. Third, we evaluated fracture angulation. Coronal plane

**Table 1**

**Characteristics of 213 patients treated surgically for Gartland Type-II or -III Supracondylar Humerus Fractures, 2008–2017.**

Parameter	N (%)
Age at surgery, yr	5.1 $\pm$ 2.1*
Age at follow-up, yr	10 $\pm$ 2.8*
Duration of follow-up, yr	5.0 $\pm$ 2.1*
Female sex	104 (49)
Race	
White	118 (55)
Black/African American	51 (24)
Asian	17 (8)
Hispanic	10 (5)
Other	17 (8)
Gartland classification	
Type II	84 (39)
Type III	129 (61)
Surgical procedure	
CRPP	205 (96)
CRIF	4 (2)
ORIF	4 (2)

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

\* Data presented as mean  $\pm$  standard deviation.

angulation was determined by the presence of impaction/comminution of the medial or lateral column on anteroposterior radiographs. Sagittal plane angulation was evaluated using the anterior humeral line (AHL), with fractures grouped according to whether the AHL intersected any part of the capitellum. Fourth, we evaluated fracture rotation. The presence of rotation was determined by the asymmetric width of the fracture ends.<sup>[17]</sup> Fractures were grouped according to the ratio of the width of the 2 fracture ends, with fractures categorized as those with a ratio between 0.85 to 1.15 and those outside that range. To evaluate the effect of the presence of multiple preoperative parameters, we summed the following for each patient, with each parameter counting as 1 unit: AHL not intersecting the capitellum, translation on lateral radiograph of 100%, posteromedial or posterolateral displacement, impaction/comminution, rotation ratio of <0.85 or >1.15, and Gartland type-III fracture.

By definition, sagittal plane translation was not present in Gartland type-II fractures because of the intact osseous hinge. Because rotation and coronal plane angulation (in the form of impaction/comminution) often varied depending on forearm position during preoperative radiography, these factors were not evaluated for Gartland type-III fractures.

**2.2.2. Postoperative factors.** Postoperative radiographs were evaluated for 3 factors. First, coronal plane deformity was evaluated using Baumann angle, and reductions were analyzed as a group. Reductions with Baumann angles in the 7.5<sup>th</sup> to 92.5<sup>th</sup> percentile (corresponding to 65°–82°) were classified as near complete/complete, and those outside that range were classified as incomplete. Second, sagittal plane deformity was analyzed as described above. When the AHL intersected any portion of the capitellum, the reduction was considered near complete/complete; all other positions were considered incomplete. Third, rotation was analyzed as described above. Reductions with rotation ratios of 0.85 to 1.15 were considered near complete/complete, and those outside that range were considered incomplete.

### 2.3. Telephone survey

Parents were contacted via telephone and asked to complete the QuickDASH (Quick Disability of the Arm, Shoulder, and Hand) and 3 PROMIS Parent Proxy questionnaires: Strength Impact-Short Form A (version 1.0), Upper Extremity computer-adapted test (version 2.0), and Pain Interference (version 2.0). Parents were also asked whether the arm that had been fractured currently appeared “normal” or “abnormal” compared with the contralateral arm. Families were given a \$5 gift card after completing the interview. The final response rate was 35%. Of the 404 nonresponses, most (98%) were the result of disconnected telephone lines or failure to reach the parent after 3 attempts. Ten families declined to participate in the telephone survey.

### 2.4. PRO measures

PROMIS Strength Impact measures a child’s ability to perform activities of daily living that require substantial muscle force.<sup>[18]</sup> The PROMIS Upper Extremity questionnaire measures physical function during activities that require the use of the upper extremity. PROMIS Pain Interference quantifies the consequences of pain on social, cognitive, emotional, physical, and recreational aspects of life. All questions are based on symptoms or function during the week before questionnaire administration.<sup>[18]</sup> PROMIS scores are reported as T-scores, with a mean ( $\pm$  SD) of  $50 \pm 10$  points. Higher scores on PROMIS measures indicate more of the outcome being measured (e.g., more pain, more strength). All means are based on the general population (typical range, 20–80 points). Measures of function, such as the PROMIS Upper Extremity and Strength Impact questionnaires, are considered to be within normal limits if scores are  $>45$  points. A PROMIS Pain Interference score of  $<50$  points is considered within normal limits. QuickDASH measures upper extremity functional disability and pain severity during the previous week.

Scores ranges from 0 (no disability) to 100 (most disability), with a national mean of 11 points.<sup>[15]</sup>

### 2.5. Statistical analysis

Relationships between dichotomous and continuous variables were analyzed using Mann–Whitney *U* tests for non–normally distributed data. Student *t* tests were used for normally distributed data. Relationships between categorical and continuous variables were calculated using Kruskal–Wallis H-tests. Categorical outcomes were analyzed using Fisher exact tests. Continuous variables are expressed as means  $\pm$  SDs. Statistical analysis was performed with Stata, version 14, software (StataCorp LLC, College Station, TX). Differences were considered significant if the 2-tailed *P* value was  $<.05$ .

## 3. Results

For all patients, the mean ( $\pm$  SD) PROMIS scores were  $57 \pm 5.5$  for Upper Extremity,  $12 \pm 2.1$  for Pain Interference, and  $54 \pm 2.6$  for Strength Impact. The mean QuickDASH score for all patients was  $1.4 \pm 6.0$ . We found no association between patient sex and any PROs at follow-up.

### 3.1. Preoperative factors

At follow-up, patients who had been treated for Gartland type-III fractures had significantly worse mean ( $\pm$  SD) QuickDASH scores ( $2.1 \pm 7.5$ ) compared with those treated for Gartland type-II fractures ( $0.4 \pm 2.1$ ) ( $P < .01$ ). We found no significant associations between any other preoperative radiographic parameter and mid-term PROMIS or QuickDASH scores (Table 2). We found no significant difference between Gartland type-II vs type-III fractures in PROMIS Upper Extremity ( $P = .33$ ), Pain Interference ( $P = .72$ ), and Strength Impact ( $P = .11$ ) scores.

**Table 2**  
Patient-Reported Outcome Scores and Preoperative Radiographic Parameters for 213 patients treated surgically for Gartland Type-II or -III Supracondylar Humerus Fractures, 2008–2017.

Radiographic Parameter	PROMIS						QuickDASH	
	Upper Extremity		Pain Interference		Strength Impact		Mean (SD)	P value
	Mean (SD)	P value	Mean (SD)	P value	Mean (SD)	P Value		
AHL intersecting capitellum								
Yes	58 (0)	.41	12 (0)	.90	54 (0)	.46	0.5 (1.3)	.93
No	57 (5.9)		12 (2.3)		54 (2.6)		1.6 (6.4)	
Translation on lateral radiograph								
100%	55 (9.7)	.11	12 (1.1)	.67	53 (3.0)	.45	2.6 (8.7)	.47
<100%	58 (2.9)		12 (3.9)		54 (3.2)		2.0 (6.6)	
Anteroposterior displacement								
Posteromedial	57 (6.6)	.57	12 (2.7)	.57	54 (2.9)	.59	2.0 (7.6)	.23
Posterolateral	58 (4.0)		12 (0.8)		54 (1.9)		0.7 (2.7)	
Impaction/comminution								
No	58 (0)	.28	12 (0)	1.0	54 (0)	.28	0.2 (0.8)	.82
Yes	58 (0.5)		12 (0)		53 (1.9)		0.6 (3.1)	
Rotation ratio								
0.85–1.15	58 (0.4)	.51	12 (0)	1.0	54 (1.6)	.51	0.6 (2.6)	.13
<0.85 or >1.15	58 (0)		12 (0)		54 (0)		0 (0)	
Gartland classification								
Type II	58 (0.3)	.33	12 (0)	.72	54 (1.2)	.11	0.4 (2.1)	.007
Type III	56 (7.1)		12 (2.7)		53 (3.1)		2.1 (7.5)	

AHL = anterior humeral line, PROMIS = Patient-Reported Outcomes Measurement Information System, QuickDASH = Quick Disability of Arm, Shoulder, and Hand, SD = standard deviation.

**Table 3**  
**Patient-Reported Outcome Scores and Preoperative Radiographic Parameters for 213 patients treated surgically for Gartland Type-II or -III Supracondylar Humerus Fractures, 2008–2017.**

No. of Parameters*	PROMIS Domain scores							
	Upper extremity		Pain interference		Strength impact		QuickDASH scores	
	Mean (SD)	P value	Mean (SD)	P value	Mean (SD)	P value	Mean (SD)	P value
1	58 (0)	.93	12 (0)	.99	53 (3.1)	.96	0.2 (0.7)	.93
2	58 (0)		12 (0)		54 (0)		0.4 (1.1)	
3	58 (2.5)		12 (3.4)		54 (3.1)		1.7 (6.1)	
4	56 (8.8)		12 (1.0)		54 (2.7)		2.1 (7.9)	
1–3	58 (2.0)	.05 <sup>#</sup>	12 (2.6)	.55 <sup>#</sup>	54 (2.5)	.40 <sup>#</sup>	1.1 (4.8)	.95 <sup>#</sup>
1 or 2	58 (0)	.11	12 (0)	.79	54 (1.4)	.36	0.3 (1.0)	.36
3 or 4	57 (6.5)		12 (2.5)		54 (2.9)		1.9 (7.0)	

\* Sum of the following preoperative parameters, with the presence of each counting as 1 unit: anterior humeral line not intersecting the capitellum, translation on lateral radiograph of 100%, posteromedial or posterolateral displacement, impaction/comminution, rotation ratio of <0.85 or >1.15, and Gartland type-III fracture.

<sup>#</sup> P values for comparison with patients with 4 parameters.

PROMIS = Patient-Reported Outcomes Measurement Information System, QuickDASH = Quick Disability of Arm, Shoulder, and Hand, SD = standard deviation.

Though disruption of a bony hinge and increased displacement, angulation, and impaction/comminution may imply a more severe injury, the number of preoperative radiographic parameters present was not associated with significant differences in PROMIS Upper Extremity, Pain Interference, or Strength Impact, or QuickDASH ( $P = .93$ ,  $P = .99$ ,  $P = .96$ , and  $P = .93$ , respectively) (Table 2). We found no significant differences in PROMIS Upper Extremity, Pain Interference, Strength Impact, or QuickDASH between patients whose fractures met 4 parameters and those whose fractures met <4 parameters ( $P = .05$ ,  $P = .55$ ,  $P = .40$ , and  $P = .95$ , respectively). Comparison of PROMIS Upper Extremity, Pain Interference, Strength Impact, and QuickDASH scores between patients whose fractures met  $\geq 3$  criteria and those that met <3 criteria showed no significant differences ( $P = .11$ ,  $P = .79$ ,  $P = .36$ , and  $P = .36$ , respectively; Table 3).

### 3.2. Postoperative factors

We found no significant difference in any PRO according to whether fracture reduction was near complete/complete, as determined by postoperative rotation ratio, Baumann angle, or AHL (Table 4). Of the patients with incomplete reduction, none

required re-reduction, corrective osteotomy, or other secondary procedure.

### 3.3. Arm appearance

No preoperative or postoperative radiographic parameter was associated with final appearance of the fractured arm (Table 5). We found no significant differences in PROs according to whether patients/families reported normal or abnormal arm appearance at follow-up (Table 6).

## 4. Discussion

Although SCH fractures often require surgical treatment, there is disagreement about which radiographic criteria indicate a need for surgery and which criteria constitute an acceptable reduction. In our cohort of patients with surgically treated SCH fractures, mean QuickDASH and PROMIS Upper Extremity, Pain Interference, and Strength Impact scores did not differ significantly according to the presence or absence of any preoperative or postoperative radiographic measure. Furthermore, all mean PRO scores were within normal limits and PROs were excellent at mid-term follow-up.

**Table 4**  
**Patient-Reported Outcome Scores and Postoperative Radiographic Parameters for 213 patients treated surgically for Gartland Type-II or -III Supracondylar Humerus Fractures, 2008–2017.**

Radiographic Parameter	PROMIS Domain scores							
	Upper extremity		Pain interference		Strength impact		QuickDASH scores	
	Mean (SD)	P value	Mean (SD)	P value	Mean (SD)	P value	Mean (SD)	P value
Rotation ratio*								
Near complete/complete	57 (5.8)	.41	12 (2.2)	.89	54 (2.7)	.38	1.6 (6.3)	.31
Incomplete	58 (0)		12 (0)		54 (0)		0.3 (1.1)	
AHL <sup>†</sup>								
Near complete/complete	57 (5.4)	.96	12 (2.3)	.86	54 (2.1)	.91	1.6 (6.4)	.63
Incomplete	57 (6.7)		12 (0)		54 (2.6)		0.71 (2.4)	
Baumann angle <sup>‡</sup>								
Near complete/complete	57 (6.2)	.98	12 (2.3)	.85	54 (2.7)	.85	1.4 (6.4)	.11
Incomplete	57 (6.2)		12 (0)		54 (2.0)		1.5 (3.3)	

\* Fractures with a post-reduction rotation ratio of 0.85–1.15 were considered near complete/complete reductions; all others were considered incomplete.

<sup>†</sup> Fractures with an anterior humeral line intersecting any part of the capitellum after reduction were considered near complete/complete; all others were considered incomplete.

<sup>‡</sup> Reductions with a Baumann angle in the 7.5th to 92.5th percentile (corresponding to 65°–82°) were considered near complete/complete; all others were considered incomplete.

AHL = anterior humeral line, PROMIS = Patient-Reported Outcomes Measurement Information System, QuickDASH = Quick Disability of Arm, Shoulder, and Hand, SD = standard deviation.

**Table 5****Radiographic Parameters by Postoperative Arm Appearance for 213 patients treated surgically for Gartland Type-II or -III Supracondylar Humerus Fractures, 2008–2017.**

Radiographic Parameter	Postoperative Arm appearance		P value
	Normal (n = 193)	Abnormal (n = 20)	
<i>Preoperative parameters</i>			
Anterior humeral line			
Intersecting capitellum	13	1	.70
Not intersecting capitellum	165	19	
Translation on lateral radiograph <sup>*,†</sup>			
100%	58	4	.23
<100%	50	8	
Anteroposterior displacement <sup>†</sup>			
Posteromedial	106	16	.09
Posterolateral	72	4	
Impaction/comminution <sup>†,‡</sup>			
None	37	5	.60
Present	33	3	
Rotation ratio <sup>†,‡,§</sup>			
0.85–1.15	49	5	.62
<0.85 or >1.15	20	3	
<i>Postoperative Parameters</i>			
Anterior humeral line <sup>¶,**,††</sup>			
Near complete/complete	162	19	.23
Incomplete	28	1	
Baumann angle <sup>**,‡,††</sup>			
Near complete/complete	161	18	.53
Incomplete	29	2	
Rotation <sup>**,§§</sup>			
Near complete/complete	172	20	.15
Incomplete	18	0	

\* Gartland type-II fractures excluded because the parameter is not applicable.

† Missing values are the result of unavailable preoperative radiographs.

‡ Gartland type-III fractures excluded because the parameter is not applicable.

§ Fractures with rotation ratio of 0.85 to 1.15 were considered minor; fractures outside that range were considered major.

¶ Fractures with an anterior humeral line intersecting any part of the capitellum after reduction were considered complete reductions; all others were considered incomplete.

\*\* Missing values are the result of unavailable postoperative radiographs.

†† Reductions with Baumann angle in the 7.5th to 92.5th percentile (corresponding to 65°–82°) were considered near complete/complete; all others were considered incomplete.

§§ Fractures with a rotation ratio of 0.85–1.15 after reduction were considered near complete/complete reductions, all others were considered incomplete.

We found no significant differences in PROs when grouping patients according to several commonly used preoperative radiographic parameters, other than significantly lower QuickDASH scores in patients with Gartland type-II versus type-III fractures. Ernat et al<sup>[16]</sup> showed that Pediatric Outcomes Data Collection Instrument and QuickDASH scores did not differ between patients with type-II versus type-III fractures or between

direction of fracture displacement. A potential explanation for the discrepancy is the difference in mean follow-up between the studies (4.1 years in our study vs 79 days theirs). The significant differences we found may not be appreciable during shorter follow-up. Alternatively, a post hoc analysis suggested that our QuickDASH difference between type II and type III groups may have been caused by uneven distribution of outliers, defined as

**Table 6****PROMIS and QuickDASH Scores for 239 patients treated surgically for Gartland Type-II or -III Supracondylar Humerus Fractures, 2008–2017.**

Parameter	PROMIS Domain Scores							QuickDASH scores	
	Upper extremity		Pain interference		Strength impact		Mean (SD)	P value	
	Mean (SD)	P value	Mean (SD)	P value	Mean (SD)	P value			
Sex									
Male	57 (5.5)	.66	12 (2.8)	.66	54 (2.3)	.94	1.4 (5.6)	.92	
Female	57 (5.6)		12 (1.0)		54 (2.8)		1.5 (6.4)		
Postoperative arm appearance									
Normal	57 (4.9)	.08	12 (0.6)	.10	54 (2.0)	.12	1.1 (4.9)	.33	
Abnormal	55 (9.8)		13 (6.8)		53 (5.5)		4.3 (12)		

PROMIS = Patient-Reported Outcomes Measurement Information System, QuickDASH = Quick Disability of Arm, Shoulder, and Hand, SD = standard deviation.

values greater than 1.5 times the interquartile range (IQR) above the 3rd quartile (Q3).<sup>[19]</sup> Of the 29 QuickDASH outliers, 25 (86%) represented Gartland type-III fractures. Thus, their study may have lacked the uneven distribution of outliers seen in ours.

Nonetheless, the mean of all PROs, when stratified by preoperative radiographic parameters, fell within normal population values. The difference in QuickDASH scores between patients with Gartland type-II vs type-III fractures, although statistically significant, may not be clinically relevant. However, without knowing the minimal clinically important differences in QuickDASH scores for pediatric patients with SCH fractures, it is impossible to determine clinical relevance. Our findings do suggest that, despite widespread use of these preoperative radiographic parameters as markers of injury severity, they have little association with these commonly used PROs after surgical SCH fracture treatment.

Postoperative radiographic parameters, including AHL, Baumann angle, and rotation ratio, were used to determine whether a reduction was near complete/complete. None of the measured parameters was significantly associated with functional outcomes. Furthermore, no patient with incomplete reduction required a secondary procedure during the follow-up period. It has been suggested that good reduction is indicated by an AHL that intersects the capitellum within its middle third.<sup>[20,21]</sup> The clinical importance of this criterion is unclear, but 1 study showed that patients with a postreduction AHL crossing the middle third of the capitellum had better elbow flexion and range of motion compared with patients whose postreduction AHL intersected the anterior third of the capitellum.<sup>[22]</sup> Although our findings do not address long-term elbow range of motion, they do indicate that patients perceive equivalent outcomes regardless of whether reductions adhere to traditional AHL guidelines. Similarly, it has been suggested that a reduction to a Baumann angle of 64° to 81° (mean, 72°) is needed to achieve a good reduction.<sup>[23]</sup> Despite several studies having investigated the effect of postoperative Baumann angle on cubitus varus deformity and carrying angle after SCH, none has established an association with PROs.<sup>[7,24,25]</sup> Our data suggest that patients with incomplete reduction as measured by postoperative Baumann angle have equivalent mid-term function to those with near complete/complete reductions. Overall, it appears that children have excellent outcomes, as measured by parent proxy PROs, after surgical reduction of SCH fracture, regardless of the quality of reduction. This raises the question as to whether the goal for a SCH fracture should be an atraumatic, expeditious, “good” reduction rather than a “perfect” reduction that may require more soft tissue manipulation and longer surgical time. Although several studies have showed that corrective procedures following malunion of SCH fractures have good clinical and radiographic results, our study suggests that it may be important to also consider PROs in fractures that are not reduced “perfectly.”<sup>[26–28]</sup> Further study, and likely more sensitive PROs, are needed to determine which parameters are well tolerated and which may predict poor PROs.

Our study has several limitations. First, our response rate was 35% (n=213), which may introduce sampling bias. However, 2% (n=8) of the nonresponders declined participation, whereas 98% (n=396) of the nonresponders were unable to be reached and could potentially have a similar distribution of outcomes to that of our responder group. Second, the study used a retrospective design and a convenience sample. By analyzing objective radiographic measures, we limited the bias introduced

by retrospectively reviewing patient records. Third, we noticed floor and ceiling effects of the PRO measures we used. These effects are considered to be present if >15% of respondents achieve the lowest or highest possible score.<sup>[29]</sup> The PROs measuring physical function had considerable ceiling effects, with 97% (n=232) and 96% (n=230) of parent proxy questionnaires resulting in the highest possible scores for the PROMIS Strength Impact and Upper Extremity questionnaires, respectively. The PROs measuring disability had considerable floor effects, with 98% (n=234) and 86% (n=206) of respondents reporting the lowest possible scores on the PROMIS Pain Interference and QuickDASH questionnaires, respectively. Notably, the QuickDASH scores were similar to those reported in other outcome studies of SCH fractures.<sup>[30,31]</sup> Because the primary aim of our study was to investigate mid-term functional outcomes at 1 time point after SCH fracture, the presence of a ceiling or floor effect should not detract from our finding that all patients had excellent outcomes as measured by the selected PROs. Finally, our surgically treated population may not reflect extremes of potential deformity because they had been surgically treated.

In conclusion, our cohort of pediatric patients treated surgically for SCH fractures had excellent outcomes according to 3 PROMIS measures and the QuickDASH, regardless of fracture severity or quality of fracture reduction. Future research is needed to define appropriate criteria for acceptable SCH fracture reduction, provide data on longer-term outcomes, and identify risk factors that lead to unacceptable cosmesis and functional limitations.

## Author contributions

**Conceptualization:** Francisco A. Eguia, Walter Klyce, R. Jay Lee.

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