Research Article

Utility of Follow-up Radiographs After Pin Removal in Supracondylar Humerus Fractures: A Retrospective Cohort Study

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Abstract

Introduction: Displaced supracondylar humerus fractures (SCFs) are common pediatric injuries, typically treated by closed reduction and percutaneous pinning (CRPP). Radiographs are obtained at pin removal and subsequently to evaluate fracture healing. We evaluated the utility of radiographs obtained after pin removal in pediatric SCF management.

Methods: A retrospective cohort study of children aged 2 to 11 years with SCF requiring CRPP at a single institution from January 2007 to July 2017 was conducted. Radiographs were taken at pin removal and minimum 3 weeks later. Demographic and treatment data were collected via chart review. Radiographic measures were Baumann and lateral humeral-capitellar angles, anterior humeral line alignment, and number of cortices with callus. The McNemar-Bowker test analyzed anterior humeral line alignment and cortices with callus. The paired *t*-test analyzed Baumann and lateral humeral-capitellar angles.

Results: One hundred patients were included (47 males and 53 females, mean 5.7 years). The mean time to pin removal was 23.8 days, and the median clinical and radiographic follow-up periods were 109.0 and 52.2 days, respectively. Fracture patterns were extension type II (21%), III (73%), IV (1%), flexion (4%), and varus (1%). No patients' fracture management changed in the acute or long-term postoperative period because of findings on post-pin removal (PPR) radiographs. Fewer cortices with callus were seen at pin removal versus PPR (<0.001). At pin removal, no differences were found in the Baumann angle (75.8 ± 5.0 versus 74.6 ± 5.9; $P = 0.053$), lateral humeral-capitellar angles (30.7 ± 12.5 versus 31.6 ± 1.3; $P = 0.165$), or anterior humeral line alignment ($P = 0.261$).

Discussion: No patients' fracture management was modified because of findings evident on PPR radiographs. The number of cortices with callus was the only radiographic measure to differ over time, as is anticipated with routine healing. Elbow radiographic alignment measures did not differ in the interval between radiographs. Therefore, PPR radiographs may not provide clinical utility in the absence of other clinical findings.

Level of Evidence: Level III, retrospective comparative study

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Supracondylar humerus fractures (SCFs) are a common condition among pediatric injuries, with an estimated prevalence of 177.4 per 100,000 children annually.[1] For modified Gartland[2] SCF types III-IV, the current standard of care is to perform closed reduction and percutaneous pinning (CRPP). The goal is to restore coronal and sagittal plane alignment while preventing neurapraxia and vascular injury.[3] Pin removal occurs after 2½ to 5 weeks, often with serial radiographs to assess alignment, fracture healing, and monitor for adverse outcomes. Complications from CRPP include neurovascular injury, loss of reduction, pin tract infection, pin migration, and malalignment (most commonly cubitus varus or extension deformity).[4,5] The decision to obtain serial radiographs after pin removal (post-pin removal [PPR]) is based on the individual surgeon's clinical discretion because a paucity of literature exists evaluating their utility. We are unaware of any studies that specifically focus on the effect that PPR radiographs had on changes in fracture management. Furthermore, no guidelines or published consensus exist regarding the timing of follow-up radiographs after pin removal.

Limited existing data are available on the necessity of postoperative imaging after SCF reduction and pin fixation. A 2004 study by Ponce et al[5] suggests that the timing of radiographs after CRPP does not affect complication rates, but are valuable in the 10 days after the procedure to identify potential complications.

Conflicting reports exist in the literature regarding the role and ideal timing of radiographs in the management of SCFs.[5-7] The decision to obtain radiographs after pin removal is based on the individual surgeon's preference and is not standardized; in addition, a paucity of literature exists to guide the decision-making process regarding interval radiographic imaging to guide fracture management. In the 2015 American Academy of Orthopaedic Surgeons (AAOS) Appropriate Use Criteria article on SCF, postoperative imaging is not discussed.[8] To add to the discussion, the purpose of this study was to evaluate the utility of PPR radiographs in SCF management in children.

Methods

This is a retrospective case review of SCF treated with closed reduction and percutaneous pinning between January 2007 and July 2017. After obtaining institutional review board approval, Current Procedural Terminology (CPT) code 24538 (percutaneous fixation of humeral supracondylar fracture) was used to identify children who underwent this procedure by four pediatric fellowship-trained surgeons at a single academic medical center. Patients were included if they were aged between 2 and 11 years at the time of injury, with a minimum of two subsequent radiographs: one taken at the time of pin removal and another at least 3 weeks later.

Electronic medical records were reviewed to collect demographic characteristics, details regarding the surgical procedure, complications (ie, malalignment after CRPP and neurovascular injury), elbow range of motion, and clinical course. Cases were excluded if the patients were skeletally mature, had distal humerus fracture other than a supracondylar fracture, were lost to follow-up (secondary to the catch-all nature of our institution), or did not receive serial imaging after pin removal. Total follow-up was defined as the date of emergency department visit to the date of last contact. Duration of pins represented the time between surgery and pin removal. SCFs were characterized using the modified Gartland classification.[2]

Radiographs, taken in the absence of casting material, were assessed to evaluate elbow joint alignment and healing. Two assessors were trained to make the measurements by the senior author, who also performed interval assessments of the measurement accuracy. Measurements were made electronically using IMPAX-6 (Agfa HealthCare) and included the Baumann angle, anterior humeral line relative to the capitellum, and lateral humeral-capitellar angles. In addition, the number of cortices with callus (defined as a bridging callus) was recorded to evaluate fracture healing. Patients are not routinely immobilized after pin removal.

The healing response was assessed using both radiographs taken at the time of the pin removal and radiographs obtained at subsequent visits. The McNemar-Bowker test was used to determine differences between the number of cortices with callus formation and to assess changes in anterior humeral line alignment relative to the capitellum. The differences in the Baumann angle and lateral humeral-capitellar angle were evaluated using a paired sample *t*-test. Cases in which PPR visit radiographs led to change in management were also recorded. Statistical analysis was performed with IBM SPSS v.24.

Results

During the study period, 100 of 495 patients who experienced SCF requiring CRPP met the inclusion criteria. Of the excluded patients, 78% were excluded because of inadequate imaging, 18% because of loss to follow-up, and 2% because of other reasons, such as irregular follow-up intervals. Demographic data are given in Table 1. Forty-seven males and 53 females, with a mean age of 5.7 ± 2.0 years, were included. The mean time to pin removal was 23.7 ± 5.6 days. The median clinical and radiographic

follow-up periods were 109.0 (range, 47 to 1,461) days and 52.2 (27 to 503) days, respectively. The predominant fracture type was extension type III (73%) as defined by the modified Gartland classification, followed by extension type II (21%), and flexion type (4%). Extension type IV and pure varus fracture types were rare (1% each) (Table 1).

Most patients sustained isolated SCF without neurapraxia or vascular injury (Table 1). Four percent of patients had ipsilateral distal forearm fracture. Three of the four ipsilateral forearm fractures were treated with closed reduction and cast application. The fourth fracture (buckle type) was treated with cast application alone.

In analyzing the radiographic outcomes of interest, 25 patients' measurements had to be excluded secondary to poor arm positioning precluding accurate measurements. Thus, the final patient cohort was 100 patients, 47 males and 53 females, with the radiographic analyses limited to a subgroup analysis of 75 patients. A representative image series is demonstrated in Figure 1. No statistically significant differences were found in the radiographic measures between the time of pin removal compared with the PPR imaging (Table 2). The lateral humeral-capitellar angle and the anterior humeral line alignment did not markedly differ over time (Table 2). More than half of the patients (60.5%) had three cortices with callus evident at the time of pin removal. At PPR, 81.6% of patients demonstrated four cortices with callus, and 17.4% had three cortices ($P < 0.001$).

There were no patients whose fracture management plan was modified because of findings evident on PPR radiographs. No patients experienced radiographic loss of reduction between the time of pin removal and PPR. No patients required a revision surgery or distal humerus osteotomy during the observed study period. At the time of final follow-up, 51.8% patients had clinically appearing neutral elbow alignment, 44.6% had mild valgus appearance, and 3.6% had mild varus appearance (of the 56 patients with documented clinical appearance in the physical examination component of the clinic note). No patients were lost to follow-up if the surgeon documented concerns for malalignment. Most patients (87.7%) achieved final elbow flexion of ≥130°.

Table 1

Demographic Data of the Entire Cohort

Demographic Data		
N = 100	**Mean**	**SD**
Age (yr)	5.7	2.0
Variable	**N**	**%**
Sex		
Male	47	47
Female	53	53
Fracture pattern[a]		
Flexion type	4	4
Pure varus	1	1
Extension type I	0	0
Extension type II	21	21
Extension type III	73	73
Extension type IV	1	1
Neurovascular injury[b]		
Neurapraxia		
Isolated AIN[c] or median N	7	7
Isolated PIN[d] or radial N	3	3
Both median and radial N	1	1
Vascular		
Pulseless, perfused	7	7
Pulseless, poorly perfused	1	1

[a] By the Gartland classification.
[b] All complications occurred in a Gartland type 3 except one PIN or radial N in a type 2.
[c] Anterior interosseous nerve (AIN).
[d] Posterior interosseous nerve (PIN).

Discussion

A growing body of literature has been questioning the utility of serial radiographs to assess pediatric orthopaedic fracture healing.[3-6,9-12] The evolving consensus of existing studies concludes that radiographs may not need to be included in otherwise uncomplicated patients. SCFs are of particular interest because they are the second most commonly occurring upper extremity fracture in the pediatric population.[13,14] The topic of SCF management has been addressed as part of the AAOS Appropriate Use Criteria,[8] although serial radiographs were not included as part of the discussion despite being a growing focus in the literature.

The ideal function of PPR radiographs is to identify loss of reduction for the purpose of early determination

Figure 1

Image series of a patient with a supracondylar humerus fracture.

regarding further intervention and to assess fracture healing to permit return to full activity. A 2008 study by Bochang et al[10] examined the role of radiographs in closed pediatric forearm fractures, and the results demonstrated that with two exceptions, nondisplaced or minimally displaced fractures with angulation of less than 10° did not require additional intervention after cast removal; thus, ongoing radiographic evaluation was not indicated. The two exceptions were greenstick fractures and fractures with angulation of greater than 10°, on the basis that 8.1% of patients with these patterns experienced loss of reduction and need for additional interventions. A 2017 study by Karalius et al[15] evaluated the role of radiographs taken at initial follow-up and pin removal in 572 patients with SCF. The incidence of revision surgery was 1% (6 of 572 patients), and per the authors, the decision to revise was made based on the initial postoperative radiographs as opposed to later imaging. They concluded that radiographs taken greater than 7 to 10 days postoperatively do not add clinical value for uncomplicated cases. The study by Karalius et al differs from the current study because of the time interval of radiography, as their study focuses on radiographs at time of pin removal and our findings focus on radiographs occurring 3 to 4 weeks after pin removal. The present study and Karalius et al serve to highlight practice variations in managing these fractures. A 2017 article by Holt et al on US trends in acute SCF management concludes that surgical intervention at tertiary centers is becoming standardized; however, neither the study by Holt nor the AAOS Appropriate Use Guidelines propose a standardized timing of postoperative radiographs.[8,16]

Similar to the aforementioned 2017 study,[15] we found that radiographs taken 6 to 8 weeks postoperatively, corresponding to PPR films, added little value in the care of patients with SCF. The three radiographic measures (Baumann angle, lateral humeral-capitellar angle, and anterior humeral line alignment) we recorded did not markedly differ between pin removal and PPR; therefore, the second set of

imaging was not clinically useful. It should be noted that the differences in the Baumann angle from pin removal to PPR trended toward statistical significance; however, the difference was not clinically meaningful. Both means were within normal values, and the absolute difference of 1.23° was within the published interrater variability.[17] A normal Baumann angle is 70° to 75°, and most patients in our cohort were within these values at the time of the pin removal.

Another utility of following pediatric fractures radiographically is to assess fracture healing. However, this approach may be more applicable in the adult population with higher rates of delayed union and nonunion in contrast to the pediatric population. Our study demonstrated that most patients had an increasing number of cortices with callus at the time of pin removal compared with PPR, which is intuitive, given the typically rapid fracture healing in children. In a large-scale Finnish study published in 2015,[18] no patients with SCFs (excluding those with lateral condyle fracture) experienced a nonunion in a cohort of over 7,000 children.

A major limitation of this study was the exclusion of 395 patients because of either loss of follow-up or lack of PPR radiographic imaging. Our institution is one of two in the state that addresses complex SCFs; thus, a portion of our patient population is unable to return for long-term follow-up because of geographic restrictions. Because of the retrospective nature of the study, routine radiography after pin removal was not standardized among all surgeons, accounting for the high number of excluded patients. Regarding the subgroup analysis of radiographic measures, we excluded 25% of the patients from the analyses secondary to poor arm positioning precluding accurate radiographic measurements. The retrospective nature of the study contributed to this limitation because there was no study protocol on ensuring quality radiographs. Another limitation is the potential for changes in surgeon's practices over the study period, as well as the individual surgeon's variation. These limitations are also related to the retrospective nature of the study and the lack of an established treatment protocol of SCF fracture management. Furthermore, because the decision to pursue any revision surgery or corrective osteotomy was at the surgeon's discretion and may not have been captured in the observed study period, the absence of these procedures in this data set does not exclude the possibility of clinically unacceptable malunion. Our study period captured most patients' outcomes in a several-month postoperative period, which may not observe long-term patient outcomes of a year or greater; however, patients and their families were encouraged to follow up with our institution if concerns did arise.

These findings suggest that serial radiographs after the time of pin removal (greater than 6 weeks postoperatively) are not a necessary component of SCF postoperative management. In the absence of clinical concerns for malunion or reports of pain, radiographs after pin removal should not be routinely obtained in the management of SCF. Serial radiographs do, however, expose children to additional radiation, accrue additional healthcare removal occurs after costs, and add time to clinic visits. Combined with the current growing body of literature that calls the ideal imaging of postoperative imaging after CRRP into question, our study indicates that roughly six-week postoperative imaging has no utility.

Table 2

Summary of Radiographic Indices

Variable	Pin Removal Mean	Pin Removal SD	Follow-up Mean	Follow-up SD	*P*
Baumann angle	75.8	5.0	74.6	5.6	0.053
Lateral humeral-capitellar angle	30.7	12.3	31.6	11.0	0.165

Variable	Pin Removal N	Pin Removal %	Follow-up N	Follow-up %	*P*
No. of cortices with callus					
1	0	0.0	0	0.0	<0.001
2	6	7.9	1	1.3	
3	46	60.5	13	17.1	
4	24	31.6	62	81.6	
Anterior humeral line alignment					
Not touching capitellum	9	11.8	8	10.5	0.261
Anterior 1/3 of capitellum	32	42.1	29	38.2	
Middle 1/3 of capitellum	33	43.4	38	50.0	
Posterior 1/3 of capitellum	2	2.6	1	1.3	

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