Journal of the Pediatric Orthopaedic Society of North America 6 (2024) 100022

Contents lists available at ScienceDirect

Journal of the Pediatric Orthopaedic Society of North America

journal homepage: www.jposna.com

Original Research

Distal humeral osteotomy for cubitus varus in children compared to adolescents

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ARTICLE INFO

Keywords:
Cubitus varus
Distal humerus
Osteotomy
Adolescents

ABSTRACT

Background: While pediatric cubitus varus has often been considered merely a cosmetic deformity, long-standing cubitus varus can lead to symptomatic pain and elbow instability in adults and may present as early as adolescence. The purpose of this study was to compare patient and radiographic characteristics, surgical factors, and symptom resolution after distal humeral osteotomy for cubitus varus in pediatric versus adolescent patients.
Methods: This is a retrospective single-institution review of 17 patients (12 patients < 10.0 years (group Peds); 5 patients > 10.0 years (group Adol)) were treated for cubitus varus with distal humeral osteotomy from 2003 to 2019. Peds had a median age of 6.3 years (range, 2.7-7.8 years) at the time of osteotomy, and Adol had a median age of 14.1 years (range, 13.5-16.7 years). A Fisher's exact test was used to compare categorical variables between Peds and Adol, and continuous variables were compared using Mann-Whitney or Student's t-test depending on normality results using the Shapiro-Wilk test. Statistical significance was set at $P < .05$.
Results: Preoperative pain was present in 17% (2/12) of Pediatric patients (Peds) but 100% (5/5) of Adolescent patients (Adols). Mechanical symptoms were present in 17% (2/12) of Peds and 80% (4/5) in Adol. Radiographic correction and final range of motion did not significantly differ between the 2 groups. The mean tourniquet time was 83 minutes in Peds and 117 minutes in Adol. Pin fixation was used in 100% (12/12) of Peds; 80% (4/5) of Adol had plates. At the final follow-up, all Peds had resolution of symptoms, but 60% (3/5) Adol had continued pain and mechanical symptoms.
Conclusions: Although both pediatric and adolescent patients have similar radiographic correction and range of motion after distal humeral osteotomy to correct cubitus varus, the surgery may be more technically difficult in adolescent patients, with longer tourniquet times and the use of plate instead of pin fixation. Adolescents should be counseled that, like adults, their symptoms may not completely resolve after correction of radiographic and clinical deformity. The authors recommend that cubitus varus be corrected in childhood prior to the development of symptoms in adolescence.
Key Concepts:

1) Cubitus varus following pediatric distal humerus fracture may present with pain and mechanical symptoms as early as adolescence.
2) Although pediatric and adolescent patients may have similar radiographic correction and range of motion after distal humeral osteotomy, the surgery is technically more difficult in adolescent patients.
3) Adolescents should be counseled that pre-operative symptoms may not completely resolve after correction of radiographic and clinical limb deformity.
4) It is the authors' opinion that cubitus varus should be surgically corrected before a child reaches adolescence, when it is technically less demanding and before mechanical symptoms and pain develop.

Level of Evidence: Level III – Retrospective Cohort Study

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https://doi.org/10.1016/j.jposna.2024.100022
Received 11 January 2024; Accepted 17 January 2024

Introduction

Cubitus varus deformity is a major complication occurring after pediatric supracondylar and lateral condyle fractures. The incidence is high, ranging from 4% to 50%, with a higher likelihood noted in those treated conservatively [1]. The etiology of the cubitus varus deformity arises from fracture malunion and presents as a combination of varus, extension, and internal rotation of the affected limb [1–4]. Historically, pediatric cubitus varus has been described as a cosmetic deformity with minimal functional deficits or pain [4–6].

The timing of corrective osteotomy in the pediatric cubitus varus patient has long been considered controversial, but it is suggested that earlier intervention allows for more favorable outcomes [7]. Bony morphologic changes from long-standing cubitus varus, including posterior trochlear overgrowth, increasing distal humerus internal rotation, lateral shift with external rotation of the proximal ulna, and overgrowth of the capitellum and radial head have been described [7]. Increased severity of cubitus varus deformity has been correlated to younger age of injury [7]. Progressive cubitus varus in adults may lead to complications including posterolateral rotatory instability (PLRI), snapping triceps, and ulnar neuropathy [8–12]. It is possible that pediatric patients may benefit from earlier corrective osteotomy in order to mitigate the risk of long-term complications; however, there is little literature to guide whether early corrective osteotomy should be performed in pediatric patients. Therefore, the primary aim of our study was to compare patient and radiographic characteristics, surgical factors, and symptom resolution after distal humeral osteotomy for cubitus varus in pediatric versus adolescent patients.

Materials and methods

The Strengthening the Reporting of Observation studies in Epidemiology guidelines were utilized in the preparation of this paper. This was a single-center institutional review-board-approved analysis of patients under the age of 18 who were treated surgically for cubitus varus with distal humeral osteotomy from 2003 to 2019 (IRB #: STU 092016-039). Patients were identified through billing records using the CPT code of 24 400 (osteotomy of humerus). Radiographs and clinical data were examined to ensure that a distal humeral osteotomy was performed for the correction of cubitus varus.

The inclusion criteria were (1) diagnosis of cubitus varus, (2) age younger than 18 years old at the time of corrective osteotomy, (3) history of an elbow injury, (4) surgery performed by a fellowship-trained pediatric orthopedic surgeon, (5) and availability of complete medical record and radiographic data for the course of treatment and follow-up period. The exclusion criteria were (1) diagnosis other than cubitus varus, (2) age older than 18 years old, (3) concurrent skeletal injuries in the ipsilateral upper extremity, (4) congenital deformity before injury, (5) physical signs that might otherwise explain pain or functional limitation, and (6) lack of clinical or radiographic data for the course of treatment and follow-up period. Injury radiographs were not available for the majority of patients, almost all of whom were initially treated in other institutions within as well as outside the United States.

Twenty patients were identified from the CPT search. Three were excluded as their humeral osteotomy was not due to cubitus varus. Our remaining patient population of 17 patients was divided into a pediatric group (Group Peds) if < 10 years old at the time of corrective osteotomy and an adolescent group (Group Adol) if ≥ 10 years old at time of corrective osteotomy. Twelve patients were identified in Peds, and 5 were identified in Adol. Indications for osteotomy were surgeon recommendation as well as family preference. Five patients were treated for their initial injury at our institution; 1 in the Pediatric group had supracondylar humerus fracture treated with closed reduction and pinning, and another was a lateral condyle fracture treated with casting. Two of the 3 patients in the Adolescent group treated at our institution were elbow fracture-dislocation The Radiographic Appearance Seemed Harmless (The Radiographic Appearance Seemed Harmless) lesions treated nonoperatively, and the other was a supracondylar humerus fracture treated with closed reduction and pinning.

Clinical and radiographic data were available for all 17 patients. Range of motion data was obtained from office notes, with no mention in the notes as to whether formal goniometer measurements were obtained. Preoperative and postoperative radiographs consisted of anteroposterior and lateral elbow radiographs of the ipsilateral limb. Preoperative and final follow-up radiographic measurements included lateral shaft condylar angle, and ulnohumeral angle. For patients with an open capitellar physis, Baumann's angle was used to measure coronal malalignment (Fig. 1), while the distal humeral joint surface to shaft axis (distal humeral angle) was measured for patients with a closed capitellar physis (Fig. 2). Due to different radiographic landmarks in the skeletally immature versus mature elbow, we were unable to directly compare Baumann's angle (Peds) to the distal humeral angle (Adol) other than to compare amount of correction. Contralateral elbow radiographs were inconsistently available to compare to the malunited side so we were unable to compare how well surgical correction restored alignment to the uninjured extremity.

All Peds had a distal humeral osteotomy using a lateral closing wedge osteotomy. Two of the 5 Adol groups had a dome osteotomy performed per individual surgeon preference, with a lateral closing wedge osteotomy performed for the other 3 Adol patients. The surgical technique utilized for the lateral closing wedge osteotomy in pediatric patients has been previously described in detail, with 2 laterally based oblique osteotomies planned to minimize the lateral prominence that occurs with the traditional closing wedge osteotomy [4].

Complications were defined as any deviation from the expected clinical course, such as the need for physical therapy or an unplanned return to the operating room, or inability to obtain functional elbow extension or flexion ($30\text{-}130^0$).

Statistical methods

Statistical analysis involved comparing demographic, clinical, surgical, and radiographic data between Peds and Adol. A Fisher's exact test was used to compare categorical variables. Continuous variables were first examined for normality with a Shapiro-Wilk test, and a nonparametric test (Mann-Whitney) was executed for the comparison between the 2 groups if normality was rejected, and Student's t-test was used if there was failure to reject the normality. Statistical significance was set at $P < .05$.

Results

Four Peds patients and 1 Adol patient were treated surgically for their initial fracture, with only one in each group surgically fixed at our institution. Comparison of Peds and Adol patient preoperative, intraoperative, and postoperative characteristics are presented in Table 1. Peds patients were statistically significantly younger at the time of initial injury (median, 3.4 years) and had a shorter time between injury and osteotomy (median, 2.9 years) when compared to Adol patients (median, 5.8 years at the time of injury [$P < .05$]; median, 8.3 years to the time of osteotomy [$P < .05$]). While all 17 patients presented with cubitus varus deformity, only 3 Peds patients presented with pain and/or mechanical symptoms (popping, locking, catching sensations), while all Adol patients presented with pain, and 80% (4/5) had mechanical symptoms. Four Adol patients underwent elbow arthroscopy either prior to humeral osteotomy or concurrently with humeral osteotomy.

Although median operative and fluoroscopy times were not significantly different between groups, median tourniquet time was statistically significantly longer in Adol ($P < .05$). Three Adol patients had tourniquet times of 120 minutes (both with dome osteotomies), one with 128 minutes, and one with 95 minutes. 92% (11/12) of Peds osteotomies had K-wire fixation (1 patient was fixed with a 1/3 tubular

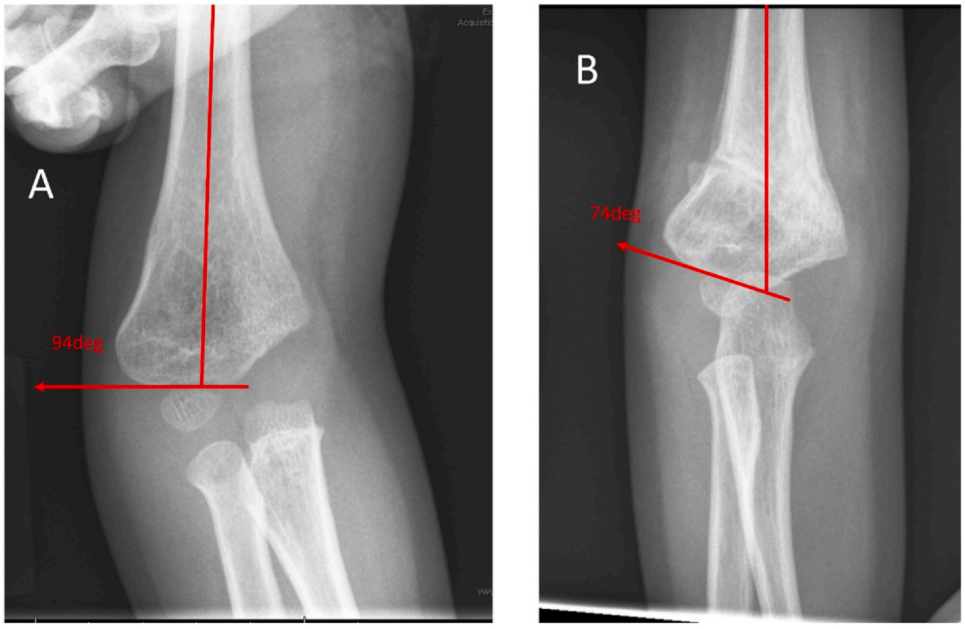

Figure 1. Radiographic measurement of Baumann's angle preoperatively (A) and postcorrection (B).

plate), while 100% of the Adol patients had plate/screw fixation ($P < .05$). Plate constructs for the Adol included 3 posterolateral anatomic locked plates via a straight lateral approach and 2 dual column recon plates for dome osteotomies that necessitated a posterior approach. All Peds osteotomies utilized a lateral approach. Preoperative range of motion, final range of motion, and time to full activities did not differ significantly between the 2 groups ($P > .05$). There was 1 Peds patient with only 40^0 of extension documented when the cast was removed at 6 weeks postoperatively; this patient failed to return for further follow-up. Another Peds patient had documented 20^0 of hyperextension at the final follow-up that was symmetric to his contralateral side. The median length of follow-up for Peds patients was 85 days and for Adol patients was 237 days.

Preoperative and final radiographic deformity were not statistically significant between the 2 groups (Table 2, $P > .05$). Final follow-up postoperative coronal radiographic correction as measured by the Baumann's angle in Peds and distal humeral angle in Adol were also not statistically significantly different ($P > .05$). Additionally, we did not note loss of correction between initial postoperative radiographs and final follow-up radiographs.

Four complications were identified, 2 in the Adol group and 2 in the Peds group. One Adol patient had pain that required hardware removal

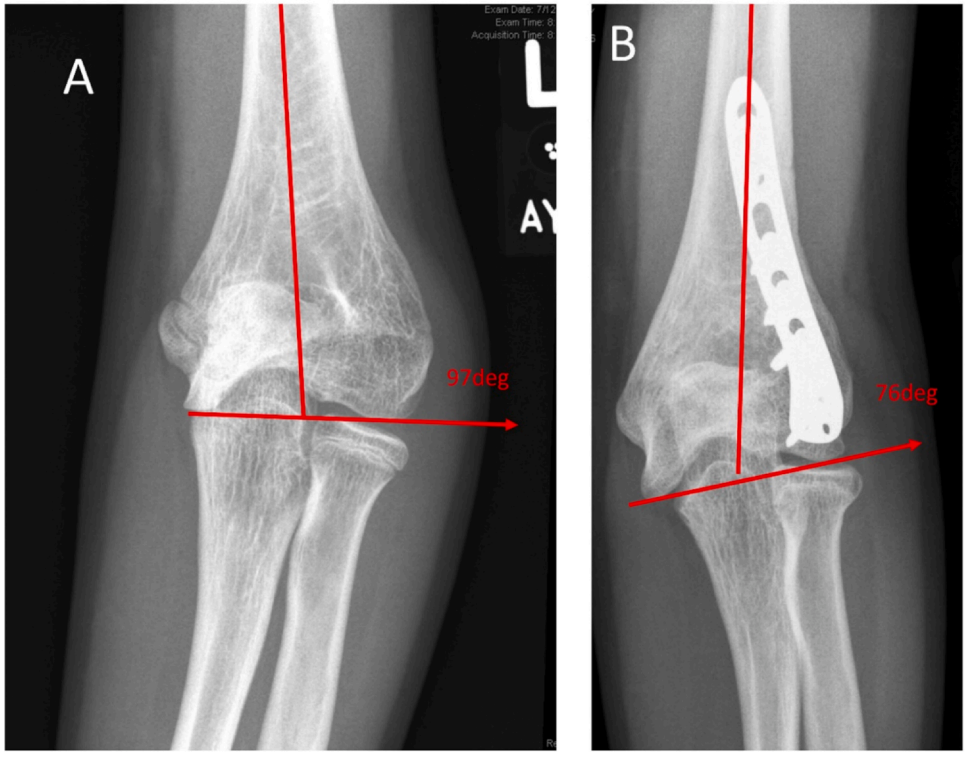

Figure 2. Radiographic measurement of distal humeral angle preoperatively (A) and postcorrection (B).

Table 1
Comparison of preoperative, operative, and postoperative characteristics of peds (< 10 years) and Adol (≥10 years).

Variable	Peds	Adol	*P-value*
Median age at time of initial injury (years), range	3.4 (1.41-6.47)	5.8 (4.68-11.71)	**.037**
Median age at time of osteotomy (years), range	6.3 (2.68-7.78)	14.1 (13.5-16.72)	**.000**
Preoperative Pain (%, n/N)	17% (2/12)	100% (5/5)	**.003**
Preoperative Mechanical symptoms (%, n/N)	17% (2/12)	80% (4/5)	**.028**
Median preoperative elbow flexion, (degrees), range; STD*	125 (100-150; ± 18)	140 (130-140; ± 4)	.075
Median preoperative elbow hyperextension (degrees), rang; STD	20 (0-30; ± 11)	5 (0-20; ± 8)	.473
Median preoperative varus carrying angle (degrees), range; STD	15 (4-40)	10 (5-15)	.148
K-wire fixation (%, n/N)	92% (11/12)	0% (0/5)	< **.002**
Plate/screw fixation (%, n/N)	8% (1/12)	100% (4/5)	
Median operative time (minutes), range	130 (62-200)	120 (90-162)	1.00
Median tourniquet times (minutes), range	84 (46-120)	120 (95-128)	**.009**
Median fluoroscopy times (seconds), range	78 (43-102.3)	81 (,60-136.4)	.727
Median Postoperative time in the cast (days), range	37 (26-70)	25 (0-46)	.073
Median Time to release to full activities (days), range	76 (49-123)	115 (41-237)	.113
Median postoperative flexion (degrees), range; STD	140 (105-150; ± 15)	130 (100-140; ± 16)	.277
Median postoperative extension (degrees), range; STD	0 (−20 to 40; ± 14)	-0 (−10 to 0; ± 4)	.722
Symptoms resolved at final follow-up (%, n/N)	100% (3/3)	40% (2/5)	**.003**
Median follow-up time (days), (range)	85 (41-525)	237 (109-1044)	.081

**STD*, standard deviation.
The bold values means that the value is < 0.05 and therefore statistically significant as per our methods.

due to the symptomatic retained plate. Another Adol patient only achieved 100^0 flexion by 4 months postoperatively; the patient had poor adherence with occupational therapy and did not return for further scheduled follow-up. One Peds patient only achieved 105^0 flexion by final follow-up at 76 days postosteotomy, while another had only achieved 40^0 extension by final follow-up at 41 days postoperatively. However, there were no neurovascular injuries, postoperative infections, or nonunions. At the final follow-up, all 3 symptomatic Peds patients had resolution of their preoperative complaints, while 60% (3/5) of Adol patients had continued pain and mechanical symptoms ($P < .05$) (Table 3). One of the 3 symptomatic Adol patients, the patient who underwent hardware removal, continued to have complaints of nonfocal elbow and forearm pain as well as a sensation of popping with activity such as softball.

Discussion

The occurrence of cubitus varus after pediatric elbow fractures is well established. While cubitus varus may rarely occur from physeal arrest or avascular necrosis, it more commonly results from malreduction of a distal humeral fracture [1–4]. The natural history as well as indications for and timing of corrective osteotomy are not well defined and this deformity historically has been dismissed as a cosmetic problem in the pediatric population [4].

Though being simply named “cubitus varus,” this deformity is described as a combination of varus, hyperextension and internal rotation [1–5]. Oppenheim et al. initially stated that these deformities were nonprogressive and due to malunion [13]. While the deformity may be nonprogressive, there was a significantly increased incidence in pain and/or mechanical symptoms in our adolescent patients, signifying the clinical progression of symptoms. Both Peds and Adol groups had a similar young age at injury, suggesting that pediatric patients may present asymptomatically other than their clinical deformity, but as they age, the deformity may lead to functional deficits or pain.

It is well described in the adult orthopedic literature that cubitus varus after a pediatric distal humerus fracture or congenital deformity can lead to posterolateral instability [10], ulnar neuropathy [11], snapping triceps [8], progressive varus of the ulna [14], and elbow joint malalignment [7]. O’Driscoll et al. reported on 25 adult elbows with symptomatic PLRI decades after their pediatric injury [10]. Despite lateral ulnar collateral ligament reconstruction, distal humeral osteotomy, or a combination of both, some of these adult patients did not have resolution of their symptoms. O’Driscoll hypothesized that cubitus varus leads to (1) medial displacement of the upper extremity mechanical axis, causing increased tensile forces and eventually attenuation of the lateral collateral ligament complex and further displacing the mechanical axis medially, and (2) medial displacement of the triceps, causing the force vector to exert a supination external rotation moment on the olecranon, leading to the first stage of PLRI [10]. While his series did not find a relationship between the age of injury and degree of cubitus varus, Cha et al. reported that increased cubitus varus correlated with increased proximal ulnar varus and a younger age of injury, suggesting that earlier correction may prevent morphologic changes in the elbow [14].

It is the authors’ experience that corrective osteotomy in the distal humerus is a much less technically demanding surgery in the pediatric patient compared to the adolescent patient. Older patients benefit from a biomechanically stronger plate and screw construct, but the anatomic distal humeral plates very rarely fit well on this abnormal, multiplanar anatomy, even after correction of the deformity. Bending and

Table 2
Radiographic measurements, preoperative and postoperative.

Median measurement, degrees (range)	Peds	Adol	*P-value*
Preoperative Baumann’s angle	90 (81-99)	N/A	N/A
Postoperative Baumann’s angle	73 (10-87)	N/A	N/A
Preoperative Distal Humeral Angle	NA	-2 (−20 to 2)	N/A
Postoperative Distal Humeral Angle	NA	15 (4-20)	N/A
Correction in Baumann’s angle/distal humeral angle	12 (6-79)	14 (6-50)	.873
Preoperative ulnohumeral angle	-15 (−24 to 4)	-6 (−18 to 4)	.178
Postoperative ulnohumeral angle	5 (−13 to 14)	5 (−3 to 10)	.958
Correction in ulnohumeral angle	19 (5-31)	15 (1-26)	.341
Preoperative lateral shaft condylar angle	33 (−20 to 48)	30 (20-52)	.419
Postoperative lateral shaft condylar angle	38 (23-54)	35 (25-53)	.774
Correction in lateral shaft condylar angle	5 (−13 to 73)	5 (−8 to 10)	.712

Table 3
Preoperative and postoperative symptoms (excluding 9 Peds patients complaining of only cosmetic deformity).

	Preoperative pain	Preoperative mechanical symptoms	Elbow Arthroscopic (ATS) findings	Postoperative symptoms
P1	Occurs 3 to 4 times a week, not related to activity, occurs at rest and night	None	N/A	None
P2	None	Sense of instability with weight bearing (ie, tumbling)	N/A	None
P3	Pain at rest, not related to activities	Reported episodes of elbow locking at 90 degrees, MRI negative for intra-articular pathology	N/A	None
A1	Pain and audible "popping" sensation over posterior olecranon fossa only with attempted hyperextension	Audible "popping" sensation over posterior olecranon fossa only with attempted hyperextension. MRI with posterolateral gutter soft tissue hypertrophy.	ATS performed 12 months prior to osteotomy; no osteochondral defects noted. Posterolateral gutter with fatty tissue and synovial hypertrophy, debrided with shaver.	Sensation of 'popping' when extending his elbow to put down the trumpet during band, no pain or popping any other time. Audible popping resolved. No symptoms other than that. Declined plate removal.
A2	Posterolateral elbow pain during throwing sports	Popping noted during throwing. Pivot shift noted with posterolateral rotational instability under anesthesia.	ATS performed concurrently with osteotomy; posteromedial olecranon osteophytes debrided during arthroscopy, no loose bodies or osteochondral lesions. Posterolateral gutter with patulous tissue	No popping, occasional medial elbow and forearm play after playing softball (ie, long softball throw across infield) but continued to play softball competitively.
A3	Occasional vague elbow pain related to activities, not currently in sports	Feeling of popping and locking unrelated to activity. MRI with chondral flaps and osteochondral lesion	ATS performed concurrently with osteotomy; debrided grade III-IV chondral changes with unstable cartilage flap in apex to medial portion of trochlea	Back to all baseline activities, mild pain with cold weather.
A4	Posterolateral pain and locking with heavy lifting and three-point stance in football, lifting with an extended arm.	Popping and locking of elbow, MRI with osteochondral lesions	ATS performed 5 months prior to osteotomy. Extensive loose bodies and chondral flaps debrided from ulnotrochlear articulation.	No pain, denies any symptoms, back to football.
A5	Posterolateral elbow pain with soccer, dance team, and cold weather	None	N/A	None

contouring plates are much more time-consuming than pin fixation, and the radial nerve may need to be identified and protected when a longer lateral column plate is used; the authors have not found this exposure to be necessary in younger patients with pin fixation. Surgical exposure for a plate and screw construct is much larger and more time-consuming than for pin fixation. In addition, the distal humeral plate may be prominent, necessitating a second surgery for hardware removal.

While our reported cohort had no complications other than one adolescent patient needing hardware removal and another with loss of flexion at 4 months postoperatively, a series of distal humeral osteotomy for pediatric cubitus varus reported at 14% complication rate and 0% reoperation rate with patients treated with current techniques and all lateral entry pins from 1998 to 2002, compared to a 53% complication rate and 32% reoperation rate for patients treated from 1987 to 1997 [15]. In that series, 13 complications (in 41 patients total) included 4 transient ulnar nerve palsies, 4 losses of fixation with deformity recurrence requiring unplanned reoperation, 4 residual varus deformities, and 1 deep infection. While technically easier in pediatric patients compared to adult patients, the technical demands of this surgery should not be underestimated.

Limitations of this study included the small size of both cohorts and that using a CPT code search to identify patients may not have identified all patients. While radiographic measurements were made by a single observer and performed in a standardized fashion, intraobserver and interobserver reliability in these measurements was not performed. Patient-reported outcomes measures and validated questionnaires were not used due to the retrospective nature of the study. Length of follow-up was sometimes brief and neither follow-up nor postoperative management was standardized. With only 5 adolescent patients treated with 2 different techniques in this study, our findings may not be generalizable to other centers. As the adolescent patients did not present until symptoms warranted, we are unable to document the progression of pain and mechanical symptoms over time. With such a small cohort and varied surgical approaches, we are unable to comment on whether the more extensive posterior surgical approach or type of fixation affected the poorer outcomes in the Adol group. We were unable to compare these patients to those who had asymptomatic cubitus varus and did not undergo surgery. However, to the authors' knowledge, this is the first study to compare patient populations and results of pediatric and adolescent patients for this relatively uncommon deformity. As this was a small cohort, power may not have been sufficient; however, post hoc power analysis revealed that 8 patients would be needed in each cohort to achieve sufficient power to detect a difference between one cohort having 99% of their symptoms resolve compared to the other cohort having 40% of their symptoms resolve.

Conclusion

Cubitus varus following pediatric distal humerus fracture may present with pain and mechanical symptoms as early as adolescence. Although both pediatric and adolescent patients may have similar radiographic correction and range of motion after distal humeral osteotomy, the surgery is technically more difficult in adolescent patients, who often require plate and screw fixation to achieve a stable construct, compared to pediatric patients who have sufficient fixation with a pin construct. Adolescents should be counseled that preoperative symptoms may not completely resolve after correction of radiographic and clinical limb deformity. It is the authors' opinion that, although technically demanding, cubitus varus should be surgically corrected before the child reaches adolescence.

Funding

This study was internally funded. No external funding was acquired for the execution of this study.

No writing assistance was utilized in the preparation of this manuscript. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Consent for publication

Due to the nature of this study (i.e., records review), informed consent was not required. A consent waiver and a HIPAA waiver were obtained from the Institutional Review Board prior to the execution of study procedures.

Statement of human and animal rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Author contributions

Ho Christine Ann: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **Okpara Shawn O.:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing, Data curation. **Wilson Phillip L.:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **Jo Chan-Hee:** Formal analysis.

Declaration of competing interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: American Academy of Orthopedic Surgeons (AAOS)—CH; American Academy of Pediatrics (AAP)—CH; Cedars Sinai—CH; Elsevier (Tachdjians 6th edition)—CH; Foundation for Advancing Pediatric Orthopedics (POST)—CH; International Pediatric Orthopedic Symposium (IPOS)—CH; NYU—CH Pediatric Orthopedic Society of North America (POSNA)—CH; Shriners Hospital—CH; Shriners Portland—CH; Wolters Kluwer UpToDate—CH; Wolters Kluwer UpToDate—CH If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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