Original Article

Functional Outcomes of Pediatric Supracondylar Fractures of Distal Humerus Treated with Percutaneous Pinning

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ABSTRACT

Background: Supracondylar humerus fractures are the most common pediatric elbow injuries. Closed reduction and percutaneous pinning (CRPP) remains the gold standard for displaced fractures. Functional outcome varies widely in different studies, which may be due to the type of fracture and time to presentation, and the criteria used to assess the functional outcome. The objective of the study was to determine the functional outcome of CRPP in children using Flynn's criteria and to identify clinical predictors of outcome.

Methods: This Prospective descriptive observational study was conducted at a tertiary care centre over six months. A total of 110 pediatric patients with Gartland type II, III, and IV supracondylar fractures were included. Outcomes were categorized using Flynn's criteria and further dichotomized into favorable (excellent/good) and unfavorable (fair/poor). Univariate logistic regression was performed to explore potential predictors of outcome.

Results: The mean age was 6.7 ± 2.4 years; with female patients comprising 58.2% (n = 64) and male 41.8% (n = 46) of the cohort. Excellent and good outcomes were observed in 78.2% and 12.7%, respectively. Postoperative infection (5.5%) and nerve injury (8.2%) were the most common complications. None of the evaluated clinical or surgical variables, including Gartland type, pin configuration, or timing of surgery, was significantly associated with outcome in univariate analysis.

Conclusion: CRPP is a safe and effective technique for managing pediatric supracondylar humerus fractures, achieving favourable functional outcomes. Preventing complications remains crucial for optimal recovery.

Keywords: Supracondylar fracture; Flynn's criteria; Closed reduction; Percutaneous pinning; Functional outcome

INTRODUCTION

Supracondylar fractures of the distal humerus are among the most common elbow injuries in children, accounting for nearly 60% of pediatric elbow fractures and approximately 3% of all pediatric fractures. These injuries typically occur between the ages of five and eight years. They are most frequently caused by falls on an outstretched hand, resulting in hyperextension forces across the elbow joint. Studies by Kakar et al.[1] and Radaideh et al.[2] have highlighted that these fractures represent a major proportion of pediatric orthopedic trauma and require prompt recognition and management to avoid long-term functional impairment.

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The Gartland classification system, first introduced to categorize extension-type supracondylar fractures based on displacement, remains the most widely used system for guiding treatment decisions. According to Espiritu et al., type II fractures demonstrate partial displacement with an intact posterior cortex, whereas type III fractures are completely displaced and unstable, often requiring operative management.[3] Delayed or inadequate treatment may lead to complications such as neurovascular injury, malunion, elbow stiffness, and cosmetic deformity.

Closed reduction and percutaneous pinning (CRPP) has become the standard treatment for displaced supracondylar fractures, as it allows stable fixation while minimizing surgical morbidity. Ahmed et al.[4] reported that CRPP provides reliable fracture stabilization with a low complication rate when performed under fluoroscopic guidance. Similarly, Alagesan et al.[5] demonstrated excellent functional outcomes in the majority of pediatric patients treated with this technique, reinforcing its role as the preferred surgical method for unstable fractures.

Various pin configurations are used during CRPP, most commonly lateral-entry pinning and crossed pinning. While crossed pinning may provide greater mechanical stability, lateral pinning reduces the risk of iatrogenic ulnar nerve injury. Comparative studies by Shah et al.[6] and Banshelkikar et al.[7] have shown that both configurations

can achieve satisfactory outcomes when accurate fracture reduction and proper pin placement are ensured.

Despite the overall success of CRPP, functional outcomes may vary depending on several factors, including fracture severity, timing of surgical intervention, pin configuration, and surgeon expertise. Khan et al.[8] and Ullah et al.[9] reported that timely surgical fixation combined with careful postoperative management plays a critical role in achieving optimal functional recovery.

Functional assessment following treatment is commonly performed using Flynn's criteria, which evaluates both cosmetic and functional parameters, including loss of carrying angle and range of motion. In a study conducted by Chaturvedi et al.[10], excellent functional outcomes were observed in 83.3% of pediatric patients undergoing CRPP, highlighting the effectiveness of this technique in restoring elbow function.

Although several studies have demonstrated favorable outcomes with CRPP, relatively few have examined clinical predictors of postoperative functional outcomes, including age at presentation, fracture displacement pattern, time to surgery, and pin configuration. Understanding these predictors is important for improving surgical planning and patient counselling.

Therefore, the present study was conducted to determine the functional outcomes of pediatric supracondylar fractures treated with percutaneous pinning using Flynn's criteria and to identify clinical predictors associated with functional outcome.

PATIENTS AND METHODS

This Prospective descriptive observational study was conducted in the Department of Orthopaedic Surgery and Traumatology at Liaquat University of Medical and Health Sciences (LUMHS), Jamshoro, Hyderabad. It spanned six months, from September 2, 2024, to March 1, 2025, following the official approval of the study by the College of Physicians and Surgeons of Pakistan and the Research Ethics Committee (LUMHS/REC/892).

The sample size was calculated using the WHO sample size calculator for a single proportion, with a confidence level of 95%, a margin of error of 8%, and an expected excellent outcome rate of 83.3% from a prior study by Chaturvedi et al. (2017).[10] This resulted in a sample size of 84 pediatric patients; however, considering the dropouts, the sample was escalated by 30%, and the final sample size was 110 patients. Consecutive patients meeting the inclusion criteria were children aged between 2 and 10 years, of either gender, who presented with displaced supracondylar humerus fractures (Gartland types II, III, or IV) within 7 days of injury. The diagnosis was confirmed radiographically. The children excluded were presented with open fractures, vascular injuries requiring repair, associated ipsilateral fractures (e.g., radius/ulna), signs of compartment syndrome, chronic renal or liver disease (assessed by serum creatinine >1.5 mg/dL or bilirubin >1.0 mg/dL, respectively), or those lost to follow-up before completion of evaluation. All patients underwent closed reduction and percutaneous pinning (CRPP) under fluoroscopic guidance. Fixation was achieved using 1.5–2.0 mm Kirschner wires in either a lateral or crossed configuration, depending on stability and the surgeon's discretion. Postoperative management included back-slab immobilization, regular follow-up at 2, 4, 6, 8, and 12 weeks, K-wires were removed at the end of the 4th week, and initiation of physiotherapy once healing was evident on radiographs. The primary outcome variable was the functional result at 12 weeks postoperatively, assessed using Flynn's criteria. The outcomes were classified as excellent (Loss of motion ≤5°, carrying angle loss ≤5°), good (loss of motion 6–10°, carrying angle loss 6–10°), fair (loss of motion 11–15°, carrying angle loss 11–15°) and poor (loss of motion >15°, carrying angle loss >15°). Functional outcome scores were calculated at the 12-week follow-up visit.

Statistical analysis was conducted using SPSS version 24.0. Categorical variables were presented as frequencies and percentages, while continuous variables were expressed as means with standard deviations. Outcomes were classified using Flynn's criteria and further dichotomized into favorable (excellent/good) and unfavorable (fair/poor) for regression analysis. Univariate logistic regression was performed using a p-value cutoff of <0.25 to identify candidate variables for multivariate analysis; however, as no variables met this criterion, multivariate logistic regression was not performed.

RESULTS

A total of 110 children with displaced supracondylar humerus fractures were included in the study. The mean age of the patients was 5.82 ± 2.61 years. Male patients constituted 41.8% (n = 46) of the cohort. The right upper limb was involved in 44.5% (n = 49) of cases. The most common mechanism of injury was a fall, accounting for 84.5% (n = 93) of the cases. Regarding residence, 56.4% (n = 62) of patients resided in urban areas.

The mean duration of fracture before treatment was 2.14 ± 0.97 days. According to the Gartland classification, 40% (n = 44) of patients had type IV fractures, 32.7% (n = 36) had type II fractures, and 27.3% (n = 30) had type III fractures. Most of the patients underwent surgery within 24 hours of presentation (66.4%, n = 73).

Regarding the surgical technique, cross-pin configuration was used in 51.8% (n = 57) of cases. Nerve injury was observed in 10.0% of patients (n = 11), and postoperative infection occurred in 6.4% of patients (n =

7). The mean carrying angle loss was 4.43 ± 4.48 degrees, and the mean range of motion loss was 4.25 ± 4.34 degrees (Table 1).

According to Flynn's outcome criteria, Excellent outcomes were achieved in 78.2% (n = 86), good in 12.7% (n = 14), fair in 6.4% (n = 7), and poor in 2.7% (n = 3). This distribution indicates that 90.9% of the patients had favorable outcomes (excellent or good), as shown in Figure 1.

In univariate logistic regression, none of the assessed variables were statistically significant at the predefined cutoff of p-value <0.25. Although Gartland type IV showed a trend toward lower odds of a favorable outcome compared to type II (OR 0.151, 95% CI 0.018–1.291, p-value = 0.084), it did not meet the threshold for significance. Similarly, cross pinning, compared with lateral pinning, showed higher odds of a favorable outcome (OR 2.333, 95% CI 0.571–9.540), but this association was not statistically significant (p-value = 0.238). Other variables, including age, gender, side of injury, mode of injury, residence, fracture duration, time to surgery, nerve injury, and infection, showed no significant association with outcome (all p-values >0.25). Since none of the variables met the predefined threshold (p-value <0.25) on univariate analysis, multivariate logistic regression was not conducted (Table 2).

Table 1: Baseline and clinical characteristics (n=110)

Characteristics	Frequency n (%)
Age (years, mean ± SD)	5.82 ± 2.61
Gender (male)	46 (41.8)
Limb involved (right)	49 (44.5)
Mode of injury (fall)	55 (50.0)
Place of living (urban)	57 (51.8)
Fracture duration (days, [mean ± SD])	4.24 ± 2.04
Gartland Type II	36 (32.7)
Gartland Type III	30 (27.3)
Gartland Type IV	44 (40)
Time to Surgery (≤24 hours)	73 (66.4)
Pin configuration (cross)	57 (51.8)
Nerve injury	11 (10.0)
Post-op infection	7 (6.4)
Carrying angle loss (mean ± SD)	4.43 ± 4.47
Range of motion loss (mean ± SD)	4.25 ± 4.33

DISCUSSION

This study reinforces the clinical effectiveness of closed reduction and percutaneous pinning (CRPP) in the management of displaced pediatric supracondylar humerus fractures. In our series, 90.9% of patients achieved favorable functional outcomes according to Flynn's criteria. These findings are consistent with previously published literature reporting high success rates following CRPP, as demonstrated by Kakar et al.[1], Radaideh et al.[2], and Espiritu et al.[3]

In our cohort, Gartland type III fractures were the most frequently observed fracture type, consistent with previously reported epidemiological trends. Studies by Ahmed et al.[4] and Alagesan et al.[5] have similarly reported that completely displaced extension-type fractures represent the majority of surgically treated supracondylar injuries in children. Early and appropriate surgical fixation is crucial in such cases to prevent complications such as malunion, neurovascular compromise, and elbow deformity.

CRPP remains the preferred surgical technique because of its minimally invasive nature, reliable fracture stabilization, and favorable postoperative recovery. Alagesan et al.[5] demonstrated that timely surgical fixation intervention combined with stable pin significantly improves functional outcomes in children with displaced supracondylar fractures. Our findings further support CRPP as the gold-standard treatment for these injuries.

The choice of pin configuration remains a subject of ongoing debate in pediatric orthopedic surgery. Crossed pinning provides greater biomechanical stability but carries a potential risk of iatrogenic ulnar nerve injury, whereas lateral pinning offers a safer alternative with slightly reduced mechanical stability. Comparative studies by Shah et al.[6] and Banshelkikar et al.[7] have reported that both configurations can achieve satisfactory functional outcomes when performed correctly. In the present study, cross pinning was used in most cases and was associated with higher odds of a favorable outcome. However, the association did not reach statistical significance.

Our results also demonstrated a low complication rate, with nerve injury occurring in 8.2% and postoperative infection in 5.5% of patients. Similar complication profiles have been reported in previous studies. Muslu et al.[11] observed that most nerve injuries associated with CRPP are transient and resolve with conservative management, while Bhatti et al.[12] reported comparable rates of minor postoperative complications without significant impact on long-term functional outcomes.

Radiological alignment is an important determinant of both cosmetic and functional recovery. Rajput et al.[13] and Gupta et al.[14] emphasized that maintaining appropriate Baumann's angle and carrying angle is essential for preventing residual deformities such as cubitus varus. In the present study, careful radiographic monitoring during follow-up ensured maintenance of fracture alignment and satisfactory functional recovery.

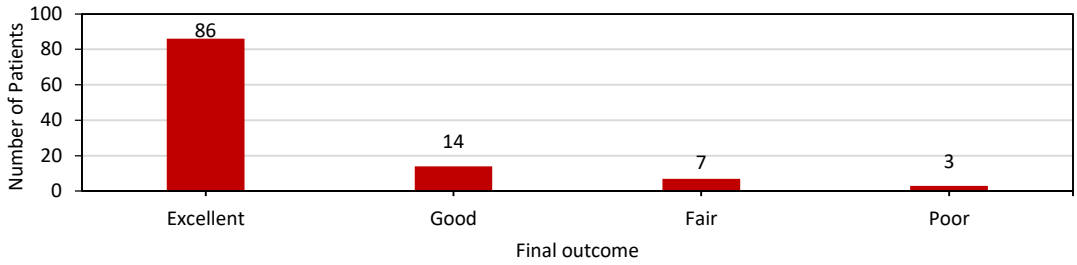

Figure 1: Distribution of outcome (Flynn's criteria)

Table 2: Logistic regression analysis for predictors

Characteristics	OR	95% CI	p-value
Age (years)	1	0.78–1.29	0.981
Gender (male vs. female)	1.09	0.29–4.09	0.903
Side Involved (right vs. left)	0.5	0.13–1.89	0.31
Mode of injury (fall vs. RTA)	1	0.27–3.67	1
Residence (urban vs. rural)	1.08	0.3–3.98	0.904
Fracture duration (days)	0.88	0.63–1.22	0.451
Gartland Type (III vs. II)	0.400	0.034–4.642	0.464
Gartland Type (IV vs. II)	0.151	0.018-1.291	0.084
Time to surgery (hours)	0.97	0.91–1.05	0.473
Pin_(crossed vs. lateral)	2.333	0.571–9.540	0.238
Nerve injury	1	0.11–8.73	1
Infection	0.57	0.06–5.31	0.625

Abbreviations: OR = Odds Ratio; CI = Confidence Interval, RTA= Road Traffic Accident

Although our study demonstrated favorable early outcomes, longer follow-up is often recommended to identify late complications. Hahn et al.[15] highlighted that deformities such as cubitus varus may develop over time due to growth disturbances or remodeling, particularly in younger children. Interestingly, demographic and clinical variables such as age, gender, side of injury, and residence were not significantly associated with functional outcome in our analysis. Similar findings have been reported by Al-Sharaa et al.[16], who concluded that surgical technique and quality of fracture reduction play a more important role in determining outcome than demographic characteristics. Our findings are further supported by regional and contemporary literature. Mengal et al.[17] reported excellent functional and radiological outcomes following closed reduction and percutaneous pinning in children with Gartland type III fractures, emphasizing the importance of meticulous surgical technique. Parteti et al.[18] demonstrated that tailoring K-wire configuration according to fracture geometry can enhance fracture stability and optimize clinical outcomes. Chinnusamy et al.[19] reported that both open and closed reduction techniques can yield satisfactory results when anatomical reduction is achieved, and stable fixation is maintained. Alam et al.[20] also reported satisfactory outcomes with lateral percutaneous K-wire fixation performed under C-arm guidance, supporting the effectiveness of image-guided pin placement in achieving stable reduction. In addition, Khan et al.[21] described favorable functional outcomes with Dorgan's lateral cross-wiring technique, suggesting that alternative pinning strategies may also provide reliable fixation when performed carefully.

Despite the encouraging findings of the present study, certain limitations should be acknowledged. The study was conducted at a single center with a relatively short 12-week follow-up period, which may limit the detection of late complications, such as growth disturbances or progressive deformity. Larger multicenter studies with longer follow-up periods are therefore recommended to further evaluate long-term functional outcomes and predictors of recovery.

In conclusion, closed reduction and percutaneous pinning provide excellent early functional outcomes in pediatric supracondylar humerus fractures. While fracture type and pin configuration may influence stability, the most important determinants of outcome remain accurate reduction, stable fixation, and adherence to postoperative rehabilitation protocols.

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analysis and interpretation of data and drafting of the article. TA contributed to data acquisition, conception and design of the study, and analysis and interpretation of data. SS contributed to the conception and design of the study and analysis and interpretation of data.

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