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Aditya Chaubey
Senior Resident, Department of Orthopaedics, R.N. Cooper Hospital and HBT Medical College, Mumbai, Maharashtra, India

Harshad Argekar
Professor, Department of Orthopaedics, R.N. Cooper Hospital and HBT Medical College, Mumbai, Maharashtra, India

Amit Yadav
Assistant Professor, Department of Orthopaedics, R.N. Cooper Hospital and HBT Medical College, Mumbai, Maharashtra, India

Siddharth Gunay
Senior Resident, Department of Orthopaedics, R.N. Cooper Hospital and HBT Medical College, Mumbai, Maharashtra, India

Subhayoti Sutradhar
Junior Resident, Department of Orthopaedics, R.N. Cooper Hospital and HBT Medical College, Mumbai, Maharashtra, India

Sunil Yadav
Junior Resident, Department of Orthopaedics, R.N. Cooper Hospital and HBT Medical College, Mumbai, Maharashtra, India

Corresponding Author:
Aditya Chaubey
Senior Resident, Department of Orthopaedics, R.N. Cooper Hospital and HBT Medical College, Mumbai, Maharashtra, India

Outcomes of closed reduction and percutaneous pinning in pediatric supracondylar humerus fractures: A case series and review of literature

Aditya Chaubey, Harshad Argekar, Amit Yadav, Siddharth Gunay, Subhayoti Sutradhar and Sunil Yadav

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Abstract
Introduction: Supracondylar humerus fractures are the most common elbow injuries in children, usually caused by falls on an outstretched hand. Treatment options range from closed reduction with immobilization to surgical fixation with Kirschner wires (K-wires). Closed reduction with percutaneous pinning is preferred as it provides stable fixation, maintains reduction, and minimizes complications such as cubitus varus and neurovascular injury.
Methods: This retrospective study included 68 children (aged 2-15 years) with supracondylar humerus fractures treated at a level-one trauma center between January 2020 and September 2023. All patients underwent closed reduction and percutaneous pinning under general anesthesia, followed by immobilization in a long arm slab. Postoperative care involved neurovascular monitoring and regular radiographic evaluations. K-wires were removed after 4-6 weeks, with follow-up continued for at least 3 months. Functional outcomes were assessed using the modified Flynn's criteria. Data were analyzed using SPSS, with significance set at $p<0.05$.
Results: The mean patient age was 6.7 years, with males comprising 63.2% of cases. The left side was injured in 61.7%. Gartland type IIIA fractures were most common (38.2%). Most surgeries (69.1%) were performed within 24 hours, and two lateral K-wires were used in 70.6% of cases. The median immobilization period was 4.5 weeks. Complications included superficial pin tract infections in 10.3% cases, with no deep infections. According to the modified Flynn's criteria, 83.8% of patients achieved excellent outcomes, 13.2% had good outcomes, and 1.5% (one case) had a poor outcome due to iatrogenic ulnar nerve palsy.
Conclusions: Closed reduction with percutaneous pinning is a reliable treatment for pediatric supracondylar humerus fractures, yielding excellent functional results and low complication rates. Attention to surgical technique is essential to minimize nerve injury.

Keywords: Supracondylar fracture, humerus, pediatric trauma, Kirschner wires, percutaneous pinning

Introduction
Supracondylar humerus fractures are one of the most common type of fractures around the elbow joint typically seen in the first decade of life following trauma due to fall on the outstretched hand [1, 2]. Epidemiological studies suggest that a higher incidence of supracondylar fractures is seen in boys and the non-dominant side is more frequently injured [3-5].

A number of treatment methods have been used over the years for the management of supracondylar humerus fractures in the pediatric age group [6, 7]. These range from closed reduction and immobilisation in a splint, application of Dunlop's traction or surgical fixation following fracture reduction by closed or open means. Surgical fixation most commonly involves pinning of these fractures using Kirschner wires placed in a number of different configurations as have been widely described in literature [8-11].

The primary goals of treatment are to achieve and maintain acceptable fracture reduction, achieve optimal functional outcomes and avoid fracture related complications. Closed reduction and percutaneous pinning of these fractures seems to be the most effective treatment modality according to present literature [12, 13] as it effectively maintains the fracture

reduction with low risk of displacement of the fracture fragments in the post-operative period which can lead to cubitus varus associated with a gunstock deformity. Concomitantly, this type of fixation is also associated with a low risk of complications like neurological injury and circulatory insufficiency as compared to more invasive surgical modalities that involve extensive soft tissue dissection causing post-operative tissue edema and vascular compromise. The risk of iatrogenic ulnar nerve injury continues to remain a distinct risk factor associated with percutaneous placement of a medial K-wire however, a number to techniques have now been described in literature to mitigate this complication [9, 10, 14].

In this study we aim to study the functional outcomes following management of supracondylar fractures of the distal humerus in children with closed reduction and percutaneous pinning.

Methods

In this study we retrospectively evaluated 68 patients aged 2-15 years who presented to our centre with supracondylar humerus fractures from January 2020 to September 2023.

At presentation, thorough clinical assessment was performed to evaluate the neurovascular status and an above-elbow slab applied for initial immobilization. Thereafter, the children were managed with closed reduction of the fracture and percutaneous pinning under general anaesthesia performed at the earliest. Operative time and configuration of K-wires used for fracture fixation were recorded in the operative notes. Distal neurovascular integrity was assessed post-operatively, following which an above-elbow back-slab was applied. The patients were discharged 24 hours post-operatively after assessing for signs of compartment syndrome.

Patients were assessed every 2 weeks for clinical and radiographic evaluation to look for loss of reduction, radiological signs of union and presence of any pin site infections. If radiological signs of union were present, the K-wires were removed usually around 4-6 weeks post-operatively and the elbow range of motion (ROM) exercises were started with monthly follow-ups for a minimum of 3 months.

Functional outcomes were determined using the modified Flynn's criteria [15] which is based on the elbow ROM and the carrying angle measured using a goniometer. The modified Flynn's criteria grades the outcomes based on the degree of loss of elbow flexion and carrying angle as compared to the opposite limb. Radiological parameters used to assess adequacy of the fracture reduction were the Baumann's angle and anterior humeral line [Figures 1-3].

Data Analysis and Interpretation

Data was entered into Microsoft Excel and analysis was done using the Statistical Product and Service Solutions (SPSS) software (version 22.0; SPSS Inc, Chicago). Descriptive statistics such as mean and standard deviation (SD) used for continuous variables; frequencies and percentages were calculated for categorical variables. Association between variables was analysed by using McNemar test for categorical variables and paired t-test for comparison of quantitative variables pre- and post-operatively. The level of significance was set at 0.05.

Results

This study included 68 children with supracondylar humerus fractures managed with closed reduction followed by percutaneous pinning with K-wires. The youngest patient in the study was 2-years-old while the oldest patient was 15-years-old. The mean age at the time of injury was 6.67 years with 63% of children below the mean age. Of the 68 patients, 43 (63.2%) were males and 25 (36.8%) were females. The non-dominant side was injured more commonly (61.7% cases). Associated injuries included distal radius fracture, seen in 2 cases which were managed conservatively with closed reduction followed by immobilisation with above-elbow slab; 2 patients also had associated midshaft radius and ulna fractures, one of these patients underwent TENS (Titanium Elastic Nailing System) nailing while the other patient in whom the fractures were undisplaced was managed conservatively.

Fall on the outstretched hand was the most common mode of injury leading to fracture in 66 of the patients while the remaining 2 sustained trauma as a result of road traffic accidents. The injury was closed in 67 cases while 1 patient had Gustilo-Anderson Type 1 open fracture that was managed with thorough wash and intravenous antibiotic administration followed by the standard protocol for management. Gartland's classification [7] was used to classify the fracture patterns based on the presenting anteroposterior and lateral radiographs. Table 1 shows the distribution of the fracture patterns based on initial radiographic assessment.

Of the 68 patients, 47 (69.1 %) underwent surgery within 24 hours of the injury, 10 (14.7 %) were operated between 24-48 hours following injury. Time between sustaining injury and undergoing surgery was 3 days in 4 (5.9 %) patients, 5 days in 2 (2.9 %) patients, 6 days in 2 (2.9 %) patients and 7 days in 1 (1.5 %) patient. The primary causes for delay in surgery were delay in initial presentation to the hospital following trauma and limitations imposed by the COVID pandemic during the initial period of the study.

Table 2 shows the different configurations of K-wire placement used for the fixation of fractures in this study.

The median period of immobilisation following surgery in an above-elbow back-slab was 4.5 weeks with the minimum period of immobilisation being 4 weeks and the maximum being 7 weeks following which elbow ROM exercises were started. Superficial pin-tract infection was seen in 7 (10.3 %) patients which was managed with a combination of local debridement, antiseptic dressing and oral antibiotics. The pin-site infections were not significant in any of the cases to warrant early removal of the K-wires and settled once the K-wires were removed. There was no incidence of deep infection in any case.

Functional outcomes assessed by the modified Flynn's criteria were excellent in 57 (83.8 %) cases, good in 9 (13.2 %) cases, fair in 1 (1.5 %) case and poor in 1 (1.5 %) case which was as a result of iatrogenic ulnar nerve palsy following placement of a medial K-wire. The mean Baumann's angle at final follow-up was 72.42 ± 4.86 degrees compared to a mean of 71.86 ± 4.88 degrees on the opposite side. This difference was not found to be statistically significant. The anterior humeral line was found to be passing through the middle third of capitellum in 49 (72.1 %) patients, through the anterior third in 16 (23.5 %) patients and through the posterior third in 3 (4.4 %) patients. There was no gross sagittal plane deformity in any of the cases where the anterior humeral line did not intersect the capitellum.

Pre-operative Anterior Interosseus Nerve palsy following the injury was noted in one patient in whom full neurological

recovery occurred within 6 weeks of the injury. One patient developed iatrogenic ulnar nerve palsy following placement of medial K-wire which did not recover in the post-operative period even at 3 months follow-up; this patient was subsequently lost to follow-up.

Fig 1: (A) Anteroposterior and lateral radiographs of elbow showing Gartland type 2B supracondylar humerus fracture in 6 year old boy (B) Immediate post-operative radiograph showing fracture fixed by closed reduction and percutaneous pinning with two lateral and one medial K-wires with acceptable reduction with Baumann's angle restored and anterior humeral line bisecting capitellum (C) Post-operative radiograph at four months follow-up showing bridging callus formation and satisfactory alignment (D) Clinically, carrying angle restored compared to opposite side with normal elbow flexion

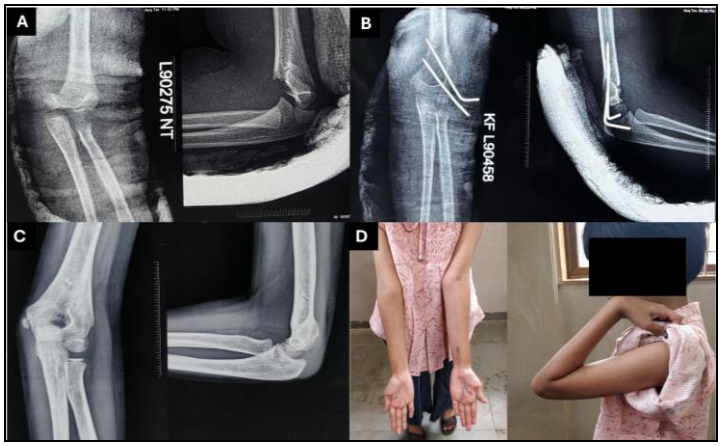

Fig 2: (A) Anteroposterior and lateral radiographs of elbow showing Gartland type 2B supracondylar humerus fracture in 8-year-old girl (B) Immediate post-operative radiograph showing fracture fixed by closed reduction and percutaneous pinning with two lateral K-wires with acceptable reduction (C) Post-operative radiograph at five months follow-up showing complete union (D) Clinically, carrying angle restored compared to opposite side with normal elbow flexion

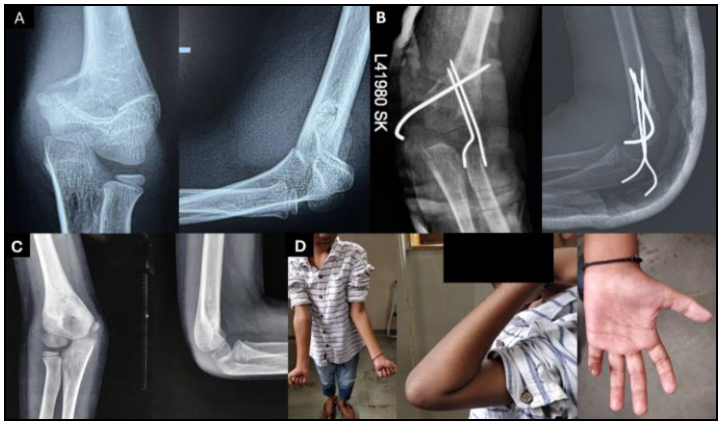

Fig 3: (A) Anteroposterior and lateral radiographs of elbow showing Gartland type 3 supracondylar humerus fracture in 4-year-old boy (B) Immediate post-operative radiograph showing fracture fixed by closed reduction and percutaneous pinning with two lateral K-wires and one medial K-wire with acceptable reduction (C) Post-operative radiograph at five months follow-up showing complete union (D) Clinically, patient had increased carrying angle compared to opposite side with normal elbow flexion and clawing of little finger due to iatrogenic ulnar nerve palsy

Table 1: Distribution of fracture patterns based on initial radiographs according to Gartland's Classification

Fracture Type based on Gartland Classification	Number of Patients (Percentage)
Type 1	0 (0.0 %)
Type 2A	21 (30.9 %)
Type 2B	14 (20.6 %)
Type 3A	26 (38.2 %)
Type 3B	7 (10.3 %)

Table 2: Configurations of K-wire placement used for the fracture fixation

Configuration of K-wires	Number of Patients
2 Lateral	48 (70.6 %)
1 Medial + 1 Lateral	8 (11.8 %)
1 Medial + 2 Lateral	10 (14.7 %)
3 Lateral	2 (2.9 %)

Discussion

In our study, majority of fractures were seen in boys and the left side was more commonly involved. This is consistent with previously described epidemiological data in already published literature [3-5].

We did not find any significant difference in functional outcomes in patients who had a delay in undergoing surgery following injury as compared to patients who were treated within 24 hours of sustaining trauma. This finding is of practical value, especially in our setting where patients, following trauma, may not seek appropriate treatment immediately or presentation may be delayed due to the lack of proximity to healthcare facilities. This also concurs with findings of Gupta *et al.*, Larson *et al.* and Kwiatkowska *et al.* [16-18] who also did not find any association of delay between injury to surgery and increased morbidity because of injury or surgery related complications.

Various different pin configurations have been described in literature for the fixation of these fractures although the pattern of K-wire placement primarily still depends on the surgeon's preference and fracture configuration following intra-operative reduction. The Bahk classification [11] had been proposed to guide decision making regarding the optimum pin configuration based on analysis of the fracture lines in coronal and sagittal planes however, the recommendations made by the Bahk classification have still not been adequately validated by large long-term prospective studies.

Although few biomechanical studies propose a cross-pin configuration to be superior to diverging K-wires placed from the lateral side, placement of a medial K-wire is associated with risk of iatrogenic ulnar nerve palsy as was seen in one case in our series as well. This was also highlighted in the study by Mangwani *et al.* [19] where 9 out of 291 patients developed post-operative ulnar nerve palsy following insertion of a medial K-wire. Skaggs *et al.* [8] suggested use of three divergent lateral K-wires instead of placement of crossed wires to improve the biomechanical stability of the construct without risking iatrogenic injury to the ulnar nerve. Use of Dorgan's technique of lateral cross-pinning where a wire is inserted from the lateral side in a proximal to distal manner has also been described by a few authors to minimise risk of ulnar nerve injury however it is still not a widely used option primarily due to lack of literature regarding its utility and risk of possible radial nerve injury on the lateral side as the nerve crosses the intermuscular septum from posterior to the anterior aspect [20-23]. The most important consideration in placement of a medial K-wire is ensuring that an appropriate surgical technique is followed including making a stab incision and dissecting down to bone before placement of the wire and inserting the wire with the elbow extended to let the nerve fall posteriorly while taking care to always stay anterior to the medial epicondyle [9, 10, 14]. This conclusion is also supported by Kwak-Lee *et al.* [24] who found no increase in the risk of iatrogenic ulnar nerve injury if an appropriate technique was followed.

Functional outcomes were evaluated based on modified Flynn's criteria which primarily considers the loss in elbow ROM and carrying angle compared to the unaffected side. 83.8 % of patients had excellent functional outcomes and 13.2 % patients had a good functional outcome. The outcome in one patient was categorised as poor owing to the incidence of iatrogenic ulnar nerve palsy leading to functional limitations. None of the patients developed a cubitus varus deformity in the post-operative period due to loss of fracture reduction. Range of elbow flexion continues to increase at a slow rate for up to 2 years in the post-operative period as shown by Holmberg *et al.* [25]. However, even in the limited period of follow-up in our study most of the patients gained near full ROM with less than 5° loss of flexion in a large majority of the cases as is consistent with the findings of Henrikson *et al.* [26].

The limitations of this study were that it was a retrospective study, and multiple surgeons were involved in the planning and execution of the surgeries which may act as a confounding factor in the interpretation of results.

Conclusion

Closed reduction with percutaneous pinning is an effective treatment for pediatric supracondylar humerus fractures with excellent functional outcomes and low complication rates. Meticulous surgical technique is crucial to minimize complications, particularly ulnar nerve injury.

Conflict of Interest

Not available

Financial Support

Not available

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