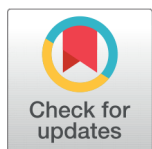


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## A Prospective Analysis of Functional Outcome In Pediatric Supracondylar Humerus Fracture

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## Abstract

**Context:** Supracondylar humerus fractures are one of the commonest upper limb fractures in children. Closed reduction and fixation with K wires is the most common method of treating these fractures. Stability of fixation is very important so as to prevent loss of reduction, which leads to deformity at elbow joint. Many factors contribute to the stability of fixation. Thus, considering all these factors at the fixation helps prevent loss of reduction.

**Aim:** This prospective study was aimed at studying the functional outcome of management of supracondylar humerus fracture in the pediatric population when the management is planned as per the fracture patterns described by Bahk. **Design:** This is a single center prospective study conducted between July 2018 and June 2019. This study was done in a medical college and general hospital, which is a tertiary care center. **Method:** 100 cases of supracondylar humerus fractures in children were analyzed prospectively. Various parameters were documented to assess the functional outcome.

**Results:** There was mean loss of motion at the elbow of 41° in conservatively managed cases and 43° in operated cases at 4th week follow up. Gradually it improved to full range. Loss of carrying angle was seen in only 8% of cases and the degree was very less. As per Flynn's criteria, 94% of cases had excellent cosmetic outcome and 6% of cases had good cosmetic outcome. Anterior humeral line passed through middle one third of capitellum in 91% of cases. Loss of Baumann's angle was seen in only 9% of cases. As per Skaggs et al criteria for loss of reduction, only 1 case had a moderate loss of reduction and 8 cases had mild displacement. **Conclusion:** Deciding about pin configuration for fixation should be done as per the fracture pattern and fracture comminution.

**Keywords:** Supracondylar humerus fracture; Bahk's fracture pattern; functional outcome; Flynn's criteria; Skaggs criteria

# 1 Introduction

Supracondylar humerus fractures are one of the commonest upper limb fractures in children, which accounts for 18% of all pediatric fractures and up to 60% of pediatric elbow fractures.<sup>(1)</sup> About 85% of these fractures are seen in children of age 5-8 years. Undisplaced or partially displaced supracondylar humerus fractures can be treated non-operatively by cast immobilization. Completely displaced and rotationally unstable fractures require surgical fixation, usually with closed reduction and percutaneous pinning.

Older children tend to sustain more comminuted supracondylar humerus fractures. Neurovascular injuries were also noted to be more common in older children.<sup>(2)</sup> Due to these factors; closed reduction seemed to be more challenging thus requiring open reduction at times.<sup>(3)</sup> The quality of reduction, Kirschner (k)-wire configuration, i.e. crossed or parallel, number of pins, medial or lateral entry pins, fracture configuration and the inherent instability of the fracture pattern are all important factors contributing to the stability of fixation.<sup>(4-7)</sup>

Gartland classification helps us decide on operative or non-operative management of the fracture. To decide on how to pin these injuries, the fracture patterns are to be considered. Some patterns are considered more unstable than others and require specific methods of fixation.<sup>(7)</sup> Bahk et al has classified supracondylar fractures of humerus based on orientation of the fracture line in sagittal as well as coronal plane<sup>(4)</sup>. In coronal plane he has described 4 fracture patterns. They are; transverse, lateral oblique, medial oblique and high fractures. In sagittal plane 2 patterns, they are, high sagittal and low sagittal fractures<sup>(4)</sup>. Deciding how to pin the fracture by seeing the pattern would help to increase the fracture stability following fixation. Not much have been studies about the fracture patterns and its effect on the stability of reduction. In this study, we have considered Bahk's fracture pattern and fracture comminution to decide how to pin the injury. We have analyzed various factors like Bahk's fracture patterns, number of pins, pin configuration, fracture stability following fixation and loss of fixation postoperatively.

# 2 Materials and methods

This is a single center prospective study conducted between July 2018 and June 2019 after approval by the Institutional Ethics Committee. This study was done in a medical college and general hospital, which is a tertiary care center. All cases of supracondylar humerus fracture that reported to outpatient department or emergency department were assessed clinically and radiologically.

## Inclusion Criteria

- Patients with Supracondylar humerus fracture
- Those who gave consent to be a part of this study
- Patients with age group below 15 yrs.

## Exclusion Criteria

- Patients with age above 15 yrs.
- Those who do not give consent for the study

History and information regarding age, sex and mode of injury was elicited from the patient and relative. Patient was clinically examined and checked for any neurovascular injury or associated injuries. Radiological evaluation was done which consists of plain radiograph of injured elbow in anteroposterior and lateral views. Various radiological parameters like fracture type (flexion/extension), fracture classification (Gartland), fracture pattern (Bahk) and any comminution were assessed and documented. The fracture patterns of all patients were classified as per Bahk's criteria [All figures] using the preoperative and intraoperative images.

Patients with stable /undisplaced fracture (Gartland type I and IIa) were managed conservatively by closed reduction and above elbow plaster back slab immobilization in flexion. Unstable /displaced fractures (Gartland type IIb, III and IV) were managed operatively by closed reduction and percutaneous pinning. Lateral only pinning was used for transverse and lateral

oblique fracture patterns, whereas medial-lateral cross pins were used to fix medial oblique and high fracture patterns. Above elbow slab was given to patient in post-operative period for 4 weeks. Patients were discharged within 2 days of the surgery. All patients were clinically and radiologically followed up in postoperative period at 1 week, 3-4 weeks, 6 weeks and 3 months. Baumann's angle, anterior humeral line and lateral capital humeral angle were measured in immediate postoperative period of 4 weeks, 3 months and 6 months in postoperative radiographs. Slab and pins were removed at the 3-4 weeks follow-up, as an outpatient procedure. Patients were evaluated for humeral-ulnar angle as the carrying angle, clinically for range of motion at elbow according to Flynn's criteria at 4 weeks, 3 months and 6 months follow up. Loss of reduction was quantitated by criteria defined by Skaggs et al. It has been shown that a change in Baumann's angle is consistent with loss of reduction. Greater than 12° is a major loss of reduction and 6-12° a moderate loss of reduction and <6° is mild displacement.<sup>(8)</sup> A total of 100 patients with supracondylar humerus fracture were included in the study.

## Operative procedure

General anesthesia was used in all patients. The elbow was extended and gripping the patient's wrist and distal forearm longitudinal traction was exerted. Lateral displacement was corrected by applying some lateral pressure. The elbow was flexed while anterior pressure was applied to the olecranon with the thumb. Reduction was checked by fluoroscopic images in anteroposterior, lateral and oblique planes. Following points were verified to check for a good reduction: 1) the anterior humeral line intersects the capitellum; 2) Baumann's angle is greater than 10 degrees; 3) intact medial and lateral columns on oblique views. Once the reduction was appropriate, the position was maintained using an elastic bandage.

Fixation was done with K-wires. Four different pin configurations were used (Table 3). They are 1) two lateral pins; 2) three lateral pins; 3) crossed pins with one lateral and one medial pin; 4) two lateral and one medial pins. Pin configurations for individual cases were decided according to the Bahk's fracture pattern and comminution. The wires were left protruding from the skin for easy removal in the outpatient clinic.

Postoperatively, the limb was immobilized in above elbow slab for 4 weeks. K-wires were removed after 3-4 weeks. Physiotherapy was started after 4 weeks. The range of motion of both the injured and normal elbows were measured, along with the humeral-ulnar angle as the carrying angles, and the functional outcome was assessed based on Flynn's criteria [Table 1].

Rating	Cosmetic factor (carrying angle loss)	Functional factor (Loss of motion)
Excellent	0-5	0-5
Good	6-10	6-10
Fair	11-15	11-15
Poor	>15	>15

Table 1: The cosmetic and functional criteria of Flynn et al

## Data analysis and interpretation

Data was entered into Microsoft Excel (Windows 7; Version 2007) and analyses were done using the Statistical Package for Social Sciences (SPSS) for Windows software (version 22.0; SPSS Inc, Chicago). Descriptive statistics such as mean and standard deviation (SD) for continuous variables, frequencies and percentages were calculated for categorical Variables were determined. Association between Variables was analyzed by using Chi-Square test for categorical Variables. Bar charts and Pie charts were used for visual representation of the analyzed data. Level of significance was set at 0.05.

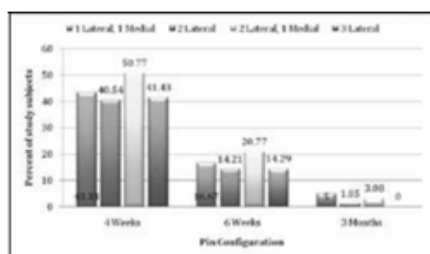
## 3 Results

Between July 2018 and June 2019, 100 patients who satisfy the inclusion and exclusion criteria were enrolled in the study. All 100 patients were 2-14 years old and most of the fractures were seen in the 5-10 age group. The mean age was 6.6 years with a median of 6 years. Incidence was higher in males and

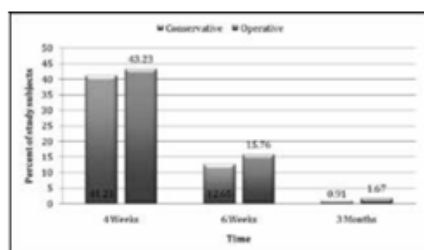
in non-dominant hand. Gartland type III (40%) was seen in major number of cases. Transverse fracture pattern (84%) in coronal plane and low sagittal fracture pattern in sagittal plane (82%) were common. Three cases had associated fractures. Two cases had nerve palsy at the time of presentation. One had median nerve palsy and the other had radial nerve palsy. Both recovered gradually by 4 weeks. One patient presented with absent radial pulse, which recovered after reduction and fixation.

Decision to operate was based on fracture classification as per Gartland. Decision on configuration of pinning was based on fracture pattern and comminution. All grade I fracture and few grade II fractures (without rotation of fragment) were conservatively managed. All grade III, IV and few grade II fractures (with rotation of fragment) were managed with closed reduction and closed reduction. 27 cases of grade I and 7 cases of grade II fractures were conservatively managed, a total of 34 cases. Remaining 66 cases (grade II (23), grade III (40) and grade IV (3)) underwent surgery. Open reduction was done in 4 cases due to soft tissue interposed between the fracture fragments. Closed reduction and fixation with pins was done in 62 cases. Four different pin configurations were used for fixation. One lateral and one medial pin for 6 cases, 2 lateral and 1 medial pin for 13 cases, 2 lateral pins for 38 cases, and 3 lateral pins for 7 cases. There was no postoperative palsy in any of the operated cases.

Functional outcome was assessed using Flynn's criteria. Loss of motion and loss of carrying angle was measured. Mean loss of motion at elbow of 41° in conservatively managed cases and 43° in operated cases at 4th week follow up. All patients showed more than 80% improvement in range of motion by 6th week follow up. By 3rd month the mean loss of motion was less than 5°, which is excellent outcome as per Flynn criteria. Only 2 patients had loss of motion >15°, of which one had an intra articular extension of the fracture and the other came late for follow up and had back slab for 8 weeks, thus had elbow immobilized in flexion for 8 weeks. Both had full range at 6 months follow up. All patients improved and had no loss of motion at 6th month follow up. When categorized cases as per pin configuration and loss of motion, maximum loss of motion was seen in cases with 2 lateral and 1 medial pinning at 4th week follow up [graph 1]. This was statistically significant when compared to loss of motion in other cases. Significant improvement in range of motion was seen by 3rd month and 6th month.



**Graph 1: Loss of Motion and Pin Configuration**



**Graph 2: Loss of Motion and Management**

Loss of carrying angle was measured at 3rd month follow up. Only 8% of cases had loss of carrying angle. As per Flynn's criteria 94% cases had excellent cosmetic outcome and 6% cases had good cosmetic outcome. There was

no loss seen in patients managed conservatively. When categorized cases as per pin configuration and loss of carrying angle, maximum loss of carrying angle was seen in cases with 2 lateral pins [Graph 2]. And this loss was statistically significant when compared to other cases. The overall outcome both functional and cosmetic was satisfactory (94% excellent and 6% good) as per Flynn's criteria.

Anterior humeral line passed through middle one third of capitellum in 91% of cases. In remaining 9% cases, line passed through anterior one third of capitellum. Loss of Baumann's angle was seen in only 9% of cases. As per Skaggs et al criteria for loss of reduction, only 1 case had moderate loss of reduction and 8 cases had mild displacement. Lateral capitolohumeral angle (LCHA) was measured in lateral radiograph of elbow [Table 2].

	LCHA
Mean (SD)	37.90 (3.11)
Median	37.0
Mode	37.0

**Table 2: LCHA values**

## 4 Discussion

Supracondylar fractures are one of the most common upper limb fractures in children. In particular, incidence peaks between the ages of 5–7 have been reported. While treating a pediatric supracondylar humerus fractures, the goals are, full recovery of elbow movements, achieving normal cosmetic appearance of elbow, protecting the patient from neurovascular complications that may occur.

Widely accepted management of pediatric supracondylar humerus fractures is closed reduction and percutaneous pin fixation. Only 4 cases were treated by open reduction and pin fixation, out of which 2 cases had soft tissue interposed between the fragments and 1 case had intra articular extension of the fracture and the other presented to us as an open fracture. Loss of reduction was seen in only one case (with intra articular extension of fracture) of these 4 cases.

Various factors affect the stability of the fixation. The quality of reduction, timing of surgery, configuration of wire fixation and more recently fracture pattern are considered as factors contributing to fracture stability.<sup>(4)</sup> Very often fracture pattern is not considered while deciding on pin configuration. Some fracture patterns are unstable than the other and thus they need specific methods of fixation. Fracture pattern is of much importance in decision-making and stability of fixation.

Lot of studies have mentioned regarding the biomechanical superiority of various pin configurations over the other. Chakraborty *et al.*<sup>(9)</sup> and Balakumar and Madhuri<sup>(10)</sup> found crossed (medial/ lateral) pinning to be superior to two parallel lateral pin fixations. However, many studies have stated that both lateral entry pin fixation and crossed pin configuration are effective in the management of Type III Gartland supracondylar fractures. Skaggs *et al.*<sup>(11)</sup> concluded that for fixation of both Type II and III supracondylar humerus fractures, lateral-only pins provide adequate stability without endangering the ulnar nerve. They also advised to avoid the regular use of crossed pin configuration in the treatment of pediatric supracondylar humerus fractures. These studies have not mentioned about criteria to decide on pin configuration. Randomly choosing on various pin configurations irrespective of fracture pattern will lead to poor results.

Bahk et al has classified supracondylar fractures of humerus based on orientation of the fracture line in sagittal as well as coronal plane<sup>(4)</sup>. In coronal plane he has described 4 fracture patterns. They are; transverse, lateral oblique, medial oblique and high fractures. In sagittal plane 2 patterns, they are, high sagittal and low sagittal fractures. He stated that, compared with transverse fractures, the other fracture patterns in coronal plane were associated with significantly more comminution and rotational malunion. Compared with low sagittal fracture pattern, high sagittal fracture pattern was associated with a significantly higher incidence of additional injuries and

were more likely to result in extension malunion.<sup>(4)</sup> Due to this difference in stability of fracture in various fracture patterns, fixation method also should be as per the pattern of fracture, in order to increase the stability of fracture fixation and improve the outcome. Transverse and lateral oblique fractures are amenable to lateral only pinning, whereas the medial oblique and high fractures need to be fixed with medial-lateral cross pins.

Comminution is also an important factor contributing to loss of reduction. Larson et al stated that medial comminution decreases fracture stability significantly. He also stated that the most stable pin configuration against the torsional forces is 2 lateral and 1 medial. The presence of medial column comminution had significant relation to loss of reduction in the lateral-entry group, though not in the crossed-pin group. It is believed that crossed-pin fixation should be preferred when there is medial cortex comminution and stability cannot be obtained with 2 lateral pins.<sup>(12)</sup> De Boeck et al.<sup>(13)</sup> stated that medial comminution should be considered as an important issue. Medial comminution was also reported as a factor related to the loss of reduction<sup>(14)</sup>. There is a chance of change in Baumann angle until bone union, if supracondylar humerus fracture with medial comminution was fixed with lateral-only pin fixation.

Considering all the above study conclusions, we had studied the fracture pattern and comminution to decide on pin configuration. Functional outcome was assessed as per Flynn's criteria. Loss of reduction was assessed as per Skaggs criteria.

Various studies have shown that the various parameters used to assess functional outcome and loss of reduction in our study are reliable. Skaggs et al showed that a change in Baumann's angle is consistent with loss of reduction. Greater than 12° is a major loss of reduction and 6-12° a moderate loss of reduction and <6° as mild displacement.<sup>(8)</sup> Silva et al also stated that Baumann angle can be used for the determination of the outcome of supracondylar humeral fractures in the pediatric population.<sup>(15)</sup> Dai et al.<sup>(16)</sup> and Silva et al.<sup>(17)</sup> stated that the alignment of the distal humerus in the frontal plane can be assessed clinically by measuring the carrying angle, and in radiographs by calculating the Baumann angle. And the quality of reduction in the sagittal plane can be assessed clinically by recording elbow range of motion and in radiographs from the lateral capitellohumeral angle or from anterior humeral line.<sup>(5,18)</sup>

There was more loss of motion at elbow joint at 4th week follow up in operatively managed cases as compared to those treated conservatively. This may be because of the increased soft tissue injury in Gartland type 3 and 4 fractures, which are amenable for operative treatment. In operated cases, patients with 2 lateral and 1 medial pins had more loss of range of motion as compared to cases with other pin configurations. This difference was statistically significant. This pin configuration was used inpatients with medial comminution and unstable fracture pattern, which have excessive soft tissue injury. Gradually the range of motion improved in subsequent follow up at 6 weeks and 3 months. There was full range of motion at elbow joint in all patients at 6 months follow up.

Loss of carrying angle was seen in only 5% of operated cases and there was no loss of angle in conservatively managed cases. Of these 5% cases, 4% cases were treated with only 2 lateral pins. Cases managed conservatively have simple, undisplaced fractures, thus there is very less chance of loss of reduction or change in carrying angle. As per Flynn's criteria these cases with loss of carrying angle were rated as cosmetically good outcome.

In our study the overall outcome both functional and cosmetic was satisfactory (94% excellent and 6% good) as per Flynn's criteria.

Anterior humeral line passed through middle one third of capitellum in 91% of cases. In remaining 9% cases, line passes through anterior one third of capitellum. Loss of Baumann's angle was seen in only 9% of cases. As per Skaggs et al criteria for loss of reduction, only 1 case had moderate loss of reduction and 8 cases had mild displacement.

Two cases had presented with nerve palsy at the time of injury. Both recovered completely without any intervention.

In a study "Analysis of displaced supracondylar fractures in children treated with closed reduction and percutaneous pinning" by Sakthivel RN et al, 74.3% showed Satisfactory and 11.4% showed unsatisfactory functional outcome as per Flynn criteria.<sup>(19)</sup> Ali Reisoglu et al in his study "Is pin configuration the only factor causing loss of reduction in the management of

pediatric type III supracondylar fractures?", found 13.7% loss of reduction in their study result, which was well correlated with the related literature<sup>(20)</sup>. Our study had loss of reduction in 9% cases, of which 2% cases had moderate loss and other 7% had mild loss. Compared to other literature, the loss of reduction was less and the functional and cosmetic outcome was excellent. This excellent result could be achieved as the pinning configuration was decided as per the fracture pattern and comminution.

The important reason for the preference of the lateral-only pin fixation is avoidance of iatrogenic ulnar nerve injury. In a systematic review the rate of iatrogenic ulnar nerve injury from cross pinning was 3.4%<sup>(21)</sup>. And also the relative risk factor was 0.30 in another meta-analysis<sup>(22)</sup>. After cross pinning, 8-fold increase in the ulnar nerve injury was reported in another study<sup>(23)</sup>. In our series, there was no iatrogenic ulnar nerve injury. Surgical technique plays an important role in prevention of nerve injury.

## 5 Conclusion

Supracondylar humerus fractures in children are very commonly encountered fractures. Treating them without complications with good functional outcome is important. Bahk's fracture pattern plays a very important role in fracture management. Deciding about pin configuration for fixation should be done as per the fracture pattern and fracture comminution. This reduces the chance of loss of reduction and improves functional outcome. In fractures that are amenable for lateral only fixation, 3 laterals pins should be preferred. Patient should be screened for other associated fractures. Small incision and passing medial wire in extension will avoid iatrogenic nerve injury.

## Tables and figures

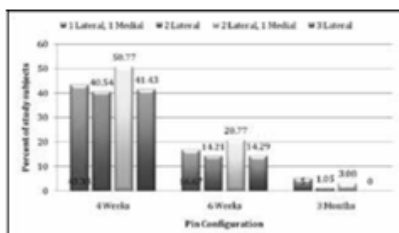
Rating	Cosmetic factor (carrying angle loss)	Functional factor (Loss of motion)
Excellent	0-5	0-5
Good	6-10	6-10
Fair	11-15	11-15
Poor	>15	>15

**Table 1: The cosmetic and functional criteria of Flynn et al**

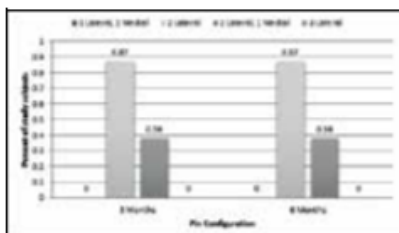
	LCHA
Mean (SD)	37.90 (3.11)
Median	37.0
Mode	37.0

**Table 2: LCHA values**





**Graph 1: Loss of Motion and Pin Configuration**



**Graph 2: Loss of Carrying Angle and Pin Configuration**



**Medial oblique fracture**  
Unstable,  $>10^\circ$  coronal plane obliquity  
Proximal fracture line exiting medially

#### Bahk Classification



**Typical Transverse fracture**  
Stable, Fracture line entering and exiting near epicondyles  $<10^\circ$  coronal obliquity with fracture



**Lateral oblique fracture**  
Unstable,  $>10^\circ$  coronal plane obliquity  
Proximal fracture line exiting laterally



**High fracture Unstable,**  
Fracture line entering and exiting above olecranon fossa, within the metaphysis



**High sagittal Unstable  $\geq 20^\circ$**   
fracture plane



**Low sagittal Stable  $<20^\circ$  fracture plane**



**3 Lateral**



**2 Lateral**



**2 Lateral & 1 Medial**



**1 Lateral & 1 Medial**

**Table 3: Pin Configurations**

**Conflict of interest:** No conflict of interest

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