Outcome Analysis of Lateral Pinning for Displaced Supracondylar Fractures in Children Using Three Kirschner Wires in Parallel and Divergent Configuration

Abstract

Background: Supracondylar humerus fracture is the most common fracture around elbow in children. Closed reduction and percutaneous Kirschner wire (pin) fixation is the standard method of managing displaced extension type (Gartland Type II and Type III) supracondylar humerus fractures. The configuration of wires is debatable. Although two crossed K-wires are mechanically stable, there is an inherent risk of ulnar nerve injury. Lateral K-wires – parallel or divergent – are good alternative. This study was aimed at identifying the best configuration for the lateral wires. **Materials and Methods:** Patients with Gartland type 3 supracondylar humerus fractures were randomized by envelope method to receive closed reduction and K-wire fixation in either a parallel or divergent fashion. The patients were followed up at 3 weeks for wire removal and at 6 weeks and 3 months after surgery. Baumann's angle, functional outcome as per Flynn's criteria, and range of motion were recorded in each visit. Effect of delay in surgery was also evaluated as a secondary outcome. **Results:** Nineteen patients received fixation with parallel wires and 11 patients had divergent fixation. No loss of reduction was seen in any patient at 3 months. No statistically significant difference was seen in the Baumann's angles and outcome according to Flynn's criteria irrespective of the wire configuration (divergent or parallel). Furthermore, the delay in surgery was also found not to have a significant effect on the functional outcome. **Conclusions:** Both parallel and divergent K-wire configurations provide satisfactory stability when accurate reduction and adequate fixation of the fracture has been done. Based on the limited number of patients in this study, one configuration cannot be judged to be superior to the other.

Keywords: *Baumann's angle, closed reduction, Flynn's criteria, Gartland's Type 3, supracondylar humerus fracture*

MeSH terms: *Pediatrics, humerus, humeral fractures*

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Introduction

Supracondylar humerus fractures being the most common pediatric fracture around the elbow account for nearly three-fourth of all upper-extremity fractures.[1-3] Closed reduction and percutaneous Kirschner wire (pin) fixation is the standard method of managing displaced extension type (Gartland Type II and Type III) supracondylar humerus fractures. Many investigators have used two crossed pins: one introduced medially and one laterally.[4-6] Few have used two or three lateral pins without any medial pin.[7] The optimal configuration of percutaneous pin fixation is however debatable. Biomechanically, a crossed pin configuration (one medial and one lateral) provides increased stability but carries the risk of iatrogenic ulnar nerve injury during insertion of the medial pin.[8-10] Conversely, lateral pin fixation avoids the danger of iatrogenic ulnar nerve injury but has been proven to be mechanically less stable compared to crossed pin configuration.[11-15] There are studies which have proven that lateral-only fixation is good enough for maintaining reduction while simultaneously avoiding injury to the ulnar nerve.[16] However, except for the study by Lee *et al.*,[17] not much discussion or brainstorming has been done on the configuration of pins when using lateral-only pins, i.e. whether to use the pins in parallel or divergent configuration. The present study compares the radiological and functional outcomes of lateral-only pin fixation in parallel and divergent configuration for Gartland Type III supracondylar humerus fractures in terms of loss of reduction, late deformity,

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and functional outcome. In addition, the effect of delay in surgery on the final Baumann's angle and the functional outcome was also evaluated.

Materials and Methods

This was a single-center prospective randomized study conducted between April 2014 and September 2015 after approval by the Institutional Ethics Committee. Children with Type III Gartland supracondylar fractures between the ages of 2 and 12 years were included. Children presenting up to 7 days of injury were considered for inclusion. Children with vascular injuries, open fractures, transphyseal injuries, with blisters, with established compartment syndrome at presentation, and those who would eventually require an open reduction due to inadequate closed reduction were planned to be excluded from the study. The children were randomized into two groups using the opaque sealed envelope technique for fixation with parallel or divergent pins. A written informed consent was obtained from the parents/legal guardians of each patient before proceeding for operative fixation. The details were recorded on Microsoft Excel Sheet and statistical analysis was done using SPSS version 20 (IBM Corporation, New York, USA).

Operative procedure

General anesthesia was used in all patients. Intravenous cephalosporin was given at the time of induction. Traction was applied with the elbow flexed to about 20°. Next, varus and valgus angular alignment was corrected by movement of the forearm. Medial and lateral fragment translation was corrected with direct movement of the distal fragment by the surgeon's thumb with image confirmation. The elbow was slowly flexed while anterior pressure was applied to the olecranon with the thumb. The limb was flexed in pronation or supination depending on the initial displacement of the distal fragment. Reduction was checked by Jones view and by oblique views to assess the reduction of medial and lateral pillars. Lateral view was obtained by moving the image intensifier and not by moving the limb. Continuity of the medial and lateral pillars on oblique views with reformed tear drop and the anterior humeral line crossing the capitellum on lateral view were taken as the signs of having obtained reasonable reduction. Once the reduction was judged to be appropriate, the position was maintained using an elastic bandage.

One K-wire (1.6 mm) was placed against the lateral condyle and the position was checked under image intensifier. It was advanced initially by hand and then after getting some purchase, with a wire driver through the fracture site to engage the opposite cortex. The first wire was aimed to pass through the olecranon fossa, thereby providing purchase in four cortices and provide room for placing one more wire on either side. One K-wire (1.6 mm) each on lateral and medial side of the first K-wire was then

inserted under image intensifier control, well separated at the fracture site in parallel or divergent manner depending on the preoperative randomization. To ensure adequate divergent placement of the wires within the bone, they were crossed by the same amount outside the skin [Figure 1]. After insertion of all the wires, stability of the fixation was assessed by applying varus and valgus stress and by putting the limb into maximum permissible flexion and extension movements. Image intensifier images were used to assess any loss of reduction after stressing the fixation. The wires were left protruding from the skin for easy removal in the outpatient clinic. The intraoperative Bauman's angle was recorded.

Postoperatively, the limb was immobilized for 3 weeks in an above-elbow plaster slab. The wires were removed at first follow-up visit i.e at 3 weeks. After removal of the wires, physiotherapy was started for regaining the range of motion under the supervision of a physiotherapist. Aggressive stretching was always avoided. Follow-up evaluations were done at 6 weeks, and 3 months from the day of surgery. Loss of reduction was assessed by the method described by Skaggs *et al*.[16] by measuring the Baumann's angle on radiographs obtained in peri-operative period and at 3 months after surgery. The maintenance of reduction was also assessed on lateral view by drawing the anterior humeral line. At the third followup (3 months after surgery), range of motion of both the injured and normal elbows was measured, along with the carrying angles, and the functional outcome was assessed based on Flynn's criteria [Figures 2 and 3].

Results

Thirty patients who fulfilled inclusion and exclusion criteria were included in the study. The average age was 7.6 years (range 2-12 years). Twenty three patients (77%) were male and 7 (23%) were female. Left side was involved in 19 and right side in 11 patients. Seventeen patients had posterolateral displacement, whereas 13 had posteromedial displacement. Four patients had radial nerve paresis at presentation, whereas two had anterior interosseous nerve
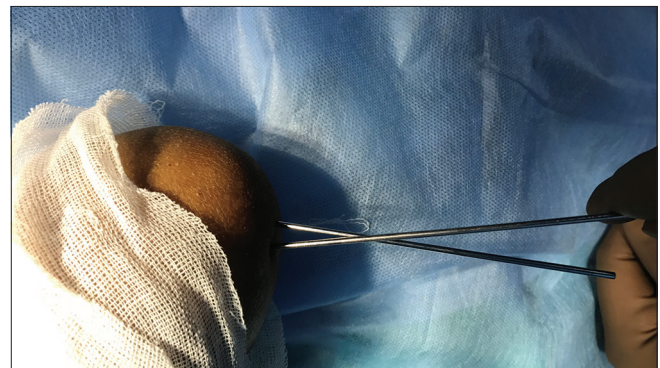
Figure 1: Intraoperative image showing a trick for achieving divergence inside the arm. the K-wires should cross each other outside for diverging inside

Figure 2: X-ray of elbow joint with arm and forearm showing (a) Preoperative radiograph with Gartland III supracondylar fracture (b and c) Immediate postoperative radiograph with divergent K-wire configuration. (d and e) Anteroposterior and lateral views after removal of K-wires 3 months postoperatively
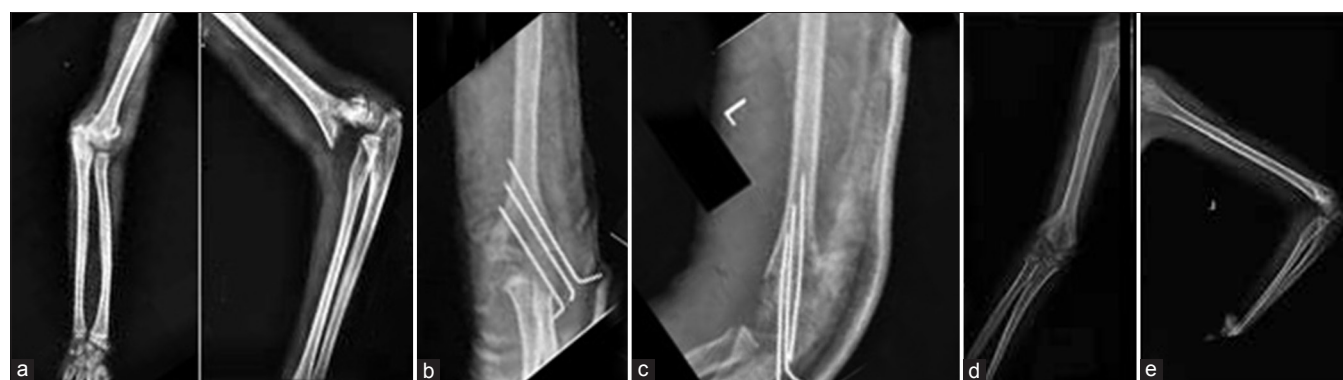

Figure 3: X-ray of elbow joint with arm and forearm showing (a) Gartland type III supracondylar fracture. (b and c) Immediate postoperative radiograph with parallel K-wire configuration. (d and e) Anteroposterior and lateral views after removal of K-wires 3 months postoperatively

palsy. There was no iatrogenic nerve injury. All the six patients with preoperatively diagnosed nerve injuries recovered within 3 months. Radial pulse was not palpable at the time of presentation in nine patients. Pulses returned in four patients immediately after reduction and fixation. However, five patients did not have palpable radial pulse even after reduction and fixation. Of these, four had pink pulseless hand and were kept under observation and one patient underwent thrombectomy by vascular surgeon. However, at 3 months, radial pulse had returned in all the patients.

Nineteen (63%) patients were treated with three parallel K-wire fixation and 11 (37%) were treated with three divergent K-wire fixation [Table 1]. Based on the method described by Skaggs *et al*.,[16] no loss of reduction was found in any patient (i.e., in none of them, Baumann's angle changed more than 6°) at follow up. Using ANOVA for intragroup Baumann's angle change, no statistically significant difference was found in Baumann's angle values measured at immediate postoperative period, at 3 weeks, 6 weeks, and at 3 months with either divergent or parallel stabilization configuration (P = 0.720 and 0.395, respectively). The mean Baumann's angles at different followups are presented in Table 2. Thus, both the

configurations of K-wires were stable, and no significant loss of reduction was found in either of them at 3 months post fixation. All the fractures eventually healed by 3 months and no case of nonunion or delayed union was identified.

The shortest time between injury and surgical intervention was 5 h and the longest was 136 h. Median delay from injury to surgery was 15 hours. While patients with delayed presentation had somewhat greater degree of swelling around the elbow in comparison to those who presented early, there was no significant difficulty in achieving reduction and fixation. The issue of nonreducible fractures was not encountered. When the patients were compared in terms of time elapsed between injury and surgery and loss of reduction using the Baumann's angle values, no significant difference was found on Friedman ANOVA in Baumann's angle values measured at immediate postoperative period, at 3 weeks, 6 weeks, and 3 months after surgery, whether the surgery was done within 12 h, 12–24 h, or after more than 24 h of sustaining the fracture (P = 0.370, 0.536, and 0.543, respectively). Functional outcome was assessed using Flynn's criteria[6] 3 months after the surgery. Out of all the thirty patients, 22 had excellent functional outcome, 6 had good outcome, and 2 had poor outcome.

Table 1: Clinical details of patients

Age (Years)	Sex	K-wire configuration	Baumann's angle postoperative	Baumann's angle 3 weeks	Baumann's angle 6 weeks	Baumann's angle 3 months	Loss of reduction Skaggs method	Carrying angle uninjured limb	Carrying angle injured limb	Extension 3 months injured elbow	Flexion 3 months injured elbow	Extension 3 months normal elbow	Flexion 3 months normal elbow	Grading based on Flynn's criteria	Time elapsed (injury to surgery) (h)
8	Male	Divergent	78	78	76	76	None	9	11	4	140	−4	140	Excellent	<12
2	Female	Divergent	77	77	77	77	None	13	13	−10	140	−5	150	Excellent	<12
5	Female	Divergent	80	79	81	81	None	12	12	0	138	0	142	Excellent	<12
9	Female	Divergent	67	70	70	64	None	12	12	−19	143	−7	152	Excellent	12-24
7	Male	Divergent	76	76	76	76	None	8	8	0	145	0	145	Excellent	12-24
9	Male	Divergent	68	70	66	66	None	8	8	3	141	−3	144	Good	12-24
8	Female	Divergent	73	74	74	74	None	13	11	−15	130	−10	140	Excellent	12-24
8	Male	Divergent	76	78	74	74	None	9	9	0	140	0	140	Excellent	>24
12	Male	Divergent	70	70	70	70	None	8	10	−4	140	−4	142	Excellent	>24
10	Female	Divergent	73	73	73	73	None	13	13	0	140	0	140	Excellent	>24
11	Male	Divergent	73	71	73	73	None	9	12	0	136	0	140	Excellent	>24
11	Male	Parallel	72	76	76	76	None	8	10	0	140	0	140	Excellent	<12
12	Male	Parallel	75	74	75	75	None	9	10	0	140	0	140	Excellent	<12
6	Male	Parallel	78	82	82	81	None	10	10	0	144	0	144	Excellent	<12
8	Male	Parallel	76	76	78	76	None	9	12	0	132	0	142	Good	<12
6	Male	Parallel	76	75	75	75	None	8	8	0	130	0	130	Excellent	<12
7	Male	Parallel	77	79	79	79	None	8	8	−4	140	−4	140	Excellent	<12
8	Male	Parallel	79	81	81	81	None	9	12	0	145	0	145	Excellent	<12
5	Female	Parallel	82	82	82	82	None	11	11	0	142	0	142	Excellent	12-24
2	Male	Parallel	76	75	74	76	None	9	9	12	140	12	140	Excellent	12-24
5	Male	Parallel	74	76	76	76	None	7	10	0	140	0	148	Good	12-24
8	Male	Parallel	77	71	77	77	None	10	12	4	145	0	145	Excellent	12-24
7	Female	Parallel	72	74	74	73	None	10	12	20	140	0	140	Poor	12-24
11	Male	Parallel	70	70	72	72	None	9	9	0	130	0	140	Good	12-24
5	Male	Parallel	78	76	76	76	None	9	13	4	82	−19	135	Poor	>24
11	Male	Parallel	73	78	75	78	None	9	13	0	142	0	144	Excellent	>24
4	Male	Parallel	80	78	77	77	None	11	11	−4	136	−4	140	Excellent	>24
10	Male	Parallel	77	74	74	73	None	9	12	0	135	0	140	Excellent	>24
8	Male	Parallel	72	76	73	72	None	10	10	0	135	−4	140	Good	>24
5	Male	Parallel	68	70	70	70	None	10	10	0	133	0	135	Excellent	>24

The functional outcome as per Flynn's criteria of the two groups (divergent and parallel) is presented in Table 3. There was no significant difference in functional outcomes between the two-wire configurations on Chi-square test.

Chi-square test showed no significant difference in functional outcomes (as per the Flynn criteria) and time of surgical intervention from injury [Table 4]. Carrying angles were measured for the injured as well as uninjured limbs at 3 months for evaluating a clinically evident varus or valgus deformity at elbow. No significant difference was found in the carrying angles of the two limbs in either of the two groups [Table 5]. While the detailed data on the range of motion of the injured and uninjured elbows are presented in Table 1, statistical analysis to look for any significant difference in the maximum possible extension and flexion between the elbows of the two groups showed no statistically significant difference on independent samples Mann–Whitney U-test.

We did not encounter any patient with medial comminution though we closely evaluated the preoperative as well as the intraoperative image intensifier images. In addition, aborting the procedure of closed reduction and pinning was

not required in any patient. There was no vascular injury in any of the patients during either reduction or fixation. One patient suffered from compartment syndrome of forearm postoperatively and was managed with fasciotomy and secondary closure. The course of followup and duration of retention of pins were not changed as the fracture was found to be healing well. Secondary pin loosening, superficial or deep infections, and pin migration were not seen in any patient.

Discussion

Closed reduction and percutaneous pin fixation for the management of pediatric supracondylar humerus fractures is widely accepted and practiced, but the optimal pin configuration is still controversial.[1,2,18,19] Chakraborty *et al.*[20] and Balakumar and Madhuri[21] found crossed (medial/lateral) pinning to be superior than two parallel lateral pin fixations. However, many studies have reinforced the observation that both lateral-entry pin fixation and crossed pin configuration are effective in the management of Type III Gartland supracondylar fractures in children.[19,22,23] Skaggs *et al.*[16] concluded that lateral-only pins provide adequate stability without endangering the ulnar nerve for fixation of both Type II and III supracondylar humerus fractures. They also advised avoiding the regular use of crossed pins in the treatment of pediatric supracondylar humerus fractures.[16]

Sapkota *et al.*[24] suggested lateral pinning with 2 or 3 K-wires for proper stabilization and ideal configuration to be divergent to hold medial and lateral columns as the treatment of supracondylar fracture without risk of iatrogenic ulnar nerve injury. Guy *et al.*[25] recommended the use of three pins on the lateral side with no evidence of loss of reduction and no iatrogenic nerve injury in their study. Lee *et al.*[17] were the first one to address the question of ideal lateral-entry pin configuration. In their series, there were a total of 61 patients; 24 with Gartland II fractures and the rest 37 with Gartland III fractures. Forty-one patients had divergent pins and twenty had parallel pins. They found the lateral-entry pins to be adequate for Gartland II

Table 2: The mean and standard deviation of Baumann's angles at different followups in the two groups of patients

Baumann's angle	Mean	SD
Divergent pin configuration		
Baumann's_angle_postoperative	73.73	4.149
Baumann's_angle_3 weeks	74.18	3.573
Baumann's_angle_6 weeks	73.64	4.032
Baumann's_angle_3 months	73.09	4.888
Parallel pin configuration		
Baumann's_angle_postoperative	75.37	3.547
Baumann's_angle_3 weeks	75.95	3.535
Baumann's_angle_6 weeks	76.11	3.230
Baumann's_angle_3 months	76.05	3.240

SD=Standard deviation

Table 3: K-wire configuration (divergent or convergent) and its relation to functional grading by Flynn's criteria

K-wire configuration	Grading based on Flynn's criteria				Total	P value based on Chi-square test
	Excellent	Good	Fair	Poor		
Divergent	9	1	0	1	11	0.330
Parallel	14	4	0	1	19	
Total	23	5	0	2	30	

Table 4: Relation between the time elapsed from injury to surgery and the functional status based on Flynn's criteria

Time elapsed (h)	Grading based on Flynn's criteria				Total	P value based on Chi-square test
	Excellent	Good	Fair	Poor		
<12	10	1	0	0	11	0.387
12-24	5	3	0	1	9	
>24	8	1	0	1	10	
Total	23	5	0	2	30	

Table 5: The mean carrying angles at 3 months of the uninjured and injured limbs in both the divergent and parallel configuration groups

Carrying angles	K-wire configuration	*n*	Mean	*P* value based on Mann-Whitney U-test
Carrying angle at 3 months uninjured limb	Divergent	11	10.36	0.350
	Parallel	19	9.21	
Carrying angle at 3 months injured limb	Divergent	11	10.82	0.703
	Parallel	19	10.63	

and III fractures. In the present study, all the fractures were treated with closed reduction and lateral fixation only.

Guy *et al*.[25] used three divergent pins; 21 patients had an excellent outcome, three patients had good outcome, and 1 achieved poor outcome due to loss of movement alone. They attributed delayed presentation due to neglect over 48 h after injury and gross swelling requiring traction and elevation to be the main factors contributing for less than ideal outcome. However, no statistically significant difference was found in our study on functional outcomes (based on Flynn's criteria) in any of the patients, whether the surgery was performed before 12 h of sustaining the fracture, within 12–24 h, or after 24 h of the injury. Thus, the time elapsed from between injury and surgery has little effect on the functional outcomes, provided a satisfactory reduction has been achieved.

To summarize, the present study found that both configurations of lateral-entry pins are equally stable with similar functional outcomes and there is no loss of reduction in the short term if appropriate reduction is done. It thus supports the other available literature that lateral-entry pins only fixation can be safely used in displaced supracondylar fractures. Delay between injury and surgery too was found not to affect the overall outcome with the prerequisite of a successful closed reduction before pinning.

There are few important limitations of the present study. A major limiting factor is small sample size and short duration of followup. We believe that studies with participation of more patients and more centers need to be carried out with longer followup to clarify whether three parallel lateral pins or three divergent lateral pins should be used for fixing Gartland 3 supracondylar humerus fractures in children.

Conclusions

As the fixation remained stable in both parallel and divergent lateral-entry K-wire configurations at every followup visit, with no loss of reduction or disparity in the functional outcomes, it can be concluded that closed reduction and fixation of Gartland type III supracondylar fractures with lateral-entry K-wires is safe and effective irrespective of the wire (divergent or parallel) configuration selected.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients' guardians have given their consent for their children's images and other clinical information to be reported in the journal. The patients' guardians understand that their children's names and initials will not be published, and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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