Original Article

A retrospective analysis of loss of reduction in operated supracondylar humerus fractures

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Abstract

Background: Loss of reduction following closed or open reduction of displaced supracondylar fractures of the humerus in children varies widely and is considered dependent on stability of the fracture pattern, Gartland type, number and configuration of pins for fixation, technical errors, adequacy of initial reduction, and timing of the surgery. This study was aimed to evaluate the factors responsible for failure of reduction in operated pediatric supracondylar fracture humerus.

Materials and Methods: We retrospectively assessed loss of reduction by evaluating changes in Baumann's angle, change in lateral rotation percentage, and anterior humeral line in 77 consecutive children who were treated with multiple Kirschner wire fixation and were available for followup. The intraoperative radiographs were compared with those taken immediately after surgery and 3 weeks postoperatively. Multivariate logistic regression analysis was performed by STATA 10.

Results: Reduction was lost in 18.2% of the patients. Technical errors were significantly higher in those who lost reduction (P = 0.001; Odds Ratio: 57.63). Lateral pins had a significantly higher risk of losing reduction than cross pins (P = 0.029; Odds Ratio: 7.73). Other factors including stability of fracture configuration were not significantly different in the two groups.

Conclusions: The stability of fracture fixation in supracondylar fractures in children is dependent on a technically good pinning. Cross pinning provides a more stable fixation than lateral entry pins. Fracture pattern and accuracy of reduction were not important factors in determining the stability of fixation.

Key words: Kirschner wire fixation, stability, supracondylar fracture

Introduction

Supracondylar fractures in children are one of the commonest upper limb fractures in the first decade of life.[1] The Gartland type 3 displaced and many of the type 2 supracondylar fractures are stabilized with Kirschner (K) wire fixation after reduction.[1,2] The stability after fracture fixation has been the subject of much debate in the past.[3] The quality of reduction, configuration of wire fixation, i.e. crossed or parallel, timing of surgery, medial or lateral entry for placement of pin, number of pins, and more recently fracture configuration and the inherent instability of the fracture pattern have all been considered as important factors contributing to the stability of fixation.[3-7] The technical errors play an important role in the final outcome.[6,7]

Some centers have guidelines on how to pin these injuries, and very often the fracture pattern is not taken into account even though some patterns are considered more unstable than others and deemed to require specific methods of fixation.[3] While there are many articles dealing with various aspects of supracondylar fracture stability after fixation, there is very little written about the role of the fracture pattern and its effect on the stability of reduction.[4,8] In this study, we have analyzed various factors including the Bahk's[4] fracture types and their effects with respect to the fracture stability following fixation, and the loss of fixation postoperatively. Instability attributable to Bahk's fracture pattern has not been evaluated as a possible confounder when assessing stability characteristics of different fixation techniques.

Materials and Methods

A retrospective analysis of ninety consecutive supracondylar fractures of humerus in children admitted from July 2004 to October 2009 operated by 15 different surgeons and trainees were included in this study. Clinical data and

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Access this article online	
Quick Response Code:	Website: www.ijoonline.com
	DOI: 10.4103/0019-5413.104219

radiographs were obtained from stored clinical records, Computerized Hospital Information Processing Services (CHIPS), and Picture Archiving and Communication System (PACS). Data related to age, gender, side, fracture configuration, surgical details, pin configuration, and timing of surgery were collected. Gartland type 2 or 3 fractures treated with closed reduction without internal fixation, fractures with intercondylar extension and osteogenesis imperfecta were then excluded.

The fracture patterns of all included children were classified using the preoperative and intraoperative images with Bakh's criteria [Table 1][4] and [Figure 1].

Faulty technique was defined for this study as a) the lack of fixation of one or more wires either in the distal or in the proximal fragment [Figures 2 and 3] b) convergence of the pin in the far cortex [Figure 4] c) pins crossing each other at the fracture site [Figure 5]. Fixation of four cortices, two in the proximal and two in the distal fragment, with adequate separation to fix two columns was considered a good fixation for the purpose of this study [Figure 6].

Adequacy of intraoperative reduction and postoperative position was assessed using Baumann's angle, lateral rotation percentage, and anterior humeral line.[3,5] The above were measured from intraoperative images or immediate postoperative radiographs and compared with radiographs taken at cast removal and the difference in the position recorded. Loss of reduction was quantitated by criteria defined by Skaggs *et al*. and it has been shown that a change in the Baumann's angle is consistent with a loss of reduction.[9] Greater than 12° is a major loss of reduction and 6°–12° a moderate loss of reduction.[10] For this study, we considered the moderate and major loss of reduction as defined by the above criteria.[3] The stability of reduction was analyzed by assessing loss of reduction in the cast postoperatively.

Analysis was carried out using Student's *t* test for the effect of individual variables on loss of reduction. The effect of quality of initial reduction and technically sound pinning on the loss of reduction was analyzed by Fisher's exact test. All significant factors were further evaluated with a logistic multivariate regression analysis to eliminate the effect of confounding factors. STATA 10 (Stata Corp., College Station, TX, USA) statistical software was used for analysis.

Results

Ninety children with displaced supracondylar fractures were admitted during the study period. There were 65 boys and 25 girls. The mean age was 7.8 years (range 10 mo - 15 yrs).

Table 1: Distribution of unstable fracture configurations types and their effect on stability (modified from Bahk *et al.* 2008)

Number of cases in this study	Fracture type	Stability	Definition
62	Transverse fractures 	Stable	<10° of coronal obliquity with fracture plane entering and exiting near epicondyles
5	Coronal lateral oblique fractures 	Unstable	≥10° of coronal obliquity with proximal fracture plane exiting laterally
3	Coronal medial oblique fractures 	Unstable	≥10° of coronal obliquity with proximal fracture plane exiting medially
3	High fractures 	Unstable	Fracture plane entering and exiting above olecranon fossa, but within the distal humeral metaphysis
Included in the low transverse group	Low sagittal fracture 	Stable	Fracture plane <20°
4	High sagittal fracture 	Unstable	Fracture plane ≥20°

Left side was involved in 67 and right side in 23 children.

Of the 90 children with supracondylar fractures of the humerus, 1 child was lost to follow up, 1 was treated with Dunlop traction, 1 had osteogenesis imperfecta, 1 had intercondylar extension, and 9 patients were having type 2 Gartland fractures, which were managed with closed reduction and casting. These 13 children were excluded from the study.

The data from the remaining 77 children, who underwent

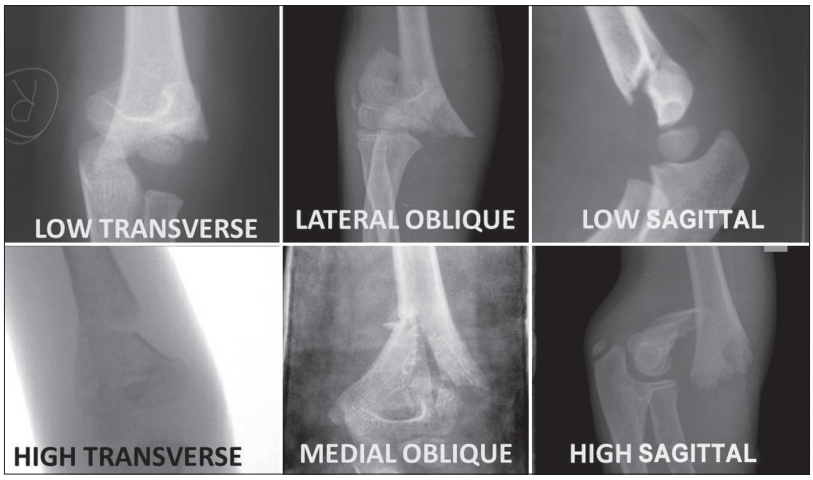

Figure 1: X-ray of elbow joint various fracture patterns as described by Bahk *et al.* 2008

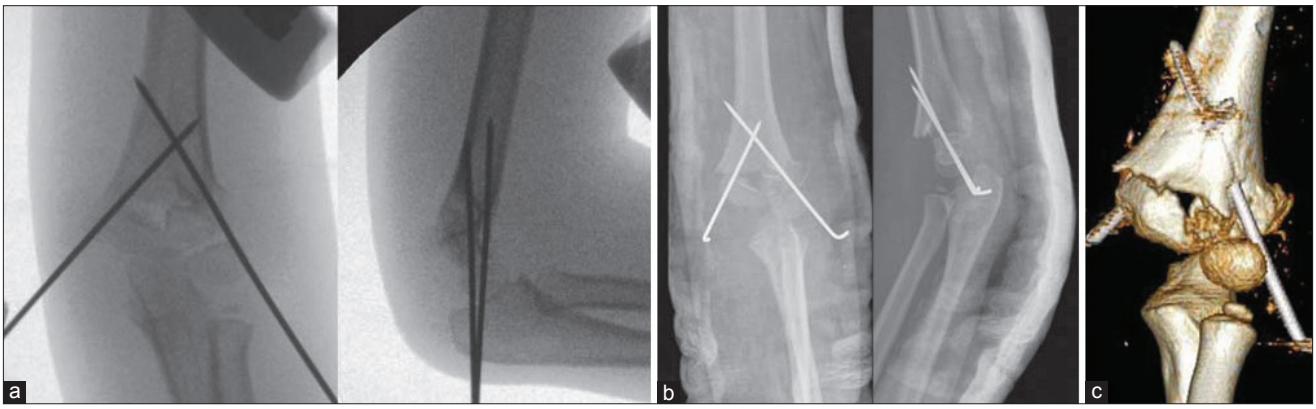

Figure 2: (a) Anteroposterior and lateral images of distal humerus demonstrating the reduction intraoperatively in a displaced supracondylar fracture of the humerus. (b) Immediate postoperative radiograph – anteroposterior and lateral views of distal humerus showing loss of reduction. (c) Three dimensional computed tomogram showing that the lateral wire failed to get adequate purchase in distal fragment. The child was taken up for repeat surgery due to major loss of reduction

operative fixation, were further analyzed. There were 67 Gartland type 3 and 10 type 2 fractures. Indication for pinning in a Gartland type 2 fracture was either gross swelling or medial comminution. Sixty four of the children underwent closed reduction and 13 underwent open reduction followed by pinning. In the second group, four were open fractures requiring wound debridement, two patients had vascular injury with ischemia and required saphenous vein grafting, eight patients had a median nerve palsy, and one child had a radial and ulnar nerve palsy documented at presentation. One child was documented to have radial and median nerve palsy and another had ulnar and median nerve palsy noticed after surgery. Both these children recovered in the postoperative period. Three children underwent a second reduction in the postoperative period because of a major loss of reduction.

The fracture patterns were classified as low transverse in 62, medial oblique in 3, high sagittal oblique in 4, lateral oblique in 5, and high transverse in 3 cases [Table 1, Figure 1]. Low transverse was the most common type in this series. The 62 low transverse fractures were classified as stable and the other 15 as unstable fractures.[4]

Loss of reduction occurred in 14 (18.2%) of the cases. The children who lost reduction had a mean intraoperative lateral rotation percentage of 14.69% and after loss of reduction a change in the average lateral rotation percentage of 41.2%. A moderate to severe Bowmann angle change of greater than 6° was seen in all except three of these children. In the three children who had a second reduction, the loss of reduction was diagnosed based on a change in the anterior humeral line intersection and lateral rotation percentage change varying from 25 to 48%. In other cases, the loss of reduction was accepted by the treating surgeon. Eventually, however, of all the 14 who lost reduction, only one child had clinical cubitus varus. He, however, did not want surgery.

The loss of reduction was analyzed in relation to the stability of fracture patterns. Reduction was lost in 12 (19.4%) of

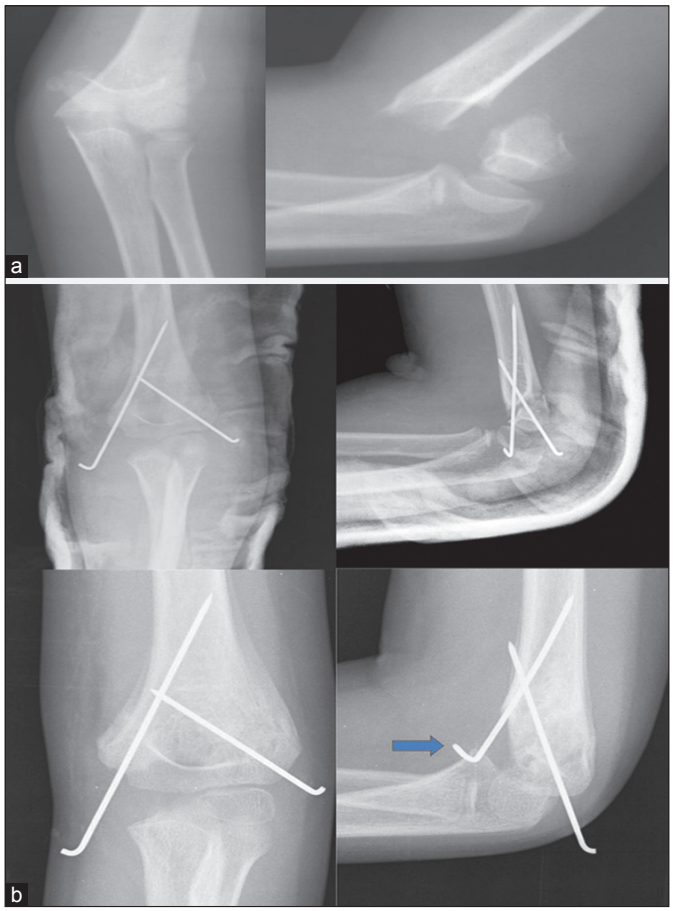

Figure 3: (a) Anteroposterior and lateral radiographs showing a low transverse Gartland type 3 extension supracondylar fracture humerus. (b) Immediate postoperative and followup radiographs showing malreduced fracture with no distal purchase (marked with arrow). There was no loss of reduction despite technically poor pinning

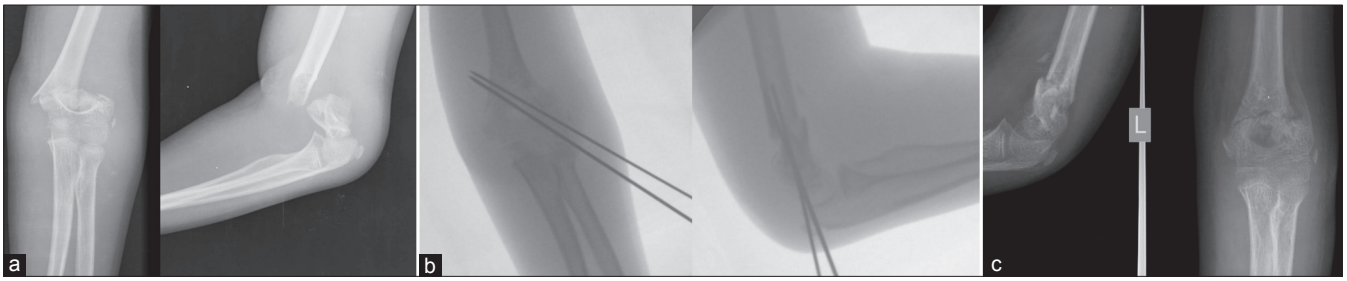

Figure 4: (a) Anteroposterior and lateral radiographs showing type 3 Gartland high transverse and sagittal oblique fracture pattern. (b) Intraoperative anteroposterior and lateral radiographs showing acceptable reduction with technically poor pinning (convergence of lateral entry pins). (c) Followup radiographs at 4 weeks show maintenance of reduction in spite of biomechanically poor construct with inadequate spread

the 62 stable cases and 2 (13.3%) of the 15 unstable cases. This was statistically insignificant ($P = 0.725$).

There were four different pin configurations used in the study. Those with lateral pins only, namely, a) two lateral pins b) three lateral pin; and others with both medial and lateral pins, namely, c) crossed pins with one medial and one lateral entry pin and d) two lateral and one medial entry pins. In the lateral entry configuration, (a) two lateral pins were used in 20 cases and (b) three lateral pins in 9 cases. Of these 29 children with lateral entry pins, 10 (34.5%) showed postoperative loss of reduction. Configurations with at least one medial pin were (c) crossed pins in 28 cases and (d) two lateral pins and one medial pin in 20 cases. In the groups which included at least one medial pin, 4 (8.3%) out of 48 cases lost reduction. A Fischer's exact *test* showed a statistically significant difference between the two groups ($P < 0.0046$).

The cases with loss of reductions were analyzed to assess the effect of faulty techniques. Thirty six cases with faulty techniques were identified based on the criteria defined

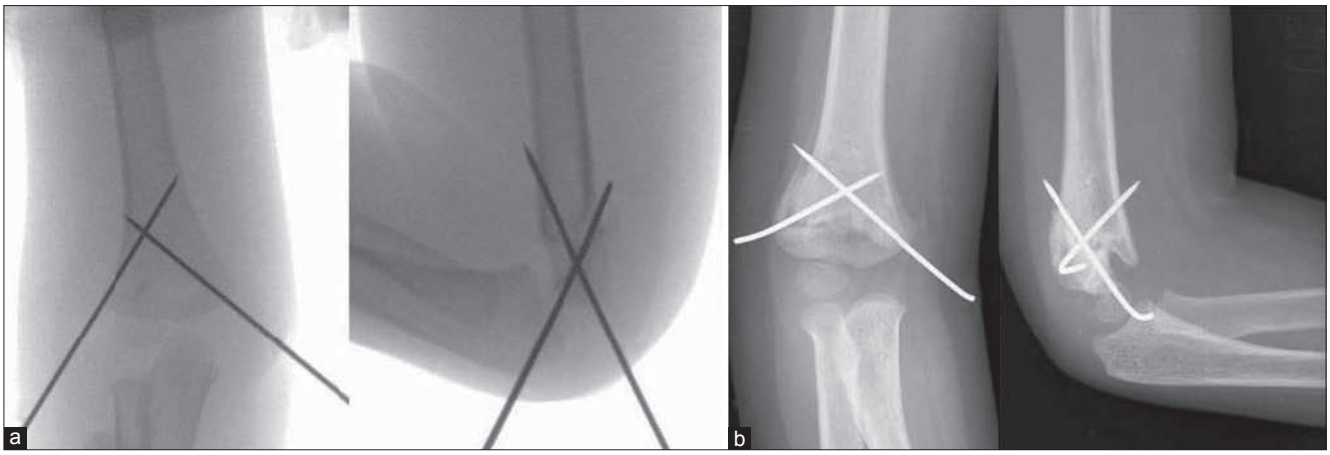

Figure 5: (a) Intraoperative anteroposterior and lateral images showing good reduction. The pins are crossing near the fracture site, providing poor hold. The anteroposterior distal to proximal pin does not have a satisfactory hold in the proximal fragment. (b) There is minor loss of reduction with malalignment and rotation at the fracture site

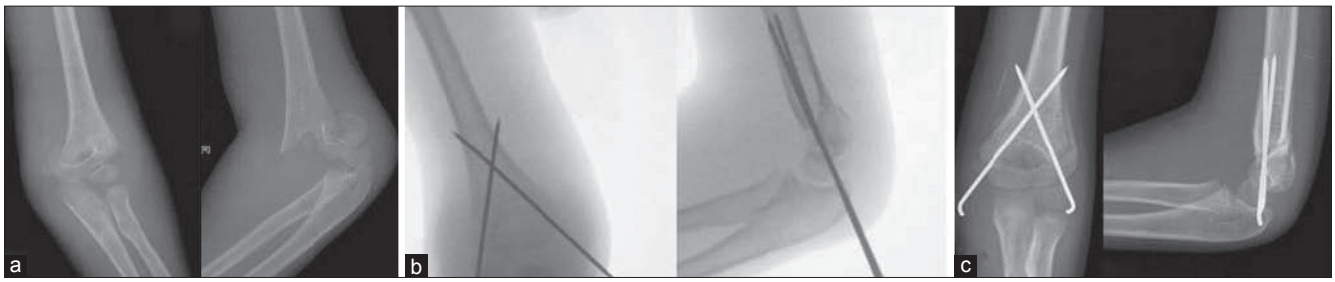

Figure 6: X-ray of elbow joint anteroposterior and lateral views showing (a) displaced supracondylar fracture humerus type III extension low transverse fracture pattern. (b) Cross pinning was done. The pins are crossing proximal to the fracture site with good reduction. (c) Maintenance of reduction and fixation at 4 weeks

earlier; 14 (38.9%) of these showed postoperative loss of reduction and all 41 cases who underwent technically sound pinning showed no loss of reduction. This was statistically significant ($P < 0.0001$). The technical errors in those who lost reduction in this study were no purchase in the distal fragment in five (two lateral and three medial) cases, no purchase in the proximal fragment cortex in two cases, and inadequate spread in seven cases.

An analysis was done to find out if the presence of the third pin influenced the postoperative loss of reduction. A total of 29 three pin constructs and 48 two pin constructs were found. Four cases in the former and 10 in the latter group showed a postoperative loss of reduction. The analysis was statistically insignificant ($P = 0.5495$).

Total number of cortical purchase by the pins used for fixation was classified as those with a) four cortical purchases or b) less than four cortical purchases. Sixty six cases had four and 11 cases had less than four cortical purchases of pins. Eleven cases in the former and three cases in the latter group had loss of reduction. The difference between these groups was not statistically significant ($P = 0.4099$).

Forty cases were done in the night (from 8 p.m. to 8 a.m.) and 37 cases in the day (from 8 a.m. to 8 p.m.). Seven in each group lost reduction which was not statistically significant ($P = 1.00$). Thus, the timing of the surgery did not affect the outcome.

The quality of initial reduction was assessed based on Baumann's angle and anterior humeral line. Anatomical reduction has been defined as anterior humeral line passing through middle of capitellum, restoration of Baumann angle, and intact medial and lateral column.[11] The acceptable reductions were those with minor degrees of malreduction in Baumann angle $\leq 6^{o}$ as per Skagg's criteria.[8] There were 33 cases with anatomical initial reduction, of which 19 had technically sound and 6 had technically poor fixation. Forty cases had acceptable initial reduction of which 19 had technically sound fixation and 16 had technically poor fixation. The quality of initial reduction did not affect the final result, provided the pinning was technically sound as shown by Fisher's exact *test* ($P = 0.342$).

Multivariate logistic regression analysis [Table 2] showed that lateral only pinning (Odds Ratio: 7.73; 95% Confidence Interval; 1.23–48.60; $P = 0.029$) and technical errors

(Odds Ratio: 57.63; 95% Confidence Interval 4.72–703.04; $P = 0.001$) were independently contributing to the postoperative loss of reduction. Gartland type, number of pins, fracture pattern, timing of surgery, quality of initial reduction, and number of cortical purchase were not significantly responsible for the postoperative loss of reduction.

Discussion

The loss of reduction after K wire fixation for supracondylar fracture surgery varies widely from 1.6 to 33.3%.[12] Our series had a 18.2% loss of reduction and the causes and prevention of this are the main focus of this study. Multiple factors such as the timing of the surgery, quality of reduction, pin configuration, and technique of pinning such as spread of the pins have been implicated in poor outcomes; adequate pin spread to two columns and specific configurations are suggested for oblique and high fractures.[3-6,13] Number of studies have emphasized the importance of stability which is influenced by the Gartland type, loss of periosteal hinge, and comminution.[8] Recently, unstable fracture patterns have been defined on the basis of the site and obliquity of the fracture.[4] These have been shown to have a high incidence of malunion, and specific pin configurations and greater monitoring are recommended.[4] In this study, we were unable to detect a significant postoperative reduction loss in these unstable patterns when comparing them with the typical transverse supracondylar fractures, indicating that other factors were responsible for loss of reduction. Multidirectionally unstable fracture has been defined recently where there is demonstrable flexion extension instability under fluoroscopy. Intraoperative instability under fluoroscopy of this type, however, was not documented in our patients.[8] We were also unable to find a significant difference in the loss of reduction in Gartland type 2 and type 3 fractures. This may be due to a very small number of Gartland type 2 fractures in the series or no real difference if the fixation provides adequate stability.

Table 2: Results of multivariate logistic regression analysis

Variable	Odds ratio	95% CI	*P* value
Number of pins (two vs. three)	2.28	0.44–11.71	0.323
Gartland types (type 2 vs. 3)	1.97	0.17–23.44	0.590
Stable vs. unstable fracture configuration	0.27	0.02–3.12	0.296
Timing of surgery: day vs. night	0.27	0.04–1.84	0.180
Number of cortical purchases (4 vs. <4)	1.21	0.18–8.38	0.843
Inadequate initial reduction vs. adequate reduction	0.28	0.05–1.51	0.138
Lateral entry Vs cross pinning	7.73	1.23 - 48.60	0.029
Technically error Vs good pinning	57.63	4.72-703.4	0.001

(*n* = 77; loss of reduction = 14; no loss of reduction = 63)

There was no difference in the loss of reduction with respect to the timing of surgery in our series. This report is in concurrence with many previous studies which found no difference in those cases treated immediately within 8 h of injury and those treated more than 8 h after the injury.[13-19] It is suggested that the surgeons may not be at their best during night due to inadequately trained supporting personnel and nonavailablity of adequate instruments in the night, so that an "optimal" condition for operating this fracture may not be available.[20] However, a child with grossly swollen, ecchymosed elbow or with neurovascular compromise should be operated at the earliest.[21] In our tertiary care center, round-the-clock availability of consultants and adequately staffed operating room personnel are probably the reasons that there was no significant difference noted in the loss of reduction in the groups operated in the day and in the night in this series. A systematic review and a prospective series had elucidated that the chances of converting to open reduction increased with delay in closed reduction and pinning.[22,23] Ramachandran *et al*. in an analysis of a retrospective case series concluded that delay in management of low energy supracondylar fracture humerus with gross swelling increased the risk of compartment syndrome.[24] The analysis, however, showed that in selected cases, delay in pinning a type III supracondylar fracture humerus did not adversely affect the outcome. The decision to delay can be made on a case-by-case basis after considering the logistic constraints like the capacity of the team and the urgency of the clinical situation. An important component of management of these fractures is an anatomical reduction.[25] Bloom *et al*. analyzed the effect of residual internal rotation after reduction in a biomechanical study on the stability of pin constructs.[25] The study concluded that stability of supracondylar fractures malreduced in internal rotation (within acceptable limits) was compromised and a third pin configuration was advocated to increase the construct stiffness. Analysis of our results concedes that even with acceptable malreduction, a technically sound pinning can avert a major loss of reduction.

A systematic review[12] has shown that cross pinning is superior to lateral entry pinning in maintaining reduction. Our findings concur with the above and show significantly higher odds of loss of reduction, 7.73 times when the patient has lateral entry pins only constructs. Biomechanical studies have shown that chances of rotational loss of reduction in lateral only constructs are high compared with cross pinning, indicating that cross pinning has greater torsional stability.[26,27] Additional medial comminution in the fracture increases the chance of varus collapse if the fracture is rotationally unstable after lateral only pinning.[11]

In spite of a very clear association between loss of reduction and lateral entry pinning with two or three pins, one of the

arguments for using a lateral pin construct is a documented higher incidence of ulnar nerve injury when a medial pin is used.[28] Proponents of cross pinning suggest that the injury to ulnar nerve can be avoided by a small medial incision and keeping the elbow extended during the pinning.[6] On the other hand, even lateral pin insertion is not without risks, and a recent meta-analysis[29] has shown that the lateral entry pin fixation carries the risk of median nerve injury, indicating that lateral entry pin is not free of nerve injury. This meta-analysis has shown that both lateral and medial entry pin has risk of neuropraxia at a weighted event rate of 3.4% and 4.1%, respectively. A 2% incidence of transient ulnar nerve paresis was recorded in the cross pinning cases (1/49) in our series, consistent with the published results. We also take care to make a small medial incision to avoid this injury.

Zenios *et al*.[30] have expressed technical difficulty in achieving adequate pin placement in lateral entry pin. To get an adequate pin spread and separation at fracture site and at the same time engage both the columns in a very low fracture makes it in principle a demanding procedure. There have been at least two series which have suggested doing a test of stability after lateral pin fixation and, if unstable, an additional third pin is added either on the lateral or medial side.[3,30] This again suggests that it is accepted by these authors that the lateral only pin constructs are susceptible to rotational instability. Screening of the elbow in lateral view in internal and external rotation after fixation is recommended to assess the stability intraoperatively. Such a screening test is now part of the protocol after fixation of supracondylar fractures in our center and has helped substantially to identify instability often due to faulty pin fixation and bring down the loss of reduction for these cases currently in our center.

Analysis of our data established the faulty implant placement as the major cause for loss of reduction. All 14 of our patients who lost reduction had at least one contributing technical error. The errors were equally divided between insufficient purchase by the pins in either the proximal or the distal fragment and a convergence of pins in the far cortex in the lateral only entry technique. A fracture treated with technical errors had a 57.63 times higher odds of losing reduction in our series. The most common error in low transverse fracture pattern was poor purchase of one of the pins in either the proximal or the distal fragment, resulting in rotational instability in the postoperative period. The additional analysis looking at total number of cortical holds of the pins and quality of initial reduction did not reach significance in our study. This could be due to the fact that while four cortical holds can be obtained with three pins, there still exists the possibility of having two pins with inadequate purchase in either of the fragments, resulting in an inadequate fixation. Our interpretation from this is that it is better to remove a pin which is not technically correct and resite it rather than adding a third pin. If a technically sound pinning is done, then an acceptable reduction which may not be anatomical can go on to union without further loss of reduction. Additional pin (third pin) analysis also showed no significant benefit, thus supporting our contention. The second common error was the convergence of lateral entry pins. This is biomechanically inferior as it creates a single hold in the proximal fragment and is thus responsible for loss of reduction. Technical errors have been found contributory to loss of reduction in other series as well.[5,6,9,11] Sankar *et al*. found three technical errors similar to those seen in our series.[6] It is likely that some of the errors in pin placements are induced by imperfect reduction.[3,9]

The limitation of this study is that this being a retrospective study, the documentation of the reasons such as instability for choosing a particular kind of pin fixation or the results of test of stability if carried out was not always available. This would have given an insight into other types of instability such as those due to soft tissue disruption which are only recognized intraoperatively and may not be recorded. This study also does not correlate the loss of reduction with clinical deformity. Most children are discharged from the clinic once they regain function and the long term follow up is not available to see the clinical effects on rotational and varus deformity. We would suggest that the role of instability and pin configuration in supracondylar fracture fixation be further validated by a prospective randomized trial.

Our observations suggest that the loss of reduction following fracture fixation is closely related to technical errors which result in inadequate purchase of the fragments by the pins or errors due to inadequate spread in lateral pinning. Cross pinning was found to be superior to an all lateral pin configuration. While the intraoperative understanding of the fracture pattern may help in achieving good fixation, factors such as the unstable fracture patterns, quality of initial reduction, and timing of surgery were not a cause for loss of reduction in our experience.

Acknowledgments

We sincerely acknowledge Dr. Rajiv Sarkar (BVSC, MSC Epidemiology) for doing the statistical analysis for this paper.

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How to cite this article: Balakumar B, Madhuri V. A retrospective analysis of loss of reduction in operated supracondylar humerus fractures. Indian J Orthop 2012;46:690-7.

Source of Support: Nil, **Conflict of Interest:** None.