Loss of Pin Fixation in Displaced Supracondylar Humeral Fractures in Children: Causes and Prevention

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Background: Although the results are generally good following pin fixation of supracondylar humeral fractures in children, occasionally there is postoperative displacement. The purposes of the present study were to identify the causes leading to loss of fixation after pin fixation and to present methods for prevention.

Methods: We evaluated 322 displaced supracondylar humeral fractures that had been treated with percutaneous pin fixation. We examined fracture classification, pin configuration, intraoperative alignment after fixation, change in alignment after fixation, details of additional procedures, and final radiographic and clinical outcomes.

Results: Adequate radiographs were available for 279 of the 322 fractures. Eight (2.9%) of the 279 fractures were associated with postoperative loss of fixation; all eight were Gartland type-III fractures. Seven of these eight fractures initially had been treated with two lateral-entry pins, and one had been treated with two crossed pins. In patients with Gartland type-III fractures, loss of fixation was successfully avoided more often when three pins were used (with fixation being maintained in thirty-seven of thirty-seven patients) as opposed to when two lateral-entry pins were used (with fixation being maintained in thirty-five of forty-two patients) ($p = 0.01$). In all cases, loss of fixation was due to technical errors that were identifiable on the intraoperative fluoroscopic images and that could have been prevented with proper technique. We identified three types of pin-fixation errors: (1) failure to engage both fragments with two pins or more, (2) failure to achieve bicortical fixation with two pins or more, and (3) failure to achieve adequate pin separation (>2 mm) at the fracture site.

Conclusions: Postoperative displacement following pin fixation of supracondylar humeral fractures in children is uncommon. In the present series, loss of fixation was most likely to occur when Gartland type-III fractures were treated with two lateral-entry pins. There were no failures when three pins were used. In all cases of failure, there were identifiable technical errors in pin placement.

Level of Evidence: Therapeutic Level III. See Instructions to Authors for a complete description of levels of evidence.

With routine pin fixation of supracondylar humeral fractures in children, the surgeon may encounter loss of fixation when either crossed pins or lateral-entry pins are used[1]. The present study was designed to examine the frequency, causes, and treatment of loss of fixation after percutaneous pin fixation of supracondylar humeral fractures in children.

Materials and Methods

Institutional review board approval was obtained prior to the initiation of the study, and retrospective data were collected for all patients. We evaluated the radiographic and clinical data on 322 consecutive children with displaced supracondylar humeral fractures who were managed with closed reduction and percutaneous pin fixation by one of six attending pediatric or-

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TABLE I Pin Configuration*

Fracture Type	Pin Configuration				Total
	2 Crossed Pins	2 Lateral-Entry Pins	3 Lateral-Entry Pins	2 Lateral-Entry Pins and 1 Medial-Entry Pin	
Gartland type-II	47	54	3	13	117
Gartland type-III	83	42	9	28	162
Total	130	96	12	41	279

*The values are given as the number of elbows.

thopaedic surgeons (including one of the authors [J.M.F.]) at one tertiary pediatric center between January 1996 and May 2002. Forty-three patients were excluded from the study because adequate postoperative radiographs were not available, leaving 279 children available for review.

The age and gender of the patient; the date of surgery; the name of the attending surgeon; the number, entry site, and configuration of the pins; the modified Gartland classification[2]; the preoperative and postoperative radiographic fracture position; the occurrence of postoperative loss of reduction and other complications; and notes on additional procedures were recorded. The medical records were reviewed for all patients who underwent additional procedures, had loss of fracture reduction, or had postoperative complications.

Three of the authors (W.N.S., N.M.H., and J.M.F.) reviewed all of the radiographs in the study. Maintenance of fracture reduction was assessed by comparing intraoperative fluoroscopic images with postoperative radiographs from the first clinic visit. Three radiographic parameters were used to evaluate postoperative displacement: the relationship of the capitellum to the anterior humeral line, the Baumann angle, and the lateral rotational percentage[3]. In all cases, the final designation of lost fixation was determined clinicall.y by the treating attending surgeon.

Surgical Technique

The participating surgeons used standard patient positioning, fracture manipulation, and reduction techniques as detailed in prior studies[3,4]. The pin configuration used to stabilize the fracture was based on surgeon preference.

When lateral-entry pins alone were used, the pins were placed either parallel to or divergent from one another[4]. When crossed pins were used, the medial-entry pin was placed with the elbow held in extension to minimize anterior subluxation of the ulnar nerve[5]. Most of the surgeons contributing these cases routinely make a 5-mm incision over the medial epicondyle to minimize the risk of ulnar nerve injury.

A long arm cast or splint was applied in the operating room. The patient was seen one week after surgery, at which time anteroposterior and lateral radiographs of the elbow were made. Patients were then seen three weeks after surgery, when the cast or splint and the pins were removed. Repeat radiographs were also made. If the fracture appeared to be healing, motion was encouraged and the patient returned six weeks after surgery for the final follow-up appointment. The success of different fixation strategies (two pins as compared with three pins) for the treatment of type-III fractures was analyzed with use of the Fisher exact test.

Results

The 279 displaced supracondylar humeral fractures in this study included 117 Gartland type-II fractures and 162 Gartland type-III fractures. One hundred and thirty fractures were treated with two crossed pins, ninety-six were treated

TABLE II Fractures with Failed Fixation

Case	Initial Pin Configuration	Technical Error (Error Type)	Treatment	Outcome
1	2 lateral-entry pins	1 pin in distal fragment (A)	Revision	Good
2	2 lateral-entry pins	1 pin in distal fragment (A)	Observation	Cubitus varus
3	2 lateral-entry pins	1 pin in distal fragment (A)	Revision	Good
4	2 lateral-entry pins	No bicortical purchase (B)	Revision	Good
5	2 lateral-entry pins	Inadequate pin separation at fracture site (C)	Examination with patient under anesthesia	Good
6	2 lateral-entry pins	Inadequate pin separation at fracture site (C)	Examination with patient under anesthesia	Good
7	2 lateral-entry pins	1 pin in distal fragment (A)	Revision	Good
8	2 crossed pins	Inadequate pin separation at fracture site (C)	Observation	Good

with two lateral-entry pins, twelve were treated with three lateral-entry pins, and forty-one were treated with two lateral-entry pins and one medial-entry pin (Table I). The average age of the children was 5.8 years (range, 1.1 to 13.6 years).

Of the 279 patients, 271 had uneventful clinical and radiographic healing following percutaneous pin fixation of the displaced supracondylar humeral fracture. Eight patients (2.9%) had postoperative loss of fixation and displacement of the fracture between the time that the intraoperative fluoroscopic images were made and the time that radiographs were made during the first postoperative visit (Table II). The mean age of the children with loss of fixation was 5.7 years (range, 2.4 to 9.4 years). All eight failures occurred in association with Gartland type-III fractures; no failures occurred in association with Gartland type-II fractures. Seven of these eight fractures initially had been treated with two lateral-entry pins. No patient who had been managed with three pins (either three lateral-entry pins or two lateral-entry pins and one medial-entry pin) had loss of fixation. In patients with Gartland type-III fractures, loss of fixation was successfully avoided significantly more often in association with the use of three pins (with fixation being maintained in thirty-seven of thirty-seven patients) as opposed to two lateral-entry pins (with fixation being maintained in thirty-five of forty-two patients) ($p = 0.01$).

Four of the patients who had a failure underwent revision pin fixation. Two additional patients underwent an examination under anesthesia. In spite of the displacement that was noted at the time of the first follow-up visit, the fractures in these two patients were deemed stable enough to be treated with a long arm cast. The remaining two patients were observed following the loss of fixation. Seven of the eight patients with a failure went on to have radiographic and clinical healing with full range of motion and normal alignment. One of the two patients who was observed after the loss of fixation had development of a cubitus varus deformity with a Baumann angle of 80°. This malunion produced a cosmetic deformity only, without impairment of function.

In each of the eight cases of failure, we were able to identify a technical error that led to loss of fixation. In the cases of four patients, the proximal fragment was only transfixed by one pin. Another patient did not have bicortical fixation with one of the two pins. The other three patients did not have adequate separation of the pins at the fracture site (>2 mm), effectively resulting in single-pin fixation.

Discussion

Retrospective and prospective clinical studies have established the effectiveness of lateral-entry pin fixation alone for the treatment of supracondylar fractures of the humerus in children[1,3,4,6-8]. Those studies have confirmed that lateral-entry pin fixation provides adequate fracture stabilization while avoiding the risk of ulnar nerve injury[9]. Surgeons who choose to use crossed pins must be aware that the ulnar nerve is at risk[10]. Surgeons who choose to use lateral-entry pins alone must be aware that adequate stabilization, while equally effective, requires attention to detail[11].

Fig. 1

Postoperative anteroposterior radiograph showing one pin in the fracture site and loss of fixation (a type-A error).

Fig. 2

Postoperative anteroposterior radiograph demonstrating that one pin has failed to achieve bicortical purchase (a type-B error).

Skaggs et al., in a recent study of supracondylar humeral fractures that were treated with lateral-entry pins alone, reported that 38% of Gartland type-II fractures and 65% of type-III fractures were fixed with three lateral-entry pins[4]. As part of their secondary results, the authors discussed eight fractures that had loss of fixation following the use of two pins; no fracture had loss of fixation following the use of three

Fig. 3

Postoperative lateral radiograph showing loss of fixation due to pins that have inadequate separation at the fracture site (type-C error).

pins. As in the present study, a technical error in pin placement was identified in the case of each failure. That case series, however, was identified from an informal survey of the Pediatric Orthopaedic Society of North America (POSNA) as well as a review of the literature, rather than from the retrospective follow-up of the primary surgeons, as we have detailed here.

In the present study, the vast majority of supracondylar humeral fractures in children healed uneventfully after percutaneous pin fixation, and loss of fixation was uncommon, occurring in only 2.9% of our patients. Seven of the eight fractures that had loss of fixation initially had been treated with two lateral-entry pins, resulting in a 7.3% failure rate among all fractures that had been treated with two lateral-entry pins. Of the forty-two Gartland type-III fractures that had been treated with two lateral-entry pins, seven (16.7%) had loss of fixation. No fractures that had been treated with three pins had loss of fixation. These data support the previous suggestion that lateral-entry pin fixation may be more technically demanding than crossed pin fixation[11]. At our pediatric trauma center, we have now adopted a protocol in which Gartland type-II fractures are treated with two lateral-entry pins whereas Gartland type-III fractures are treated with three lateral-entry pins.

In all instances, loss of fixation was due to a technical error associated with pin placement at the time of the initial procedure. All of these fixation errors were identifiable from a review of the radiographs and were classified as type A, B, or C. A type-A error was defined as the failure to engage both fragments by two pins or more. Typically, one pin was placed too anteriorly, missing the distal fragment, or one pin was placed in the fracture site (Fig. 1). A type-B error was defined as the failure to achieve bicortical fixation with two pins or more (Fig. 2). A type-C error was defined as inadequate pin spread to control rotation (Fig. 3). Successful fixation requires the avoidance of type-A, B, and C errors (Fig. 4).

We stress the importance of assessing intraoperative stability after percutaneous pin fixation by first extending the elbow and examining the distal fragment for displacement. If the alignment remains satisfactory, gentle rotation and varus and valgus stress is performed, and fracture stability is checked under fluoroscopy. If the fracture fragments remain in anatomic alignment and their relative positions have not changed, then satisfactory fixation is confirmed. However, if there appears to be a change in fracture alignment, repositioning of one or two of the lateral pins and/or the addition of a third lateral pin is warranted. Fixation should then again be tested for stability. This technique of intraoperative stress-testing evolved over the course of the study period. As this was a retrospective series, we were not able to identify which cases were tested intraoperatively, nor can we comment as to how this would have affected the outcome of specific cases in this series.

On the basis of this retrospective study, the functional importance of loss of fixation was limited. Seven of eight patients who had a failure of fixation went on to have radiographic and clinical healing with a full range of motion and normal alignment, and only one patient had development of a cubitus varus deformity; however, this was only a cosmetic deformity, and it did not require corrective osteotomy. A short-

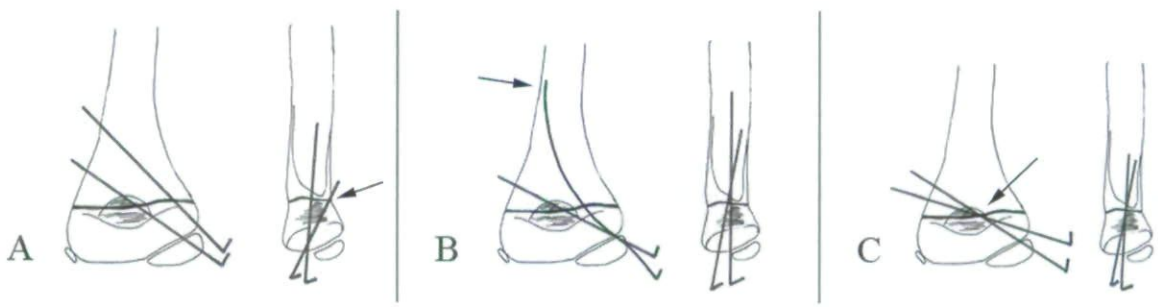

Fig. 4

Illustrations depicting type-A, B, and C errors in pin-fixation technique. *A:* The black arrow demonstrates the anterior pin failing to transfix the proximal bone. *B:* The black arrow demonstrates one pin without bicortical purchase. *C:* The black arrow demonstrates pins too close together at the fracture site.

coming of the present retrospective study, however, is that it may underestimate the true functional impact of loss of fixation because of the limited long-term patient follow-up.

While postoperative loss of fixation following pin fixation of displaced supracondylar humeral fractures in children is uncommon, it can and does occur. In our series, loss of fixation was most likely to occur when a Gartland type-III fracture was treated with two lateral-entry pins. There were no failures when three pins were used. All eight failures were due to identifiable technical errors in pin placement. We have adopted a protocol of using three lateral-entry pins for type-III fractures and two lateral-entry pins for type-II fractures. Regardless of pin-fixation technique, we believe that testing fracture stability intraoperatively under fluoroscopy is an invaluable way to determine the quality of fixation. ■

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