Lateral-Entry Pin Fixation in the Management of Supracondylar Fractures in Children

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Lateral-Entry Pin Fixation in the Management of Supracondylar Fractures in Children

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Background: There has been controversy regarding the optimal pin configuration in the management of supracondylar humeral fractures in children. A crossed-pin configuration may be mechanically more stable than lateral pins in torsional loading, but it is associated with a risk of iatrogenic injury to the ulnar nerve. Previous clinical studies have suggested that lateral pins provide sufficient fixation of unstable supracondylar fractures. However, these studies were retrospective and subject to patient-selection bias.

Methods: A displaced supracondylar humeral fracture was fixed with only lateral-entry pins in 124 consecutively managed children. Medical records and radiographs were reviewed to identify any complications, including loss of fracture reduction, iatrogenic ulnar nerve injury, infection, loss of motion of the elbow, and the need for additional surgery. In addition, eight displaced supracondylar humeral fractures that had been reduced and fixed with lateral pins at other institutions and had lost reduction were analyzed to determine the causes of the failures.

Results: Sixty-nine children had a type-2 fracture, according to Wilkins's modification of Gartland's classification system; forty-three (62%) of those fractures were stabilized with two pins and twenty-six (38%), with three pins. Fifty-five children had a type-3 fracture; nineteen (35%) of those fractures were stabilized with two pins and thirty-six (65%), with three pins. A comparison of perioperative and final radiographs showed no loss of reduction of any fracture. There was also no clinically evident cubitus varus, hyperextension, or loss of motion. There were no iatrogenic nerve palsies, and no patient required additional surgery. One patient had a pin-track infection. Our analysis of the eight clinical and radiographic failures of lateral pin fixation that were not part of the consecutive series showed that the loss of fixation was due to fundamental technical errors.

Conclusions: In this large, consecutive series without selection bias, the use of lateral-entry pins alone was effective for even the most unstable supracondylar humeral fractures. There were no iatrogenic ulnar nerve injuries, and no reduction was lost. The important technical points for fixation with lateral-entry pins are (1) maximize separation of the pins at the fracture site, (2) engage the medial and lateral columns proximal to the fracture, (3) engage sufficient bone in both the proximal segment and the distal fragment, and (4) maintain a low threshold for use of a third lateral-entry pin if there is concern about fracture stability or the location of the first two pins.

Level of Evidence: Therapeutic study, Level IV (case series [no, or historical, control group]). See Instructions to Authors for a complete description of levels of evidence.

The best pin configuration for the stabilization of supracondylar humeral fractures following satisfactory reduction in children is controversial. Iatrogenic injury to the ulnar nerve is a well-known complication of insertion of a medial pin through the medial epicondyle, with reported prevalences of 5% (seventeen of 345 fractures) and 6% (nineteen of 331 fractures) in two large series[1,2]. Injury to the ulnar nerve has been reported to be due more often to the pin constricting the cubital tunnel than to direct penetration of the nerve[3]. While these nerve injuries usually resolve within a year, persistent ulnar nerve palsy has been reported[1,3]. Authors of retrospective clinical studies have concluded that insertion of pins through the lateral condyle alone, which avoids injury to the ulnar nerve, is as clinically effective as insertion of crossed pins through the medial epicondyle and the lateral condyle for stabilization of supracondylar humeral fractures[1,4,5]. Unfortunately, those retrospective studies were subject to selection bias, with the treating surgeon choosing lateral pins only for the most stable fractures.

We prefer the term "lateral-entry pins," as described by Waters[6], to "lateral pins" because properly placed pins should not engage the lateral column only; rather, they should be separated maximally at the fracture site and engage the medial column proximal to the fracture site. The primary purpose of this study was to assess the efficacy of lateral-entry pins in the operative management of displaced supracondylar humeral fractures in a consecutive series of children in which lateral-entry pins were used regardless of fracture stability, eliminating the possibility of selection bias. Our secondary purpose was to help establish guidelines for placement of lateral-entry pins by identifying technical errors of pin placement in patients in whom the fixation failed.

Materials and Methods

We evaluated the medical records and radiographs of all children in whom a displaced extension-type supracondylar humeral fracture had been treated by two attending pediatric orthopaedic surgeons at one children's hospital over the four-year period of August 1996 through September 2000. Complete medical records and true anteroposterior radiographs of the distal part of the humerus and lateral radiographs of the elbow made perioperatively as well as at the time of fracture-healing were available for 124 patients. The data recorded included the age of the patient, the nature of the injury (open or closed), the preoperative and postoperative neurovascular status, the type of reduction (open or closed), the number of lateral pins, the duration of follow-up, complications, and the management of the complications. Wilkins's modification of the Gartland classification for supracondylar humeral fractures was used[7]. In this classification, a type-I fracture is not displaced. A type-II fracture is extended but not translated, with the posterior cortex intact and the capitellum posterior to its normal intersection with the anterior humeral line. A type-III fracture is displaced with none of the cortex intact. The variability of this classification system has been well described and compares favorably with that of other fracture classification systems[8]. The time interval between the surgery and pin removal, any postoperative loss of fracture reduction, and the need for a second surgical procedure were also documented. The range of motion of the elbow was assessed clinically at approximately six weeks after pin removal.

Maintenance of fracture reduction was assessed by comparing perioperative radiographs with radiographs made at the time of fracture union. The Baumann angle was compared between these radiographs to assess maintenance of reduction in the coronal plane. The Baumann angle is formed between the physeal line of the lateral condyle and a line perpendicular to the long axis of the humerus. This angle can be used to detect varus angulation of the distal part of the humerus, and a normal angle is in the range of 9° to 26°. The difference, if any, between the measurement made perioperatively and that made at the time of fracture union was recorded. As the Baumann angle has been shown to vary 6° for every 10° of humeral rotation[9] on the anteroposterior radiograph, we empirically chose a difference of 12° between the perioperative and final Baumann angles to represent a meaningful change; this allowed for minor variations in arm positioning during the radiographic evaluation as well as measurement variability. On a lateral radiograph of a normal elbow, a line along the anterior aspect of the humerus should intersect the ossification center of the capitellum, and this was the criterion that was used to confirm fracture reduction in the sagittal plane. A change in this relationship between the perioperative radiographs and those made at the time of fracture-healing indicated a loss of reduction.

The Student t test was used to determine the significance of any changes in the Baumann angle.

In addition, eight supracondylar fractures that had been treated with lateral-entry pins alone and had subsequently lost fixation were identified from an informal survey of members of the Pediatric Orthopaedic Society of North America (POSNA) as well as from a literature review. Only cases for which adequate radiographic documentation could be obtained were included in this part of the study. Radiographs were evaluated to determine if technical factors associated with loss of reduction could be identified.

Surgical Technique

The patient is positioned supine, and the fracture is reduced by manipulation. If satisfactory alignment cannot be achieved, open reduction is necessary. The elbow can be held in the flexed position with a sterile elastic bandage to maintain fracture reduction and free the surgeon's hands. Two 0.062-in (0.157-cm) Kirschner wires or two 2.0-mm Steinmann pins are inserted from the lateral condyle across the fracture site with the goal of achieving maximum separation of the pins at the fracture site. The pin size is subjectively chosen by the surgeon on the basis of the patient's age and size. One pin is directed up the lateral column, and a second pin is directed toward the medial column. Both pins must penetrate the opposite proximal cortex. Placement of a pin across the olecranon fossa is acceptable and may add two more cortices of fixation. Attention is paid to ensure that adequate bone fixation is achieved in the proximal-medial segment (metaphysis) and the lateral-distal fracture fragment. In the sagittal plane, a slight anterior-to-posterior entry is attempted as the capitellum is anterior to the center of the humerus (Figs. 1-A, 1-B, and 1-C).

Varus and valgus stress as well as flexion and extension stress are gently applied to the fracture to evaluate stability under fluoroscopy. If an open reduction is performed, fracture stability can be assessed by direct visualization. If there is any concern about the fracture stability or whether the pin placement is optimal, a third pin is placed from the lateral side as well. The surgeon may also subjectively decide to use a third

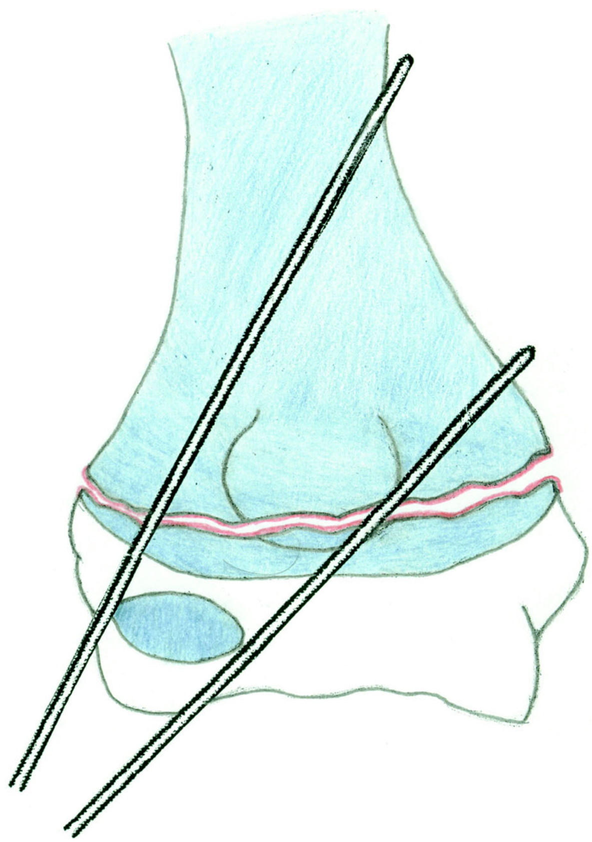

Fig. 1-A

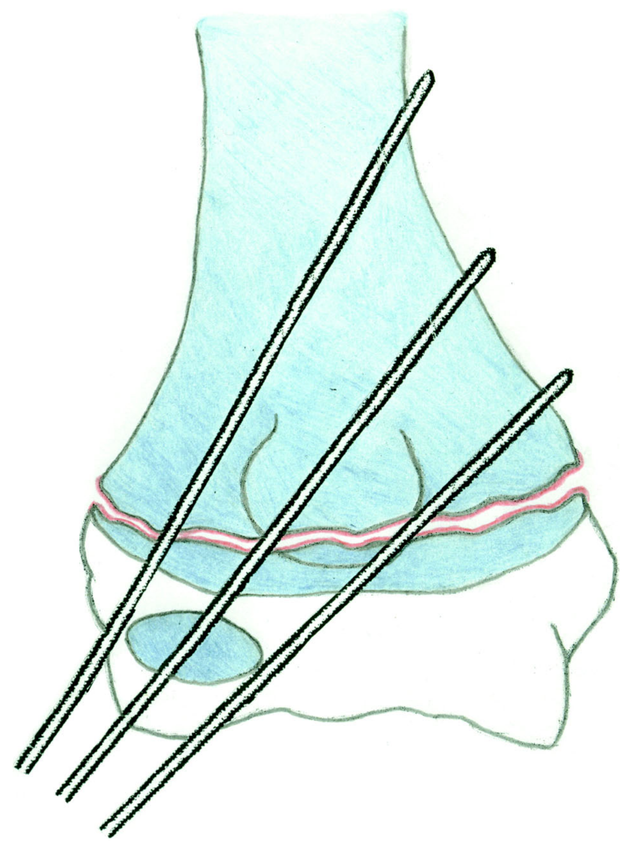

Fig. 1-B

Figs. 1-A, 1-B, and 1-C Correct positioning of lateral-entry pins. **Fig. 1-A** In the anteroposterior plane, the pins should be maximally separated at the fracture site, should engage the medial and lateral columns just proximal to the fracture site, and should engage an adequate amount of bone in both the proximal and the distal fragment. **Fig. 1-B** Positioning when three pins are used.

pin prior to stress-testing in a large, older patient or if the fracture appears markedly unstable preoperatively.

Results

There were sixty-nine type-2 fractures and fifty-five type-3 fractures, according to Wilkins's modification of Gartland's classification[7]. Lateral-entry pins alone were used for all fractures. Forty-three (62%) of the type-2 fractures were stabilized with two pins and twenty-six (38%), with three pins. Nineteen (35%) of the type-3 fractures were stabilized with two pins and thirty-six (65%), with three pins. There were sixty-five boys and fifty-nine girls. The mean age of the patients was four years (range, eight months to fourteen years).

One fracture was open at the time of the injury. Two fractures could not be reduced and required an open reduction. The remaining 121 fractures were treated with closed reduction and percutaneous pinning. There were twelve preoperative nerve palsies: four (3%) involving the anterior interosseous nerve, three (2%) involving the radial nerve, three involving the ulnar nerve, and two (2%) involving the median nerve. Six of those nerve injuries resolved immediately after the surgery, and the other six resolved within ten weeks after the injury. There were no iatrogenic nerve injuries.

The radial pulse was monitored preoperatively and postoperatively. One hundred and seventeen patients had a palpable radial pulse before surgery, and seven did not. The pulse was identified with Doppler ultrasound in five patients, and a pulse could not be detected in two. Following reduction and pinning of the fracture, five patients continued to have a diminished radial pulse, and three of them had additional intervention. Two of the three patients required exploration of the brachial artery and vascular repair, and the third patient was found to have an intact arterial blood flow on an arteriogram and had no further intervention. There were no iatrogenic vascular injuries. All preoperative vascular injuries occurred in association with type-3 fractures. One child presented with a pin-track infection seven days after surgery. The child was treated with antibiotics while the pins were in situ. The pins were removed at fourteen days following surgery, and the infection resolved. Cast immobilization was continued for one additional week.

The pins were routinely removed three weeks following surgery, and the patients were routinely evaluated approximately six weeks following pin removal. All patients were followed for a minimum of nine weeks after surgery. No patient had a clinically evident cubitus varus deformity, elbow hyper-

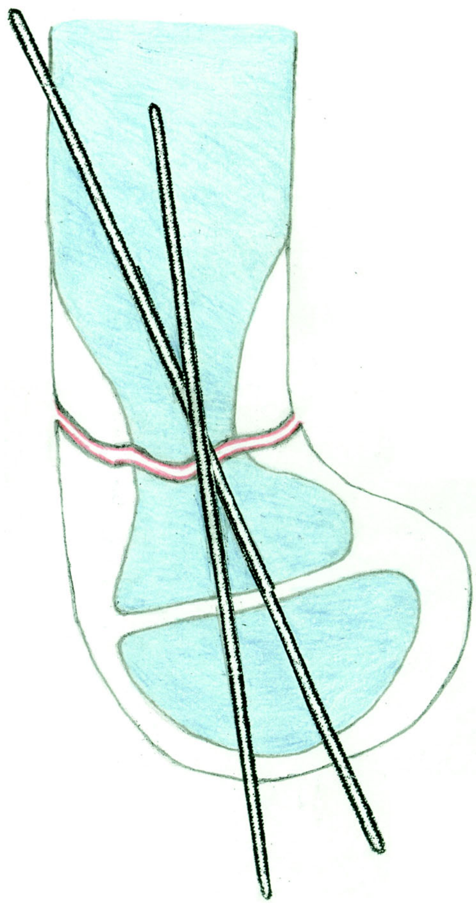

Fig. 1-C
In the lateral plane, the pins should incline slightly in an anterior-to-posterior direction in accordance with normal anatomy.

extension, or loss of motion at the time of the last clinical visit. No patient underwent additional surgery related to the supracondylar fracture.

The Baumann angle on the intraoperative or immediate postoperative anteroposterior radiograph was compared with the angle on the radiograph made at the time of fracture union, at approximately three weeks. The mean Baumann angle (and standard deviation) was 17.7° ± 5.1° (range, 16.7° to 18.5°) immediately after surgery and 17.6° ± 4.9° (range, 16.6° to 18.4°) at the time of union. The mean difference was 0.05° ± 0.2° ($p = 0.878$). There was no significant difference between the type-2 and type-3 fractures with regard to the Baumann angle at the time of union. The mean Baumann angle measured immediately postoperatively was 17.4° ± 5.1° (range, 16.2° to 18.7°) in the patients with a type-2 fracture and 17.9° ± 5.2° (range, 16.5° to 19.4°) in those with a type-3 fracture ($p = 0.876$). The mean Baumann angle at the time of union was 17.4° ± 4.9° (range, 16.1° to 18.5°) in the patients with a type-2 fracture and 17.8° ± 5.0° (range, 16.4° to 19.2°) in those with a type-3 fracture ($p = 0.893$). The greatest difference between the perioperative and final Baumann angles was 7°, which was deemed to be not relevant because of the effect that elbow rotation can have on the Baumann angle. No child had clinical or radiographic evidence of cubitus varus at the follow-up examination.

The reduction of the fracture in the sagittal plane was not affected by the patient's age, the fracture type, or the number of pins used to stabilize the reduction. Comparison of the perioperative and final radiographs showed that no patient had a change in the position of the capitellum relative to the anterior humeral line. No child had elbow hyperextension at the follow-up examination.

Our review of the radiographs of the eight supracondylar humeral fractures with loss of reduction after treatment with lateral-entry pins identified technical points of pin placement that may be associated with loss of fracture reduction. Two lateral pins had been used for all eight fractures. In five, the pins were too close together and engaged only the lateral column at the level of the fracture site (Fig. 2). In each of these cases, fracture reduction was lost when the distal fragment rotated around the two pins. In another case, the two lateral pins crossed at the fracture site (Fig. 3). In the remaining two cases, the two lateral pins did not engage the distal fragment. We did not find any cases in which fracture fixation was lost after use of three lateral-entry pins.

Discussion

Closed reduction and percutaneous pin fixation for the management of supracondylar humeral fractures in children has gained wide popularity, but the optimal pin configuration remains controversial[10-13]. Several authors of retrospective clinical studies have recommended lateral pin fixation of these fractures[1,5,14]. The authors of the largest study[1], of 345 patients, concluded that fixation of both type-2[7] and type-3[7] supracondylar humeral fractures in children with only lateral pins provides adequate fixation while avoiding iatrogenic injury to the ulnar nerve. A weakness of that study was that 75% (118) of the 157 type-3 fractures were fixed with a cross-pin (medial and lateral-entry) technique, which introduced a possible selection bias (performance of lateral pinning in only the most stable type-3 fractures).

In the present study, all fractures, regardless of the degree of instability, were treated successfully with lateral-entry pins alone. Postoperatively, the largest change in the Baumann angle was only 7°. This compares favorably with changes in the Baumann angle following cross-pinning, reported to be a mean of 6.4° for type-2 and type-3 fractures in one series[5] and 5° for type-3 fractures in another series[15].

We were much more likely to use three lateral-entry pins for type-3 fractures (used for 65% [thirty-six] of fifty-five fractures) than we were for type-2 fractures (used for 38% [twenty-six] of sixty-nine fractures), and we recommend employing three lateral-entry pins if there is any concern about fracture stability or pin position after the first two pins have been placed.

Prior to pin placement, the surgeon may use subjective criteria in the decision whether to use three lateral-entry pins. Such criteria may include a severe type-3 fracture, a large pa-

Fig. 2
This fracture lost reduction because the distal fragment rotated around two pins that were so close together they functioned biomechanically as one.

tient, and/or an older patient. Instability on stress testing would be an absolute indication for placement of a third lateral pin.

A recent biomechanical study demonstrated that two divergent lateral-entry pins offer more stability in extension loading than do two crossed pins[16]. The same study also showed that two divergent lateral-entry pins provide greater stability in varus and valgus loading than do two parallel lateral-entry pins. In that study, the parallel pins were close to each other and engaged only the lateral column, in contrast to the divergent pins, which were more widely separated at the fracture site and engaged both the medial and the lateral column. On the basis of these results and our clinical experience, we believe that the most important factor for biomechanical stability is maximal separation of the pins at the fracture site; we think that whether the pins happen to be parallel or divergent is less important. It has been shown that crossed pins do provide more torsional stability than do two lateral pins[16,17] but do not offer significantly more torsional stability than do three lateral pins[17]. A careful review of the study by Zionts et al.[17] reveals that all of the lateral pins in the lateral pin configurations that were tested were limited to the lateral column, with little separation between the pins. Thus, Zionts et al. did not evaluate the lateral pin configuration that we assessed in our study. In addition, although the aforementioned studies provide insight into the inherent stability of certain pin configurations, the ability to apply their findings to the clinical setting is limited because the studies were performed on Sawbones and/or cadaveric specimens without soft-tissue attachments and the impact of postoperative immobilization was not assessed.

There have been reports of clinical failures of lateral pins[15,18,19]. Kallio et al. found loss of fixation in eleven (14%) of eighty patients in whom only two lateral pins had been used[18]. The authors reported that the loss of fixation was always the result of poor initial reduction or inadequate pin placement. Their analysis of the failures revealed several technical errors in pin placement, including failure to engage the pins in the

Fig. 3
Anteroposterior radiograph demonstrating pins crossing near the fracture site and perhaps not engaging adequate bone in the proximal fragment. This fracture healed in a malreduced, varus position.

proximal segment in six patients, failure to fix the distal fragment properly in two patients, and an inadequate separation or size of the pins in the remaining three patients[18].

Our analysis of the eight fractures with loss of reduction led us to draw the same conclusion as Kallio et al.—that is, all failures were associated with a technical error in pin placement. In addition, only two lateral-entry pins were used in all of the procedures that failed. This suggests that perhaps three lateral-entry pins should be used more frequently. The opinion that fixation with lateral-entry pins is technically more difficult than cross-pinning has been expressed, but we do not believe that the technical demands are prohibitive.

The analysis of the fractures with loss of reduction revealed several apparently important technical points for effective fixation with lateral-entry pins. One should aim to maximize pin separation at the fracture site and engage the medial and lateral columns proximal to the fracture. Pins should engage sufficient bone in both the proximal and the distal segment, with the surgeon paying particular attention to the distal-lateral bone and the proximal-medial bone as sites that are prone to inadequate fixation. Perhaps most importantly, the surgeon should have a low threshold for using a third lateral-entry pin if there is concern over fracture stability or pin location following the placement of the two lateral-entry pins. Since an optimal pin configuration requires fixation of both the medial and the lateral column, we believe that the term "lateral-entry pin fixation"[6] is an accurate description of this technique. ■

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