Safe Cross-Pinning of Pediatric Supracondylar Humerus Fractures With a Flexion-Extension–External Rotation Technique

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Abstract

The issue of pin configuration for fixation of displaced supracondylar humerus fractures continues to be controversial.

In this article, we report on a large single-surgeon 12-year series in which a flexion-extension–external rotation technique of cross-pinning was used. We retrospectively reviewed all pediatric extension-type supracondylar humerus fractures treated by a single surgeon. The cases of 214 children (mean age, 5.8 years) and 215 medial-entry pins were reviewed in the final analysis. Surgical technique involved a classic hyperflexion maneuver and placement of lateral-entry pins. Indications for medial-entry pins included instability to intraoperative torsional stress examination or medial column comminution. The elbow was then extended to no more than 60° of flexion. The glenohumeral joint was externally rotated to position the medial epicondyle directly en face to the radiographic beam before placement of a medial-entry Kirschner wire.

All reviewed patients had medial-entry pin placement with a flexion-extension–external rotation technique. Mean follow-up was 13 weeks. No ulnar nerve neurapraxias were reported.

Consistent protection of the ulnar nerve during percutaneous placement of a medial epicondylar pin for supracondylar humerus fracture can be accomplished with partial elbow extension and glenohumeral external rotation after placement of lateral-entry pins.

Displaced fractures about the supracondylar humerus are unstable secondary to complete bicortical disruption. Nonoperative treatment of pediatric extension injuries necessitates immobilization in a position of hyperflexion and poses the risk of compartment syndrome, loss of reduction, and malunion. The current gold standard for displaced supracondylar humerus fractures is operative fixation with closed reduction and percutaneous pinning, first described by Swenson.[1] There is no agreement about optimal pin number, configuration, patient positioning, or insertion technique. Biomechanical and cadaveric studies suggest that cross-pinning offers the most biomechanical stability in torsion.[2,3] Many surgeons are proponents of exclusively lateral-entry techniques because of the real potential for injury to the ulnar nerve in its proximity to any medial epicondylar starting point, even if the nerve is not directly traumatized at the moment of insertion.[4,5]

Proposed variations in intraoperative technique have included prone positioning,[6,7] open pinning,[8] mini-open techniques,[7,9,10] posterior intrafocal pinning,[11] semi-sterility,[12] lateral cross-wiring,[13] nerve stimulation monitoring,[14] digital protection,[15] and, in a recent series reporting good results and no ulnar nerve injuries, a flexion-extension technique of cross-pinning.[16] Positioning of the injured extremity at the time of medial-entry pinning is of paramount importance. Adult cadaveric studies have demonstrated a 45% increase in the length of the cubital tunnel with procession from extension to flexion.[17] Pediatric patients have a known high rate of bilateral ulnar nerve dislocation and subluxation, varying with skeletal maturity.[18]

We conducted a study to evaluate a large single-surgeon series of patients treated with cross-pinning by a consistent flexion-extension–external rotation technique and the attendant risk of ulnar nerve injury.

Materials and Methods

We retrospectively reviewed the cases of all patients treated with percutaneous skeletal fixation of the supracondylar hu-

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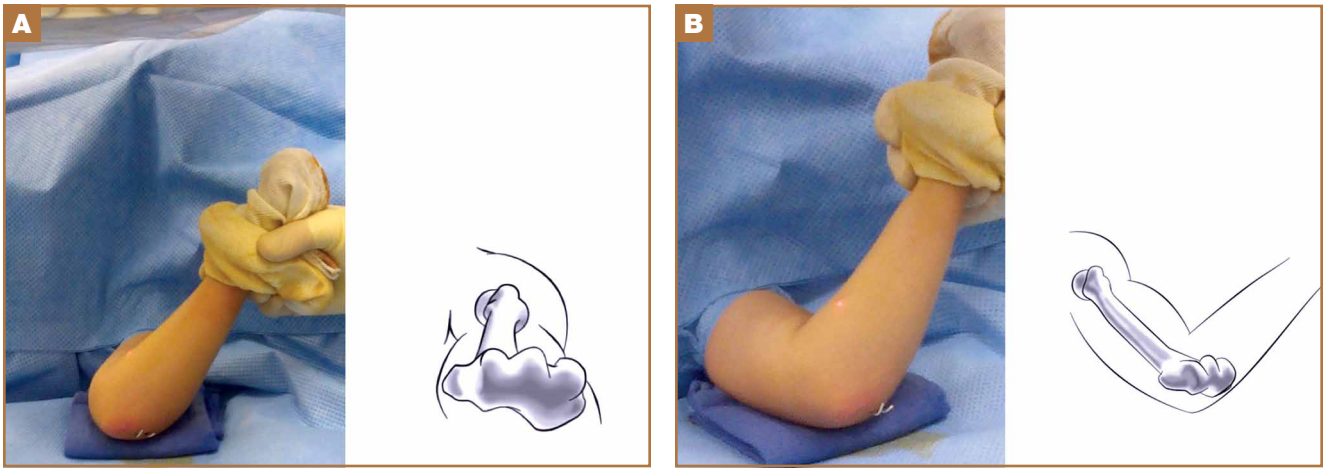

Figure 1. (A) Photograph and osseous anatomy during intraoperative positioning of injured extremity in partial elbow extension and glenohumeral external rotation after placement of lateral-entry pins. (B) Surgeon's view during intraoperative positioning of injured extremity in partial elbow extension and glenohumeral external rotation after placement of lateral-entry pins.

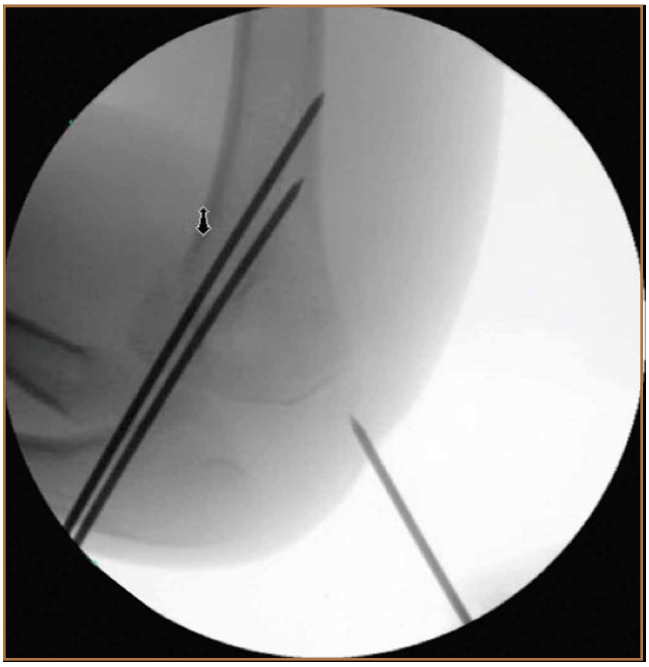

Figure 2. Rotational position of upper arm in preparation for medial pinning. During pin placement, elbow is placed into extension with elbow not flexed past 60°.

merus (*Current Procedural Terminology* [CPT] code 24538) by Dr. Settecerri between January 2000 and September 2011. This study was conducted in accordance with the institutional review board protocol at our institutions. Inclusion criteria were Gartland type II and III fractures of extension type, a percutaneously placed medial epicondylar pin, and at least 3 weeks of patient follow-up. All patients had their surgery at a level I trauma center in a large metropolitan area, and all patients included in the study were treated with a consistent flexion-extension–external rotation technique of cross-pinning. All preoperative, intraoperative, and postoperative records and radiographs were reviewed. Recorded patient information included sex, side of injury, Gartland classification, concomitant neurovascular injuries, number and configuration of pins, all postoperative complications or need for subsequent surgery, specific preoperative and postoperative ulnar nerve status, and length of follow-up.

Surgical Technique

The patient is positioned supine with the sterilely prepared injured arm supported in extension on a hand table. A C-arm image intensifier is placed at the head of the operating table. With firm longitudinal traction applied, varus-valgus reduction is performed. Once anteroposterior fluoroscopy confirms anatomical alignment, the traditional hyperflexion maneuver is performed. Interposed brachialis musculature in severely displaced injury is "milked" free proximal to distal before any attempted reduction. One or 2 divergent 1.6-mm bicortical wires are placed in the hyperflexed elbow through the lateral condyle with fluoroscopic confirmation of bicortical placement. Intraoperative stability is checked with torsional, flexion-extension, and varus-valgus stress. Remaining instability to torsion, medial column comminution, or persistent fluoroscopic instability for certain type II fractures precipitates placement of a medial pin. A medial pin is not placed if the fracture involves or exits the medial epicondyle. The elbow is then extended to no more than 60° of flexion. Whenever swelling permits, digital pressure is applied to the ulnar nerve proximal and distal to the epicondyle to verify that anterior subluxation has not occurred. The glenohumeral joint is simultaneously externally rotated to place the medial epicondyle directly en face to the radiographic beam (**Figures 1A, 1B**). A 1.6-mm Kirschner wire is percutaneously placed through the medial epicondyle with lateral cortex purchase proximal to the fracture site and a sagittal plane orientation parallel to the humeral shaft (**Figure 2**). The medial pin is not advanced

until a confirmatory check image verifies a perfect medial approach by the tip of the pin being directly juxtaposed against the medial aspect of the medial epicondyle (**Figure 3**).

All pins are bent and cut 1 cm above the skin, and petrolatum gauze (Xeroform; Covidien, Mansfield, Massachusetts) with a sterile dressing is applied. Postoperative immobilization is maintained with a long-arm, bivalved cast at no more than 90° of flexion. Displaced fractures are kept for an overnight outpatient stay for neurovascular surveillance and discharged on postoperative day 1. Patients are seen in the office within the first week for neurovascular examination, radiographs, and cast overwrapping. Casts are removed at 3 weeks; all pins are removed, and self-directed elbow range-of-motion exercises are begun. Patients are followed for 6 weeks after surgery unless range of motion is full and painless at home, in which instance parents cancel the final appointment.

Results

Four hundred eleven patients underwent percutaneous skeletal fixation of a supracondylar humerus fracture by Dr. Settecerri between January 2000 and September 2011. In 236 patients' cases (45 Gartland type II fractures, 191 Gartland type III fractures), 237 medial pins were used. Operative details were available for all 236 patients. Two hundred twenty-one (93.6%) of these patients had adequate follow-up. Six fractures were flexion type (2.5%) and were excluded. Two hundred fourteen patients (104 male, 110 female) representing 215 medial pins were included in the final analysis. Mean age of included patients was 5.8 years (range, 1-15 years).

Preoperative injuries included floating elbow (13 patients; 6.1%), anterior interosseous nerve palsy (12; 5.6%), radial nerve palsy (2; 0.9%), ulnar nerve palsy (1; 0.4%), and preoperative loss of palpable radial or radial and ulnar pulses (6; 2.8%). One patient underwent postreduction angiogram and expectant management of a brachial artery occlusion with retrograde filling. All preoperative complications had documented resolution by 6-week follow-up, except for improving but altered median nerve sensation at 10-week follow-up in 1 patient.

Postoperative complications at final follow-up included avascular necrosis of the distal humerus and fishtail deformity (2 patients; 0.9%), superficial pin-tract infections requiring incision and drainage (2; 0.9%), distal humeral osteomyelitis (3; 1.4%), and septic elbow (1; 0.4%). No patients had symptoms of ulnar nerve palsy in the postoperative period.

Discussion

The foremost consideration in pediatric supracondylar fixation is adequate maintenance of reduction in a position of relative elbow extension to minimize the risk of compartment syndrome. Biomechanical data have demonstrated the superiority of cross-pinning, particularly in torsion.[2] Recent ex vivo data suggest that a laterally divergent configuration in which the first pin is parallel to the metaphyseal flare and the second crosses the fracture at the medial edge of the coronoid fossa may provide comparable stability.[13] Zenios and colleagues[19] performed sequential intraoperative fluoroscopic testing in displaced supracondylar fractures and determined that 2 properly placed lateral-entry pins would stabilize only a minority of patients. Rotational instability, which persisted even after a third lateral-entry pin in 24% of cases, could only be conferred by the placement of a medial-entry pin. The potential for cubitus varus with pure rotational instability is a significant consideration and hitherto has not been addressed in a prospective study.

Figure 3. Confirmation of placement of medial-entry pin in less than 60° of elbow flexion.

Zaltz and colleagues[18] reported that ulnar nerve subluxation or dislocation occurs in up to 17.7% of the pediatric population (depends on age) and that clinical signs of generalized laxity were predictive of bilateral ulnar nerve instability at the elbow. Cadaveric studies have demonstrated significant elongation of the ligaments of the cubital tunnel and the pre–cubital ulnar nerve with elbow flexion.[17] Ulnar nerve symptoms can appear late,[20] with a "papal sign" or "sign of benediction" appearing 2 to 3 weeks after surgery and usually resolving in weeks to months. This correlates with the suspected etiology of iatrogenic ulnar neurapraxia, which is uncommonly a direct injury at time of pin placement. A study of 6 ulnar nerve neurapraxias after cross-pinning that were surgically explored revealed direct penetration of the nerve in only 2 patients, with improper placement of the pin in the cubital tunnel in 5 patients and a constricted retinaculum in 3 patients.[21] Early postoperative ultrasonographic evaluation of the ulnar and radial nerves has revealed dynamic changes in excursion and ulnar nerve diameter with medial pin placement,[11,22] though this has not been correlated with neurogenic symptoms or clinical outcomes.

The most significant issue with medial-entry pinning continues to be the increased risk of iatrogenic ulnar nerve injury.

This risk has not been obviated by commonly practiced mini-open techniques or placement of the elbow in semi-extended positions.[23] The independently reported rates of ulnar nerve neurapraxia with medial pin placement vary from 0% to 15% in recent prospective and retrospective data.[9,10,24-26] When medial-entry pins are systematically used, however, they can be and are safely placed.[15] A recent large meta-analysis (pooled-risk analysis) of 32 trials compared cross-pinning with lateral-entry pinning and found that the "number needed to harm" with a medial pin was 28 and the rate of iatrogenic ulnar nerve injury was 3.53%.[5] In another meta-analysis, by Brauer and colleagues,[27] any medial pin placement resulted in a 1.84-fold increase in the likelihood of ulnar nerve injury. The investigators recognized that their results could not take variations in technique of medial pin insertion into account with their analysis. Furthermore, clinical examination of young children is crucial and often difficult. All patients in our series had intact sensation over the small finger, intact ability to abduct the fingers, and no signs of clawing. Our series, and outlined technique, along with the anecdotal experience of many pediatric orthopedic surgeons who prefer to use medial pins, has shown that medial pins can be placed safely and continue to be placed safely without harm for fixation of unstable supracondylar humerus fractures.

For medial pin placement when deemed necessary for fracture stability in our patients, placement in no more than 60° of flexion minimizes tension on the ulnar nerve and the ligaments of the cubital tunnel.[17]

Our study's limitations include its retrospective, noncontrolled design. As the treatment (medial-entry pin) yielded no patients with the primary outcome measure (ulnar nerve neurapraxia), a comparison group was not possible. Furthermore, most pediatric elbow fractures are not treated by fellowship-trained orthopedic surgeons in large-volume tertiary-care centers. Last, our minimum follow-up was relatively short (3 weeks), which is consistent with the literature and appropriate to the management of this injury in most cases.

Other authors have cautioned against hyperflexion during medial pin placement to minimize the risk of ulnar subluxation anterior to the medial epicondyle, particularly when the arm is swollen and the nerve nonpalpable.[18,23] In our experience, the medial epicondyle has been a reliable palpable landmark even in an injured elbow. Most reports of surgical technique describe a partially extended position of medial-entry pinning. For medial pin placement when deemed necessary for fracture stability in our patients, placement in no more than 60° of flexion minimizes tension on the ulnar nerve and the ligaments of the cubital tunnel.[17] Forearm pronation has also been shown to be a position of ulnar nerve tensioning in adults, whereas glenohumeral external rotation and forearm supination do not significantly increase tension on the ulnar nerve.[28] To our knowledge, additive upper extremity nerve tension testing has not been performed in pediatric patients. This almost certainly is important when considering the potential cumulative effects of shoulder abduction, shoulder depression, glenohumeral rotation, elbow flexion, forearm rotation, and wrist flexion on the position of the nerve relative to the medial epicondyle.

Conclusion

A reproducibly safe method of fixation with maximal stability remains the ultimate goal of percutaneous supracondylar fixation. Knowledge of the effects of tension on the ulnar nerve with arm positioning is crucial. In each patient, fracture stability should be assessed during surgery. The described reproducible method of medial-entry pinning, when necessary, will minimize the risk of iatrogenic complications.

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This paper will be judged for the Resident Writer's Award.