Mid-America Orthopaedic Association Physician in Training Award

Surgical Technique

Pediatric Supracondylar Humerus Fractures: A Technique to Aid Closed Reduction

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Abstract

Background Anatomic reduction of some displaced pediatric supracondylar humerus fractures is not attainable via closed manipulation, thus necessitating open reduction. Open reduction has been associated with increased complications, including elbow stiffness, scarring, iatrogenic neurovascular injury, and longer hospital stays. Using a Schanz pin to aid in closed reduction may decrease the

need for conversion to an open procedure, possibly reducing morbidity.

Description of Technique A percutaneously placed 2.5-mm Schanz pin was drilled into the posterior humeral diaphysis and used as a joystick to reduce anterior and posterior, varus and valgus, and rotational deformity. The fracture then was stabilized with 0.62-mm K-wires placed under fluoroscopy and the Schanz pin then was removed.

Methods We retrospectively reviewed all displaced pediatric supracondylar humerus fractures treated by one surgeon from March 2002 through December 2010, with 143 fractures meeting criteria for inclusion. These fractures then were divided into two groups. Group 1 (90 fractures) included fractures treated before implantation of the Schanz pin. In this group, if successful reduction could not be achieved via closed manipulations, a formal open reduction was performed. In Group 2, (53 fractures) the Schanz pin technique was used to assist with reduction of fractures that were not reduced successfully by closed manipulations. All fractures were stabilized with the 0.62-mm K-wires after the reductions. To equalize group size, the 37 most remote fractures in Group 1 were removed, leaving a final 53 fractures in each group for analysis. Demographics, injury data, operative technique, complications, and radiographic reduction were analyzed. The minimum followup for both groups was 3.3 weeks (average, 13 weeks; range, 3.3–130 weeks).

Results Fewer fractures in Group 2 (one of 53, 1.9%) compared with Group 1 (seven of 53, 13%) underwent open reduction. Ten fractures in Group 2 underwent the Schanz pin technique, and none of these had open reductions. We found no difference between the groups concerning fracture alignment at final followup or post-operative complications.

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Conclusions A posteriorly placed Schanz pin aids in anatomic reduction and decreases the need for open treatment of displaced pediatric supracondylar humerus fractures, without compromising the complication rate or final radiographic outcome.

Level of Evidence Level III, retrospective comparative study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Pediatric supracondylar humerus fractures are the most common fractures around the pediatric elbow [7, 9, 14]. These fractures often are divided into flexion and extension types, depending on the mechanism of injury and the distal fragment's direction of displacement. Approximately 97% to 99% of pediatric supracondylar humerus fractures are extension-type injuries [9, 14]. Because remodeling is limited [1], meticulous reduction and anatomic alignment are essential to restore normal elbow function and prevent future complications from malreduction and resultant abnormal joint kinematics [9, 14, 15].

Closed reduction with pin stabilization, introduced by Swenson in 1948 [18], is the most common type of treatment for displaced (Gartland Types II and III [9, 14]) pediatric supracondylar humerus fractures [9, 18]. A Gartland Type II fracture is defined by displacement of the anterior cortex greater than 2 mm, while the posterior cortex remains intact, but it may be hinged. Gartland Type III fractures are completely displaced with no significant cortical contact [9, 14].

Acceptable reduction is not always attainable through closed manipulation. The median nerve and/or brachial artery may become entrapped in the fracture site, impeding closed reduction [14]. In 1965, Staples referred to this injury as a “dislocation of the brachial artery” owing to its interposition into the fracture site [16]. Elstrom et al. in 1975 used the terms “irreducible supracondylar fracture of the humerus” after reporting two cases where the fracture was irreducible by closed manipulation [5]. Open reduction of these fractures revealed interposition of the median nerve and brachial artery in the fracture site of one patient and the median nerve and brachialis muscle in another patient [5]. When closed manipulation does not yield anatomic alignment (defined as restoration of the humeral capitellar angle greater than 9° on the AP view, intact medial and lateral columns on oblique views, and bisection of the anterior humeral line through the middle third of the capitellum on the lateral view [14]), a formal open reduction must be performed. The need for open reduction has been reported in 3% to 15% of displaced fractures [3, 9, 12, 14].

Historically, open reductions of pediatric supracondylar humerus fractures have been associated with increased

complications, including elbow stiffness, scarring, iatrogenic neurovascular injury, and long hospital stays [3, 5, 9, 10, 12, 13, 19]. Reitman et al. [13] reviewed 65 patients treated with open reductions and found 21% of them to have “poor” or “fair” results, according to the criteria of Flynn et al. [6]. In comparing the results of 44 patients who were treated with open reductions and pinning with results of 55 patients who were treated with closed reductions and pinning, Ozkoc et al. [10] found patients with closed reductions had improved functional outcome scores and elbow extension when compared with patients with open reductions.

Several authors explored techniques to assist in closed and/or open reduction of the displaced pediatric supracondylar humerus fractures. Suh et al. [17] retrospectively reviewed patients who had two minimally invasive techniques. The first technique involved thumb manipulation of the fracture via a 2-cm incision into the antecubital fossa. The second technique used anterior pressure on the spike of bone from the distal diaphyseal fragment from a small-sized suction tip that was inserted via a 2-mm to 3-mm antecubital incision. After reduction, the fractures were stabilized with K-wire placement. Both reduction groups showed fracture healing and returned to normal elbow ranges of motion. They concluded that their two minimally invasive reduction techniques were advantageous over conventional open reduction and internal fixation. Eberl et al. reported on antegrade nailing of displaced pediatric supracondylar humerus fractures and described 9% “good” and 91% “excellent” results, according to the Linscheid-Wheeler score [4]. Prone positioning was described by Fowler and Marsh to assist with fracture reduction, and they reported all fractures healed without loss of reduction [7]. Functional outcomes were not reported in that technical study [7].

In 2009, Parmaksizoglu et al. [11] described a method of reduction similar to our reported technique. Their technique involved placing a K-wire from laterally to medially in the humeral diaphysis, “below the deltoid muscle.” The K-wire was used as a joystick to aid in manipulation of the humeral diaphysis to achieve fracture reduction with the subsequent stabilization with K-wires. Twenty-two of the 23 pediatric supracondylar humerus fractures in their series had “excellent” or “good” clinical outcomes, according to the criteria of Flynn et al. [6], and no fractures had open reduction [11]. However, they did not compare the outcomes with the fractures treated before implementation of this joystick method. The primary differences between the technique described by Parmaksizoglu et al. and ours are the direction and location of pin placement. Their pin is placed from medial to lateral at the level of the deltoid where the radial nerve is medial or posterior at that level. In our technique, the Schanz pin is placed from

posterior to anterior in a more distal location where the radial nerve is lateral. More distal placement allows the pin to be closer to the fracture site and potentially provides more control of the fracture.

We describe a novel technique of percutaneous, posterior humeral diaphyseal Schanz pin placement to aid in the reduction of displaced pediatric supracondylar humerus fractures. We determined whether (1) implementation of the Schanz pin technique decreased the rate of conversion to an open procedure, (2) decreased the operative time and length of hospital stay between formal open reduction and reduction with the Schanz pin technique, and (3) avoided adverse final radiographic alignment and complications.

Surgical Technique

Injury films were analyzed for displacement and fracture patterns. Substantial coronal displacement at the fracture was seen on the AP radiograph (Fig. 1). Rotational and sagittal displacement also was seen on the lateral radiograph (Fig. 2). The indications for surgery were displacement in any plane greater than 2 mm (Gartland Type II or III). Contraindications were Gartland Type I or nondisplaced fractures. Use of the Schanz pin technique began in October 2007. A specific algorithm for number of reduction attempts, time spent doing a closed reduction, or fracture characteristics was not followed. The surgeon used the technique when he was unable to obtain an acceptable reduction with closed manipulation alone.

The patient was administered general anesthesia and was positioned supine on the operative table and the image intensifier of the c-arm was draped and used as a table for the patient's arm (Fig. 3). Closed reduction of the fracture was attempted initially in all patients. Closed reduction of

the fracture was attempted initially in all patients in the following sequence: (1) axial traction, (2) varus or valgus manipulation to correct coronal displacement, and (3) sagittal alignment was restored with hyperflexion to correct the extension deformity (or hyperextension to correct the rarer flexion deformity). Pronation or supination of the forearm was performed to correct and fine-tune the reduction. A reduction was considered acceptable when the anterior humeral line bisected the middle third of the capitellum as observed on the lateral radiograph and the humeral capitellar angle was normal (range, 9° – 26°) on the AP radiograph [9, 14]. If closed manipulation failed to yield an acceptable reduction, a 2.5-mm terminally threaded Schanz pin (Synthes[®], Paoli, PA, USA) was placed percutaneously in the posterior humeral diaphysis. To place this pin, the patient's shoulder was abducted to 90° and maximally externally rotated (Fig. 4). A 1-cm skin incision

Fig. 2 This preoperative lateral radiograph shows a Gartland Type III fracture with likely rotational instability.

Fig. 1 This preoperative injury AP radiograph shows marked displacement.

Fig. 3 The patient is in supine position and the image intensifier of the c-arm is used as the operative table.

Fig. 4 The arm is positioned in 90° abduction and maximal external rotation for pin placement.

Fig. 5 This intraoperative fluoroscopy image shows insertion of the Schanz pin before its use during reduction.

was made in the posterior arm and blunt dissection was carried down until the surface of the posterior humeral diaphysis was encountered. The incision was made in the distal third of the humeral shaft to avoid the radial nerve, which is lateral at this location. After the blunt dissection, we inserted the Schanz pin through the posterior cortex (Fig. 5). The pin then was advanced through both cortices. Once in place, a T-handle Universal Chuck (Synthes® Universal Chuck with T-Handle, Synthes®, Paoli, PA, USA) was attached to the pin. The pin was used as a joystick to assist in reduction of the anterior and posterior translation and reduction of varus and valgus malalignment. The pin was most instrumental in derotating the humeral shaft, which was often the impediment to a

successful anatomic closed reduction. After fracture stabilization with percutaneous pinning with 0.62 K-wires, the Schanz pin was removed.

Patients and Methods

We retrospectively identified 156 displaced (Gartland Types II and III) pediatric supracondylar humerus fractures treated surgically in 156 patients from March 2002 through December 2010 using the Current Procedural Terminology (CPT) [1] codes 24538 and 24545: closed reduction percutaneous pinning and open reduction internal fixation, respectively. We excluded 13 patients for the following reasons: failure to followup through radiographic union (four), ipsilateral elbow injury (one), open fracture (two), no injury films available (two), primary treatment at another institution (one), and skeletal maturity (three). These exclusions left 143 pediatric supracondylar humerus fractures in 143 patients for study. The 143 patients were divided into two groups depending on whether treatment occurred before (Group 1, 90 fractures) or after (Group 2, 53 fractures) implementation of the Schanz pin technique (to aid in closed reduction). To equalize group size and decrease the effect of improving skill, the most remote 37 fractures were removed from Group 1, leaving 106 total fractures, 53 in each Group, with a study period of June 2004 through December 2010. The minimum followup for both groups was 3.3 weeks (average, 13 weeks; range, 3.3–130 weeks). No patients were recalled specifically for this study; all data were obtained from medical records and radiographs. We had prior institutional review board approval.

Each fracture was classified using the Gartland classification for pediatric supracondylar humerus fractures [9] (Table 1). All patients were seen and evaluated in the emergency department with the exception of one who was seen in the physician's office. Neurovascular examinations were performed and recorded. The patients underwent splinting in a comfortable position with the arm placed in a posterior, long arm splint. No closed reduction was attempted in the emergency department. The timing of the surgeries was determined by the surgeon and operating room availability. Patients with fractures with associated vascular compromise were taken to the operating room emergently on presentation.

We found no difference in sex or age between the two groups (Table 1). Each group had similar ($p = 0.800$) followup periods, with the average followup for Group 1 being 14 weeks (range, 3.3–130 weeks) and the average for Group 2 being 12 weeks (range, 3.7–69 weeks).

All fractures underwent fluoroscopic-guided closed reduction while the patients were under general anesthesia. In Group 1 (53 fractures; June 2004 through September

Table 1. Demographics and injury data

Group	Total	Gender		Age of patients (years) Average (range)	Gartland classification	
		Males	Females		Type II	Type III
All fractures	108	55 (52%)	51 (48%)	5.9 (0.4–12)	35 (33%)	71 (67%)
Group 1	53	25 (47%)	28 (53%)	5.8 (0.4–10.8)	20 (38%)	33 (62%)
Group 2	53	30 (57%)	23 (43%)	6.1 (1.1–12.1)	15 (28%)	38 (72%)
p value		0.331		0.481	0.302	

2007), fractures that did not have successful reduction via closed manipulation underwent formal open reduction. In Group 2 (53 fractures; October 2007 through December 2010), the fractures that were not reducible by closed manipulation underwent the Schanz pin technique to aid in closed reduction. After anatomic reduction was achieved (by closed manipulation, open reduction, or closed manipulation and Schanz pin placement), all fractures were stabilized with 0.62 K-wire placement. Various pinning techniques were dictated by the surgeon at the time of surgery based on which configuration allowed stable maintenance of reduction. After reduction and stabilization, the patients' arms were placed in a bulky dressing and immobilized in a posterior long arm plaster splint or a long arm cast with the elbow flexed to 90° and the forearm in neutral rotation.

Operative time and length of stay were recorded. The length of stay was determined two ways. The first was the time from admission to discharge and the second was the operative start time to the time of discharge. Six of the seven patients in Group 1 who underwent open reduction and all of the patients in Group 2 who were treated with the Schanz pin technique had data available to determine lengths of stay. One patient in Group 1, treated with open reduction, had associated injuries that had longer hospitalization and therefore was not included in the length of stay analysis. Although patients with polytrauma are different from patients with isolated injuries, they still were included in the study analysis (with the exception of length of stay), since the final radiographic reduction and/or complications related to treatment of their elbow injuries are not affected by other injuries. Patients with concomitant elbow injuries were excluded.

Patients were seen for an initial postoperative visit at 7 to 10 days. Clinical examination at that time was limited to motor and sensory functions of the hand owing to the cast or splint on the extremity. Anteroposterior and lateral radiographs were obtained to verify maintenance of reduction and alignment. Patients were kept immobilized for 3 to 4 weeks, at which time they were seen in the office again for repeat clinical examination and radiographs. If bridging callus was seen, the pins were removed in the

office, immobilization was discontinued, and activities were gradually advanced as tolerated. Patients were seen again 4 to 6 weeks after pin removal for repeat radiographs and physical examination. Clinical evaluations that were completed at the final followup included measurements of ROM, motor function, and determination of any complications of treatment. Owing to an inconsistent reporting method, ROM data were not incorporated in the analysis. However, if subsequent visits revealed motion loss, patients were referred to physical therapy and followed until satisfactory motion was achieved. All fractures were followed until there was fracture union and resolution of any complications. Complications that were assessed for included neurologic injury (motor and/or sensory deficits), vascular injury, compartment syndrome, pin site infection, deep infection, nonunion, or malunion (as defined by Baumann angle below) [9].

Anteroposterior and lateral radiographs were evaluated at the patient's final followup to determine final coronal (Fig. 6) and sagittal (Fig. 7) alignment. This final followup was the last recorded visit in the medical records and is equal to the last clinical followup (average, 13 weeks; range, 3.3–130 weeks). The Baumann angle [9, 14], or humeral capitellar angle, was measured on AP radiographs using the Picture Archiving and Communication System (Carestream Vue PACS, Carestream, Rochester, NY, USA) to determine normal (range, 9°–26°), varus (< 9°) or valgus (> 26°) alignment [9, 14]. Lateral radiographs were analyzed with reference to the capitellum and its position relative to the anterior humeral line (anterior, at, or posterior).

Descriptive statistics were completed to provide the mean, range, percentages, and distribution of variables. We used a chi-square analysis to determine differences in proportions between the groups regarding conversion to an open procedure, reduction, and complications. Continuous data were normally distributed and the groups had similar variances. Therefore we used independent samples t-tests to analyze differences between the groups regarding operative time, length of stay, reduction on the final AP and lateral radiographs, complications, and followup time. Data were analyzed using PASW[®] Statistics 18.0 (IBM[®], Armonk, NY, USA).

Fig. 6 A final AP radiograph obtained at the last followup shows acceptable coronal alignment.

Fig. 7 The final lateral radiograph shows acceptable sagittal alignment with the anterior humeral line, traversing the middle third of the capitellum.

Results

Eight of the 106 fractures (7.5%) underwent open reduction. We found a decrease ($p = 0.027$) in the number of fractures having an open reduction in Group 2 (one fracture, 1.9%) compared with Group 1 (seven fractures, 13%). When comparing only Type III fractures in each group, the

Table 2. Operative time and length of stay

Group	Average operative time (minutes)	Average length of stay: admission to discharge (days)	Average length of stay: operative start time to discharge (days)
Group 1 (Open reduction)	33 (range, 18–43)	0.9 (range, 0.3–1.6)	0.6 (range, 0.2–1.4)
Group 2 (Schanz pin)	22 (range, 8–34)	0.7 (range, 0.3–0.9)	0.5 (range, 0.2–0.8)
p value	0.029	0.138	0.200

rate of conversion to an open reduction was lower ($p = 0.028$) in Group 2 than in Group 1: one of 38 Type III fractures (2.6%) in Group 2 and six of 33 Type III fractures (18%) in Group 1 were treated with open reduction. One Type II fracture in Group 1 was treated with open reduction. The one fracture treated with open reduction in Group 2 did not undergo the Schanz pin method before conversion to open reduction. It was not specified in the operative note why the Schanz pin was not used, and because the study is retrospective, no assumptions can be made regarding why it was not used. None of the 10 fractures in Group 2 for which the Schanz pin technique was used had open reduction.

Fractures in Group 1 had a longer ($p = 0.029$) operative time (average, 33 minutes; range, 18–43 minutes), when compared with fractures in Group 2 (average, 22 minutes; range, 8–34 minutes) (Table 2). We found no difference in the time of admission to the time of discharge ($p = 0.138$) or the operative start time to the time of discharge ($p = 0.200$) for fractures in Group 1 compared with fractures in Group 2 (Table 2).

We observed no difference between Group 1 and Group 2 regarding the final reduction on AP (varus or valgus malalignment) or lateral (location of anterior humeral line relative to the capitellum) radiographs ($p = 0.245$ and $p = 0.301$, respectively). Twelve (11%) fractures healed with varus malalignment (seven in Group 1 [13%] and five in Group 2 [9%]). Two fractures, both in Group 1, were noted to have valgus malalignment. Lateral radiographs revealed the middle of the capitellum to be anterior to or at the anterior humeral line in 98 (92%) fractures (48 in Group 1 [91%] and 50 in Group 2 [94%]).

There was no difference for individual complications of nerve injury, vascular injury, compartment syndrome, nonunion, pin site infection, or deep infection between Groups 1 and 2 (Table 3). Two patients in Group 1 (3.7%) had superficial pin tract infections. No patients had compartment syndrome, deep infections, or nonunions develop. More patients ($p = 0.046$) in Group 2 had total nerve injuries than in Group 1: 15% versus 3.8%, respectively. All

Table 3. Complications

Group	Iatrogenic nerve injury	Vascular injury	Compartment syndrome	Pin site infection	Deep infection	Nonunion
Group 1	1	1	0	2	0	0
Group 2	0	1	0	0	0	0

Table 4. Nerve injuries

Group	Total	AIN or median	PIN or radial	Ulnar nerve	AIN and radial
Group 1	2	1	1	0	0
Group 2	8	4	3	0	1
p value	0.046				

AIN = anterior interosseous nerve; PIN = posterior interosseous nerve.

nerve injuries were documented preoperatively (Table 4) with the exception of one fracture in Group 1. This patient did not have a detailed preoperative examination but had a documented anterior interosseous nerve palsy postoperatively; for analysis, this was considered an iatrogenic nerve injury. All nerve injuries resolved without persistent deficit. All vascular injuries were noted preoperatively. There were two preoperative brachial artery injuries: one in Group 1 and one in Group 2. The brachial artery injury in Group 2 resolved after closed reduction. One brachial artery injury in Group 1 required exploration by vascular surgery with the release of constricting bands and the subsequent return of flow. There were no iatrogenic vascular injuries.

Discussion

Pediatric supracondylar humerus fractures are the most common pediatric elbow fracture [7, 9, 14] and they require anatomic alignment to restore normal elbow function [2, 9, 14, 15]. Anatomic alignment is not always achievable through closed manipulation and open reduction is performed in 3% to 15% of displaced fractures [3, 9, 12, 14]. Open reduction of pediatric supracondylar humerus fractures has been associated with increased complications and poorer outcomes, often reported using the criteria of Flynn et al. [3, 5, 6, 9, 10, 12, 13]. Several operative tricks and techniques have been described in the literature, but to our knowledge, no study has been designed to show a decrease in the need for open reduction with these techniques [4, 7, 11, 17]. Our technique of Schanz pin placement in the posterior humeral diaphysis was associated with a reduction in the conversion rate to an open procedure and in operative time without affecting final radiographic alignment or complications.

There are several limitations to the current study. First, we did not have standardized documentation of the preoperative and postoperative physical examinations. The higher rate of preoperative nerve injury in Group 2 may be attributable to more comprehensive documentation of preoperative examinations and better availability of the records in the most recent patients. Postoperative physical examination documentation did not routinely include specific elbow ranges of motion, but was more commonly reported as “good” or “full,” and therefore, could not be reliably used to compare the two groups. Second, we could not measure some possible factors that may have contributed to a decrease in the rate of conversion to an open procedure and/or decreased operative time. This includes the evolving experience of the surgeon regarding closed manipulation and percutaneous pinning techniques. The surgeon’s experience with operative technique and efficiency during the period that this study reviewed likely improved, potentially decreasing total operative time. Third, we had no way to determine the number of times a closed manipulation was performed or length of time before there was conversion to an open procedure or use of the Schanz pin. With the retrospective nature of the study, we were unable to determine whether the 10 fractures in Group 2 treated with the Schanz pin technique would have had open reduction or if further closed manipulation (without use of the Schanz pin) would have yielded an acceptable reduction. Fourth, we lacked followup of less than 6 weeks in 22 patients. Because our primary intent was to document the technique and show its ability to decrease the need for conversion to an open procedure, we believed followup to radiographic union was sufficient. It is the practice of the treating orthopaedic surgeon to follow patients through fracture union and return of pain-free function (strength, ROM) which usually occurs at 10 to 12 weeks. Slowly resolving neural injury and return to normal function dictated further clinical evaluation. Since the followup was similar in the two groups and the primary outcome measure of the study was conversion to an open reduction procedure, we elected to include all patients with adequate followups until fracture union and pin removal. As no difference between the groups was noted for final healed fracture alignment, any clinical differences beyond this point could not be directly attributed to reduction technique, but were more likely a result of fixation methods, patient compliance, or were multifactorial.

Parmaksizoglu et al. [11] described a technique that involved use of a K-wire placed from lateral to medial in the proximal humeral diaphysis beneath the deltoid, with subsequent use of this K-wire as a joystick to help control and reduce the deformity of pediatric supracondylar humerus fractures. They described the results of 23 fractures treated with this reduction tool and reported 22 of the 23 to have “excellent” or “good” clinical outcomes [11] according to the criteria of Flynn et al. [6]. They did not compare their results of this technique with results of fractures treated before use of this technique. Their technique and the technique we describe with the pin in the posterior humeral diaphysis are similar with the exception of the location and direction of pin placement. Each technique avoids the course of the radial nerve, with a more proximal and lateral placement, as they describe a more distal and posterior placement, as presented in this study. A potential advantage of the more distal placement, as described in the current study, is better control of the fragment owing to the proximity of the pin to the fracture. In addition, comparing results before and after implantation of this technique allows observation of the technique’s utility in reducing the rate of conversion to an open procedure and the operative time.

Our findings show that a Schanz pin placed in the posterior humeral diaphysis can aid in closed reduction of displaced pediatric supracondylar humerus fractures. Furthermore, we found that use of this technique may decrease the need for conversion to an open reduction without compromising the radiographic reduction or clinical outcome.

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