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Lateral External Fixation—A New Surgical Technique for Displaced Unreducible Supracondylar Humeral Fractures in Children

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Background: Percutaneous Kirschner wire fixation represents the classic treatment for displaced supracondylar humeral fractures in childhood. This type of treatment first requires satisfactory reduction of the fracture. Failure to achieve a satisfactory reduction or inadequate stabilization can result in instability of the fracture fragments, which can result in either an unsatisfactory cosmetic or functional outcome. In our experience, these problems can be overcome with the use of a small lateral external fixator.

Methods: Between 1999 and 2005, thirty-one of 170 Gartland type-III supracondylar humeral fractures were treated with a lateral external fixator. The outcome of treatment was analyzed with regard to limb alignment, elbow movement, cosmetic appearance, and patient satisfaction.

Results: In twenty-eight of the thirty-one patients, a satisfactory reduction was achieved with closed methods. All children except one had a normal or good range of movement. The cosmetic result was excellent in all cases. All of the children and their parents stated that they would choose this treatment again.

Conclusions: The use of a small lateral external fixator seems to be a safe alternative for the treatment of displaced supracondylar fractures of the humerus when a closed reduction appears to be unattainable by means of manipulation alone or when sufficient stability is not achieved with standard methods of Kirschner wire fixation.

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

Supracondylar humeral fractures constitute the most common fracture pattern around the elbow in the pediatric population. However, the treatment of these fractures represents a challenge for most surgeons. Problems with the correct diagnosis, reduction, and fixation appear to form the main reasons for the special position of this fracture in pediatric traumatology. Some surgeons prefer open reduction for the treatment of Gartland type-III displaced fractures, especially if they lack experience with these fractures or if a perfect reduction cannot be achieved by means of manipulation alone. Generally, the literature has described better results following closed reduction of displaced supracondylar humeral fractures. Thus, it appears that the experience of the surgeon often determines whether he or she will proceed with open or closed reduction.

In most cases, fixation is achieved either with use of bilateral crossed Kirschner wires or with use of two Kirschner wires that are inserted through a lateral approach. One of the problems with Kirschner wire fixation is the risk of persistent instability. If the wires are not placed properly, rotational control may not be achieved, often resulting in displacement and cubitus varus. Usually a cast or splint is applied following stabilization with percutaneous Kirschner wire fixation, but doing so can delay the start of early motion to facilitate functional elbow recovery.

Problems or complications associated with Kirschner wire fixation include iatrogenic ulnar nerve injury caused by medial pins, superficial and deep infections, and loss of fixation with malunion mainly in the cubitus varus position, findings that were confirmed in a multicenter study from 1991 to 1995.

We have used a small lateral external fixator to solve some of the problems associated with stabilizing type-III su-
pracondylar fractures\textsuperscript{22,23}. Because external fixators are widely utilized for the treatment of fractures, most surgeons are familiar with the technique of applying them. The small external fixator provides major advantages over other methods. First, it facilitates the achievement of a satisfactory reduction through an indirect approach. Second, it provides rigid stability while allowing elbow motion, which eliminates the need for additional plaster immobilization. Third, because it involves the use of a purely radial (lateral) approach, damage to the ulnar nerve is avoided.

We present our experience with this method, the technical details of applying the fixator, and our initial results. We propose this method as an alternative technique for the treatment of supracondylar humeral fractures in cases in which the reduction may be difficult, open reduction may be needed, or sufficient stability cannot be achieved with Kirschner wires.

**Materials and Methods**

Between June 1999 and March 2005, 170 Gartland type-III displaced supracondylar humeral fractures\textsuperscript{5} were treated surgically in our department. Thirty-one fractures (18\%) were stabilized with the use of a lateral external fixator. The other fractures that were treated surgically were stabilized with either crossed pins or multiple lateral pin fixation.

The lateral external fixator was used for type-III supracondylar humeral fractures of several different patterns, including (1) fractures in which an adequate closed reduction could not be achieved in the usual manner, (2) fractures with an angle in excess of 30° in the sagittal plane, which were by definition oblique fractures with a higher risk of displacement\textsuperscript{24}, (3) fractures with comminution for which simple pin fixation would not achieve adequate stabilization, (4) fractures in which the original reduction that had been achieved and stabilized with percutaneous pin fixation had displaced, resulting in unacceptable alignment, and (5) open fractures and fractures with a risk for compartment syndrome. The indications for the use of the external fixator were independent of age.

We analyzed patient charts and radiographs for demographic data (age, sex, affected side), the type of fracture, the indication for the use of an external fixator, operative time, postoperative data (the duration of external fixator use, cast use, and the duration of cast use), complications (pin-track infections, nerve palsy), range of movement before and after fixator removal, and patient/parent satisfaction.

**Principles of Lateral Fixator Application**

When applying the fixator, the surgeon must understand that the anatomy of the distal part of the humerus has a unique geometry, with a figure-of-eight cross section in the horizontal plane. The cross-sectional diameter of the lateral condylar (radial) column makes up approximately 60\% to 65\% of the total cross section of the supracondylar area (Fig. 1). If there is rotation of the distal fragment, there will be very little contact in the medial (ulnar) condylar column and therefore Kirschner wires may not be able to provide adequate fracture fixation, resulting in cubitus varus. When the lateral external fixator is used, the lateral condylar column can be stabilized by compressing the fragments, which will secondarily prevent medial column collapse.

**Surgical Technique**

All surgical procedures in the present report were performed by or in the presence of the same experienced pediatric surgeon (T. Slongo). The procedure is performed in the operating suite with the patient under general anesthesia. The small external fixator (Synthes), with 4-mm connector rods, is used.
If available, radiolucent carbon fiber rods are preferred as they allow better radiographic visualization of the fracture site. However, standard 4-mm stainless steel rods can be used and can provide equally good stabilization. Depending on the patient’s age, we use two 2.5 or 3.0-mm self-drilling and self-tapping Schanz pins and a 1.6-mm Kirschner wire.

The child is placed in the supine position, as far laterally toward the side of the table as possible, so that the affected upper extremity can be laid easily on the surface of the receiver of the image intensifier. The entire upper extremity, including the shoulder, is prepared and draped free. The image intensifier serves as the work table and should be set up so that it can be pivoted 45° to each side. The extremity is not rotated; rather, the image intensifier is rotated around the extremity. The fracture is first reduced prior to the insertion of the Schanz pins. In most cases, this reduction is achieved with closed methods. Performing a provisional reduction first with the image intensifier facilitates correct axial drilling of the Schanz pins and prevents problems with the soft tissues. Placing the pins prior to achieving fracture reduction can result in tension on the soft tissues as the fracture fragments are manipulated.

The first 3-mm-diameter Schanz pin is inserted 2 cm proximal to the fracture line, avoiding injury to the radial nerve. The radial nerve crosses the lateral supracondylar ridge of the humerus at the diaphyseal-metaphyseal junction, and then it courses anterior to the cortex of the humeral diaphysis. The Schanz pin should be inserted at 90° to the longitudinal axis of the proximal humeral fragment and secured in the medial cortex. In order to avoid injury to the ulnar nerve, care should be taken not to fully perforate the medial cortex (Fig. 2).

Next, the second Schanz pin is inserted in the distal fragment. This pin should be 2.5 to 3.0 mm in diameter, depending on the size of the fragment. If the metaphyseal fragment is sufficiently large, the pin can be inserted proximal to the physis. If the distal fragment is very small, the distal Schanz pin can be inserted into the center of the capitellum. In our experience, single pin penetration of the epiphysis has not resulted in subsequent growth arrest. Again, this second Schanz pin should be placed perpendicular to the longitudinal axis of the distal fragment, making it parallel to the elbow joint. As with the first pin, it is important to avoid fully perforating the medial cortex of the distal part of the humerus (Fig. 3). We do...
not use percutaneous Kirschner wires as joysticks to manipulate the fragments because we have often found that they do not provide satisfactory leverage to manipulate the fragments into position. The larger-diameter Schanz pins provide more rigid fixation of the fragments and can be used more effectively as joysticks to manipulate the fracture fragments.

To use the two Schanz pins as joysticks, it is important that they are inserted perpendicular to the long axes of the respective fracture fragments. The advantage of placing the pins perpendicular to the respective fragments is that they can be used as guides to determine the quality of the final reduction: if the pins are parallel in the coronal plane following the reduction maneuver, then the alignment of the fracture fragments should be satisfactory.

To facilitate final attachment of the Schanz pins to the fixator, the tube-to-tube clamps and the steel or carbon rod are loosely applied to the Schanz pins. The final reduction is then monitored with use of the image intensifier. Once the desired reduction has been accomplished, the tube-to-tube clamps are tightened, securing the bar to the Schanz pins. The external fixator and two single Schanz pins provide good stabilization in the coronal plane, but there can still be some tendency for the fracture fragments to have rotational instability if forces are applied in the horizontal plane. To provide additional rotational stability, a 2.0 or 1.6-mm Kirschner wire is drilled retrograde from the lateral aspect (radial side) of the distal fragment into the proximal-medial cortex of the proximal fragment, crossing the fracture just proximal to the olecranon fossa. Alternatively, if the obliquity of the fracture is in the same direction the Kirschner wire is supposed to be placed, the pin can be passed antegrade from the lateral aspect of the proximal fragment to the medial aspect of the distal fragment. This single Kirschner wire is termed an anti-rotation wire, and it can be left free because it has no influence on axial stability (Fig. 4). Radiographic documentation of the reduction and fixation is accomplished with radioulnar, ulnar-radial, and anteroposterior images. As the final step, it is important to test the elbow range of motion and the stability of the fracture in maximum extension and flexion (Fig. 5) while observing the fracture site in real time with the image intensifier. If maximum extension and flexion are not possible or if the reduction is not stable, the external fixator and the fracture should be adjusted.

Postoperative Care

Depending on the child’s anxiety and the concern shown by the parents, a dorsal splint can be applied for protection and/or comfort. Because fixation usually is very secure, supplemental support usually is not necessary. The child can be allowed free motion of the affected upper extremity, avoiding any weight-bearing activities. Doing so has the advantage of permitting the child to use the extremity for school activities such as writing. As with any external fixator, it is important to perform pin care on a daily basis. It is not necessary to initiate physical therapy in the immediate postoperative period. The first postoperative radiographs are made between three and five weeks after the procedure to assess fracture-healing. We favor a longer time-period between the operation and the first radiographs in order to allow fracture consolidation to take place, thus reducing the number of radiographs made. Once there is good callus formation, as shown by callus bridging at least three of four cortices, the external fixator can be removed with little or no sedation.

Results

The ages of the thirty-one patients ranged from two to fifteen years, with 84% (twenty-six) of the children being between the ages of five and thirteen years. Three children had...
an open fracture: one had a Gustilo and Anderson type-I fracture, and two had a type-II fracture\textsuperscript{25,26}. The male-female ratio was 1.5:1. The left upper extremity was involved two times more often than the right. In three of the thirty-one patients, open reduction was required. One of these three patients initially presented with an open fracture. In the second patient, the fracture site was explored surgically because of concern about a neurovascular injury with an impending
compartment syndrome. In the third patient, an open reduction was performed because of an inability to achieve a satisfactory reduction with use of the external fixator. The reduction was found to be prevented by interposed muscle. The intraoperative and postoperative data regarding the patients are presented in Table I.

Eight children had neurological deficits involving the radial nerve (n = 4), the ulnar nerve (n = 3), and the anterior interosseous branch of the median nerve (n = 1) prior to the treatment of the fracture. In addition, one patient presented with no palpable distal pulse. All of these deficits resolved after the reduction of the fracture and stabilization with the external fixator.

Two pin-track infections occurred and were successfully treated with oral antibiotics. Eleven patients used a supplemental dorsal splint for comfort postoperatively.

Following consolidation of the fracture and removal of the external fixator, twenty-eight children were found to have bilateral symmetrical elbow axes within the physiological cubitus valgus range of 5° to 10°. Two children had a loss of physiological valgus, and one child had a cubitus varus deformity of 5°. This varus deformity was not of any cosmetic or functional concern to the parents or the patient.

Follow-up was performed at our outpatient clinic. The range of motion right before removal of the external fixator varied between a full range of motion to nearly no motion in one child. In all cases, the external fixator was removed, without a second session of general anesthesia, after a mean of five weeks (range, four to seven weeks). In the cases of twelve patients, sedation was provided during the removal procedure.

The mean duration of follow-up (and standard deviation) was 40.9 ± 23.6 months (range, seven to eighty-one months). Three months after removal of the fixator, thirty of the thirty-one children had a normal range of motion of the elbow. A normal range of motion was defined as flexion of 140° to 150° with extension to 0° or even slight hyperextension, whereas a good range of motion was defined as a maximum flexion-extension deficit of 10°. Only one patient had severe limitation of elbow motion. In that patient, two months after removal of the fixator, the range of elbow flexion-extension was from 70° to 45°. The motion improved with physiotherapy, but not to a satisfactory level, and the patient was still being followed in our outpatient clinic at the time of the latest follow-up.

The cosmetic result was excellent in all cases, and the acceptance of the external fixator was considered excellent by both the children and the parents. Subjectively, wearing the fixator was not seen as a hindrance either at home (in the case of smaller children) or at school. On the contrary, being able to use the arm freely for school was seen as positive. Asked if they would accept the same type of treatment again, all children and parents replied that they would.

Discussion

Supracondylar humeral fractures are common. The peak incidence is between the ages of five and ten years. The type-III supracondylar humeral fracture is challenging, as reflected in the literature, and there is still some controversy with regard to the ideal treatment method. In most cases, the standard technique includes closed reduction with manipulation followed by stabilization with either cross-pins or multiple lateral pins. These techniques usually produce a satisfactory cosmetic and functional result. However, there are occasions in which a more aggressive approach is needed. Often, an open reduction with or without an alternative method of fixation is required. Although better results usually are reported following closed reduction, the optimal treatment is still unclear in the literature on severely displaced type-III supracondylar humeral fractures. Some authors have recommended a minimally invasive medial approach. Our experience with the use of the lateral external fixator demonstrated that, in most cases, an excellent cosmetic result and a good functional result can be achieved and that open reduction can be eliminated. If adequate alignment cannot be achieved with manipulation, our experience demonstrated that, in the majority of cases, the fragments can be manipulated into a satisfactory position with use of the Schanz pins. These pins can then be secured to a small external fixator. The stability afforded by the fixator can prevent secondary displacement.

However, it must be clearly emphasized that we see this method as an alternative supplement to the existing methods. The main indications are (1) fractures that are irreducible with use of the usual closed techniques, (2) oblique fractures that do not appear to be stabilized adequately with the classic methods, especially fractures with angulation of >30° in the sagittal plane, and (3) comminuted fractures. The main goals are to avoid the need for an open reduction and to achieve fracture stabilization, which prevents secondary displacement with its risk of malunion in cubitus varus.

We are aware of the limitations of this study because of its retrospective nature. Nevertheless, the review of our cases over the last seven years (comprising approximately 18% of all surgically treated supracondylar humeral fractures) demonstrated that this method is very simple to use, requires little expenditure, and can achieve satisfactory results. Even in cases in which there is an inability to achieve complete correction of
the rotation of the distal fragment, the stability provided by the fixator can prevent the distal fragment from tilting into varus. The advantage of this treatment, which allows early mobility of the elbow, was demonstrated by the good active range of elbow motion that the patients exhibited at the time of fixator removal, thus reducing rehabilitation time.

In conclusion, unstable or markedly displaced supracondylar humeral fractures (Gartland type-III) remain a treatment challenge. The introduction of the lateral external fixator provides another method with which closed reduction and stabilization of this fracture can be achieved. Its stability prevents the occurrence of secondary displacement. As all of the pins are inserted from the lateral side of the distal part of the humerus, injury to the ulnar nerve can be avoided. This method allows for immediate elbow movement and is well accepted by the children and parents. The surgeon who treats pediatric trauma will find this technique to be of use for avoiding open reduction when a satisfactory reduction cannot be achieved with the usual closed manipulative methods.

References


