

Pitfalls of lateral external fixation for supracondylar humeral fractures in children

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Abstract

Introduction Closed reduction and percutaneous pinning is a standard treatment for dislocated supracondylar humeral fractures in children. However, the management of these fractures remains challenging. The aim of this study was to evaluate lateral external fixation as a treatment alternative for these fractures.

Materials and methods All supracondylar fractures treated with lateral external fixation between 2005 and 2007 were evaluated retrospectively. Long-term outcome was assessed with regards to carrying angle, malalignment, and motion.

Results Twenty-eight patients with Gartland type III fractures and one with a Y-type fracture were included in the study (mean age 6.5 years). Cosmetic results were excellent in 88%, good in 8%, and fair in one patient. Functional results were excellent in 83%, good in 10%, and fair in 7%. However, 3 patients (10%) showed complete radial palsy postoperatively. In all of these patients, high insertion of the proximal pin (2.9–3.6 cm above the fracture) was noted. On revision, one superficial lesion and one total transection of the nerve at the level of the proximal pin was detected. One patient showed no macroscopic damage. The transected nerve was reconstructed using an autograft, and all patients completely recovered within 2–6 months.

Conclusion Lateral external fixation is an alternative method for the treatment of displaced or unstable supracondylar fractures in children, facilitating reduction and

improving fracture stability. However, iatrogenic radial nerve injury is a risk, and we therefore strongly recommend inserting the proximal pin under direct vision within 2 cm from the fracture line using a drill sleeve.

Keywords Supracondylar humeral fracture · External fixation · Nerve injury · Technique · Children

Introduction

Dislocated supracondylar humeral fractures are common in the pediatric age group, and are the most frequent fractures of the elbow region in children (representing 3–7% of all fractures seen in children) [1, 2]. These fractures are classified according to Gartland [3]. For Gartland type II (angulated with posterior cortex intact) and type III (completely dislocated) fractures, several different methods of fixation have been advocated [4]. After reduction, stable retention can be difficult, and insufficient rotational control can lead to secondary displacement and cubitus varus. External fixation is a well-established method for the treatment of fractures at different locations. Taller introduced the use of an external fixator for supracondylar fractures of the humerus in children in 1986 [5]. In 2008, Slongo published his series of Gartland type III supracondylar humeral fractures treated with a lateral external fixator, and this technique has been promoted as a safe alternative to Kirschner wire fixation [6]. In contrast to Slongo's series with no neurological complications, we observed radial nerve injuries in our patients. That stimulated us to perform a retrospective study.

The purpose of the current study is to evaluate the short- and long-term results in children treated with a lateral external fixator, with attention paid to the treatment method

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used. In 2005, we implemented lateral external fixation mainly for Gartland type III fractures, with highly satisfactory results, but also with severe complications. In this paper we describe the method and the results of applying it in 29 patients treated between 2005 and 2007, focusing especially on potential complications.

Materials and methods

From February 2005 to September 2007, 29 patients with a supracondylar humeral fracture were treated with lateral external fixation in our institution. The indication for lateral external fixation was a fracture of the distal humerus, a supracondylar fracture with dislocation in at least two directions, or a secondary dislocation of a supracondylar fracture after closed reduction and unilateral percutaneous pinning. We reviewed the charts retrospectively to identify demographic data, including gender and age, clinical and radiographic findings, associated injuries, and postoperative complications. Functional and cosmetic outcome was assessed at follow-up examinations according to the criteria of Flynn [7], which evaluate carrying angle, malalignment, and loss of motion (Table 1).

Operative method

The pre-reduction examination included an evaluation of neurovascular integrity and the status of the soft tissues about the elbow. Surgery was performed or supervised by a senior pediatric trauma or orthopedic surgeon. An attempt at closed reduction was performed in the supine position under general anesthesia in the OR. Fluoroscopy was used intraoperatively, confirming preliminary reduction. It is important to note that the image intensifier is rotated around the patient's extremity and not vice versa in order to maintain the results of reduction. A small external fixator (Synthes) and two self-drilling and self-tapping Schanz pins were placed 2.5 mm distally and 3 mm proximally (Fig. 1). After a 5 mm stab incision, a 2.5 mm pin was inserted from lateral to medial into the center of the fracture fragment. The pin was placed proximally to the physis,

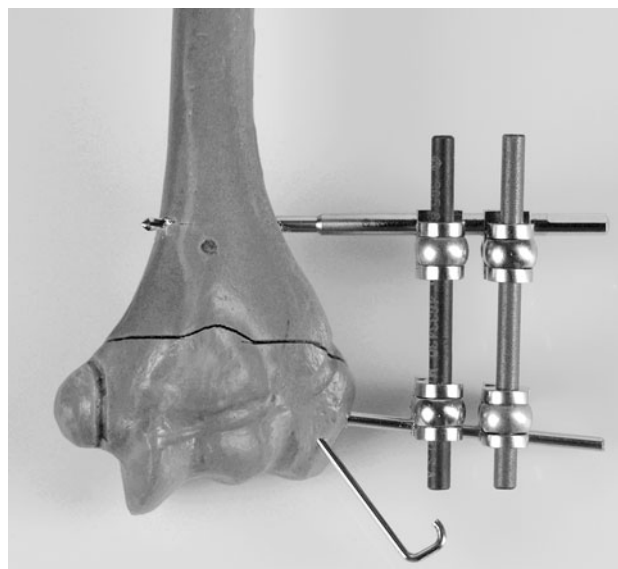


Fig. 1 Position of the small external fixator in a bone model

parallel to the elbow joint. For the second pin (3 mm), a small incision was made to allow the insertion of a drill sleeve to protect the soft tissues, and the pin was placed into the distal metaphysis. The pin was inserted rectangular to the longitudinal axis of the humerus from lateral to medial, and secured in the medial cortex. If satisfactory reduction was not achieved initially, the pins were then used as joysticks to manipulate the fragments. Open procedures were only required due to unsatisfactory reduction in four of our patients.

Stabilization was achieved by connecting the proximal and distal pin with two 4 mm carbon fiber rods. In addition, to enhance rotational stability, a 1.6 mm K-wire was inserted from a distal lateral starting point, directing upward and medially, and secured in the medial cortex. The K-wire was shortened and left in place. The definitive results, alignments and positions of the implants were finally monitored with an image intensifier.

A dry sterile dressing was applied and a cuff and collar or a long arm cast was placed according to the surgeon's preference.

Follow-up

The patients were discharged on postoperative day 1 or 2. Postoperative X-ray was performed in all patients before discharge. Daily pin care was assured mostly by the parents, and in some cases by the pediatrician. The children were followed once a week to check the pin tracks as well as motor and sensory neurological status. Immobilization was continued for about 4 weeks. A follow-up radiograph was obtained at 4 weeks and the pins were removed when good consolidation was demonstrated, either in the outpatient

Table 1 Criteria for grading outcome, as developed by Flynn et al. [7]

Result	Rating	Cosmetic factor: carrying-angle loss (degrees)	Functional factor: motion loss (degrees)
Satisfactory	Excellent	0–5	0–5
	Good	5–10	5–10
	Fair	10–15	10–15
Unsatisfactory	Poor	>15	>15

office or in anxious children under general anesthesia. Unrestricted elbow motion was then allowed and encouraged. Long-term follow-up included clinical and radiographical examinations 3 months postoperatively, followed by clinical examinations on a yearly basis. The final outcome was reviewed by measuring range of motion, valgus-varus deformity in comparison to the contralateral side, as well as by proving the neurovascular status. The results were rated according to the criteria of Flynn et al. [7] by evaluating carrying angle, malalignment, and loss of motion.

Statistical analysis

In this report, all data are expressed as means, standard deviations and ranges. To estimate the relative risk for radial nerve injury, the 95% confidence interval assuming a Poisson distribution was calculated.

Results

Twenty-nine patients were included in the study (14 girls and 15 boys). The mean age at injury was 6.5 ± 1.7 years (range 2.4–9.9 years). The right arm was involved 11 times, and the left arm 18 times. Twenty-eight patients had a Gartland type III fracture, while one child presented with a Y-type fracture of the distal humerus (Table 2).

In 24 patients (83%), we decided preoperatively on the basis of the degree of dislocation to stabilize the fracture with lateral external fixation. Five patients (17%) initially underwent closed reduction and K-wire fixation, 4 in our clinic and one in another hospital; inadequate reduction or

instability on the early postoperative follow-up X-ray necessitated revision, and lateral external fixation was performed.

Open reduction was necessary because of unsatisfactory reduction in four patients (14%), three with Gartland type III fractures and one with a Y-type fracture. One of these patients showed compromised hand perfusion after reduction, and the entrapped radial artery had to be explored and freed surgically.

Neurological complications

Upon routine preoperative examination, only one patient presented with partial motor palsy of the ulnar nerve, which resolved spontaneously after reduction and fixation of the fracture. One patient showed partial motor palsy of the median nerve postoperatively, with complete spontaneous recovery.

Postoperatively, 3 serious neurological complications (10%; 95% confidence interval, 2–30%) occurred in the form of complete radial palsy. In these 3 patients, the preoperative neurovascular status was intact. All 3 patients had a high-positioned proximal pin, 2.9–3.6 cm above the fracture line (Fig. 2), in common. The first patient, an 8-year-old girl, underwent microsurgical revision after 4 days, and we

Table 2 Patients, fracture types and treatments

	Number	Percentage
Total number of patients	29	100
Female	14	48
Male	15	52
Fracture type		
Gartland type III	28	97
Y type fracture	1	3
Side of injury		
Right	11	38
Left	18	62
Treatment		
Primary	24	83
Secondary	5	17
Reduction		
Closed	25	86
Open	4	14

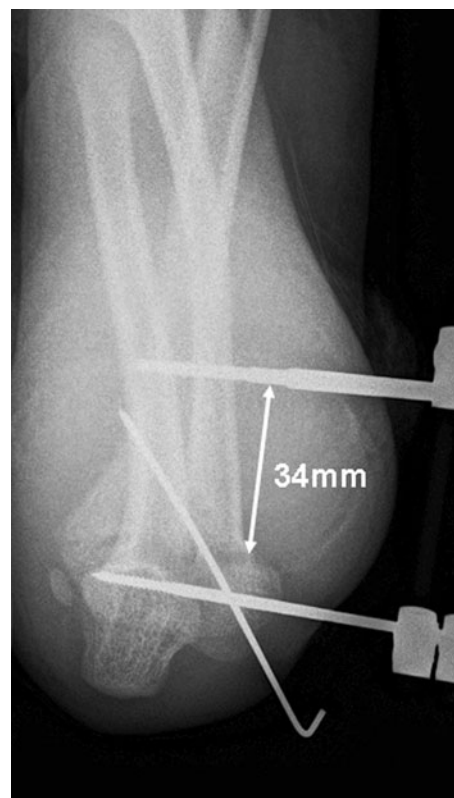


Fig. 2 Example of a high-positioned proximal pin in a patient with iatrogenic radial nerve injury

found the radial nerve to be in direct contact with the proximal pin. The nerve showed a hematoma and the transection of a small number of nerve fascicles at the level of the implant, indicating an iatrogenic injury of the radial nerve. After microsurgical nerve repair, full recovery of the radial nerve was achieved within 7 months. The second patient, a 12-year-old boy, had complete postoperative sensorimotor radial palsy. Microsurgical exploration on the third postoperative day showed an iatrogenic neurotmesis of the radial nerve next to the proximal pin. Nerve repair with a sural nerve graft allowed full recovery of sensorimotor function with only a mild Tinel phenomenon persisting at the level of the nerve lesion. Surgical exploration in the third patient with clinical radial palsy, a 5-year-old boy, did not show macroscopic damage of the nerve, and complete recovery of the neurapraxia was observed within 2 months. However, it remains unclear whether the nerve dysfunction was caused by the procedure or by the initial trauma.

Follow-up was performed in our outpatient clinic. One patient presented a superficial pin tract infection, needing oral antibiotic therapy. No other complications occurred.

The external fixator was removed after consolidation (mean 4 ± 0.5 weeks, range 3.4–5.1 weeks). The removal was uneventful in all patients: in 17 children (59%) it was performed under general anesthesia, and in 12 (41%) under nitrous oxide administration in the outpatient clinic.

At the last clinical follow-up (mean 17.2 ± 9.8 months, range 3–38 months), none of the patients showed signs of growth arrest or disturbance. The cosmetic results were good (8%) or excellent (88%); only one patient (4%) had a loss of carrying angle (of 20° , rated poor). The functional outcome was excellent in 83%, good in 10%, and fair in 7% (Table 3). No muscular atrophy or loss of strength was seen, and neurological status was intact in all patients.

Discussion

Successful treatment of displaced supracondylar humeral fracture in children depends on safe and stable reduction and fixation of the distal fragment to prevent axial rotation and hyperflexion in order to avoid postoperative deformity

Table 3 Surgical outcomes according to the criteria developed by Flynn et al. [7]

Result	Rating	Cosmetic factor: carrying-angle loss (%)	Functional factor: motion loss (%)
Satisfactory	Excellent	88	83
	Good	8	10
	Fair	–	7
Unsatisfactory	Poor	4	–

[1, 8, 9]. Fixation techniques after reduction of supracondylar fractures in children are still the source of controversy in the literature. Some advocate lateral entry pins only, because lateral pinning avoids injury to the ulnar nerve, but this provides reduced mechanical stability. Others advocate medial/lateral entry pins with at least one medial and one lateral pin, which provide enhanced mechanical stability but also an increased risk of potential iatrogenic injury to the ulnar nerve (reviewed by Brauer et al. [10]). As an alternative to K-wire fixation, elastic stable intramedullary nailing (ESIN) has also been reported to provide good stability and avoid iatrogenic lesions of the ulnar nerve [11–13].

External fixation is a well-established method for the treatment of fractures at different locations, and has also been advocated in supracondylar fractures of the humerus [5, 6].

In our series we were able to show good to excellent cosmetic results in 96% and good to excellent functional results in 93% of patients with this method. Nevertheless, iatrogenic radial nerve injuries occurred in three patients, thus necessitating surgical revision in all patients and a sural nerve autograft in one patient. Fortunately, all three patients recovered entirely after revision.

In 1986 Taller et al. [5] first described the use of an external fixator as alternative treatment for displaced supracondylar humeral fractures in children. Gris et al. [14] published their results on the use of a transarticular external fixator for the treatment of unstable supracondylar humeral fractures in thirteen pediatric patients in 2004. The method was described as simple and versatile, combining the advantages of traction and surgical fixation. In 2008, Slongo et al. [6] published their experience with lateral external fixation, which is comparable to the method described in this paper. Thirty-one children with Gartland type III fractures were treated with good results. No major complications occurred, and they concluded that lateral external fixation is a safe alternative for the treatment of displaced supracondylar fractures when closed reduction appears to be unattainable by means of manipulation alone, or when sufficient stability is not achieved with standard methods of K-wire fixation [6]. Our own experience coincides with theirs, and overall results of long-term outcome in our patients with unstable or markedly displaced supracondylar fractures were good to excellent. The external fixator has been shown to be an additional treatment option for supracondylar humeral fractures in children. Our data support the recommendations of Slongo et al. [6]; the main indications are fractures of the distal humerus, which potentially remain unstable with classical methods (mainly type III fractures and oblique fractures in the sagittal plane), fractures that are irreducible when the usual techniques are applied, and secondary dislocated

fractures after closed reduction and unilateral percutaneous pinning. Nevertheless, we observed neurological complications in 10% of our patients, questioning the safety of this method.

Iatrogenic injury of the distal radial nerve may occur during surgery and has been described in adults, particularly with distal locking screws of intramedullary nails [15, 16]. Different anatomic studies have explored the course of the radial nerve in adults and labeled the distal one-third of the humerus a “danger zone” due to the tethering of the radial nerve as it passes through the lateral intermuscular septum [17–19]. The radial nerve passes from the posterior to the anterior compartment of the arm at the junction of the middle and distal thirds of a line drawn from the lateral edge of the acromion to the lateral humeral epicondyle [19].

When we introduced lateral external fixation in 2005, the method included inserting the proximal pin into the distal metaphysis; the exact pin placement was not further defined at this time. Concerned by the occurrence of radial nerve injuries, the cases were carefully reviewed. It was found that in all patients with such injuries, the proximal pin was inserted too high: 2.9–3.6 cm above the fracture line in the so-called “danger zone.” In two patients, direct injury to the radial nerve caused by the pin was visible; in one patient the nerve was intact at revision, and contact with instruments or the implant must be considered a potential cause of neurological dysfunction. We have to admit that the anatomic conditions were not respected, and as a consequence we defined that the proximal pin has to be placed in an open technique distally, avoiding proximal metaphysis. This rule was reinforced by the publication of Slongo et al. [6], which advocated that the pin should be placed within 2 cm of (above) the fracture line.

In the pediatric age group, the small bone surrounded by fat, swollen soft-tissue makes it particularly difficult to correctly place a pin. Detailed knowledge of the local anatomy is vital, and individual variability in radial nerve location must be taken in account during the surgical procedure [17]. Furthermore, radiographic and clinical confirmations of the orientation of distal alignment are important, as the altered anatomy of a dislocated fracture can additionally increase the risk of neurovascular injury [4]. Despite using a drill sleeve, we had a high number of radial nerve lesions. In our experience, the altered anatomical conditions may lead to high insertion of the proximal pin. We therefore strongly recommend a formal incision and retraction of the soft tissue before inserting the proximal pin. The pin can then be placed under direct vision within 2 cm of the fracture line using a drill sleeve. The advantage of smaller incisions does not outweigh the disadvantage of possible nerve injury.

The management of postoperative neurological compromises after supracondylar fractures of the humerus is controversial. Postoperative palsy of the median and ulnar nerve is common and may exceed 10% in Gartland type III fractures [20]. Since most of these injuries occur due to traction of the nerve during the dislocation, most lesions are neurapraxias and usually recover spontaneously within approximately 8 weeks. If these lesions are associated with a vascular compromise, entrapment of nerves and arteries is more likely and early revision should be considered [20, 21]. Lesions to the radial nerve are a completely different issue in supracondylar fractures because this nerve is less likely to suffer traction injuries during dislocation. If iatrogenic lesions due to the operative technique can be excluded, an observation period of 8 weeks seems reasonable. If there is any suspicion, however, that the nerve may have been injured surgically, we advocate early revision within days or at the time of removal of the implants.

Although good results can be achieved in children after microsurgical reconstruction, even with delayed nerve repair, procedures become more difficult in this case, and intraoperative evaluation of a neuroma in continuity is very difficult.

Its retrospective nature and the lack of a control group are the main limitations of this study. Nevertheless, the review of our patients treated with this new method demonstrated that lateral external fixation is an effective therapy for markedly displaced supracondylar fractures in children, but it also shows that there is a risk for radial nerve damage (95% confidence interval, 2–30%) during insertion of the proximal pin.

Conclusion

In conclusion, lateral external fixation of supracondylar humeral fractures in children is an alternative method for the treatment of displaced or unstable fractures. One lesson to be learned from this study is that even though lateral external fixation is a simple method that facilitates the reduction and stability of fixation of the fracture, iatrogenic radial nerve injury during insertion of the proximal pin is a risk. The indication for lateral external fixation therefore needs to be deliberated over. It should be performed by an experienced surgeon who is aware of the local anatomy. We strongly recommend inserting the proximal pin under direct vision within 2 cm of the fracture line, using a drill sleeve.

Conflict of interest The authors declare that there is no actual or potential conflict of interest in relation to this article.

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