Surgical treatment of traumatic pediatric humeral diaphyseal fractures with titanium elastic nails

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Received: 16 September 2008 / Accepted: 24 February 2009 / Published online: 13 March 2009
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Abstract

Background Nearly all pediatric humeral shaft fractures can be successfully treated with closed methods. Some patients, however, require internal fixation either because of an inability to maintain an adequate reduction, significant soft tissue injury, or concomitant fractures.

Methods This is a retrospective review of all traumatic humeral shaft fractures treated at our hospitals between 1999 and 2006. Thirteen pediatric patients ranging in age from 4.8 to 16.7 years (mean age 12.0 years) were treated surgically with titanium elastic nails (TENs). Relative surgical indications included open fractures, inability to maintain an acceptable reduction, the presence of ipsilateral forearm fractures (floating elbow), concomitant lower extremity fractures, and closed head injury. Two patients had associated radial nerve injury at presentation.

Results The patients were followed for a mean of 29 months. All fractures healed in good alignment. There were no intraoperative complications, including neurologic

or vascular injury, and no patient developed an infection postoperatively. Two patients had nail migration, one of whom developed nail protrusion through the skin. One patient with preoperative radial nerve injury ultimately underwent tendon transfer to restore wrist extension. Of the 13 patients, 12 reported a full return to sports and other activities with no limitations or discomfort.

Conclusions When surgical stabilization of pediatric humeral shaft fractures is indicated, TEN fixation is effective and has a high rate of union and a low rate of complications. This technique is familiar to most orthopaedic surgeons treating pediatric fractures.

Level of evidence Level of evidence: IV (case series)

Keywords Complications · Elastic nails · Fixation · Fracture · Humerus · Intramedullary · Pediatric · Trauma

Introduction

Humeral shaft fractures comprise approximately 2.5% of all traumatic fractures in children and are second only to the clavicle in birth fracture incidence [1–3]. Pathologic fractures through unicameral bone cysts are also extremely common. Humeral shaft fractures uniformly do well from a functional and cosmetic standpoint following non-operative treatment using functional bracing, coaptation splinting, hanging arm casts, or sling immobilization. Newborns and infants have substantial remodeling capability, and deformities up to 45° [1] remodel with growth. Older children also have a certain amount of remodeling potential; however, authors have recommended that the deformity should be reduced to <30° for proximal third, <20° for middle third, and <15° for distal third shaft

This study was conducted at Washington University School of Medicine, St. Louis Shriners Hospital for Children, and St. Louis Children's Hospital, St. Louis, Missouri, USA.

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fractures before proceeding with non-operative treatment [1, 3, 4]. These guidelines are generally not due to functional limitations but rather for cosmesis.

Indications for surgical stabilization of humeral shaft fractures in children are mainly associated with improved mobilization in polytrauma, wound care in open injuries, and nursing care in children with closed head injuries. A small number of fractures are unable to be reduced adequately or maintained in adequate alignment, and these should also be treated surgically. The surgical treatment of humeral shaft fractures in adults involving the use of plate and screw constructs, rigid nails, and flexible nails has been extensively studied both retrospectively and prospectively [1, 5–12]. However, the amount of information in this field available on pediatric patients is quite limited. At our institution, titanium flexible nails are the preferred implant for stabilizing humeral shaft fractures operatively. While there are a handful of adult case series reporting excellent healing with Enders nails [13, 14], there are no dedicated reports in the pediatric literature describing the results of this technique and its complications [10–12]. Several small case series have shown the efficacy of this implant in treating pathologic humeral shaft fractures in children and, in particular, in promoting healing in unicameral bone cysts [15–17]. The aim of this report is to describe the technique and results of operative stabilization of pediatric humeral shaft fractures with titanium elastic nails.

Materials and methods

After obtaining institutional review board approval for the study, we used the operative logs of the two senior authors (J. E. Gordon, M. B. Dobbs) to identify all children with humeral shaft fractures treated operatively at our institution between 1999 and 2006. Thirteen patients were identified who were treated with a titanium elastic nail system (Synthes, Paoli, PA). During this period of time, no other technique was used to stabilize humeral diaphyseal fractures. Medical records from the emergency room, operating room, hospital, and outpatient clinic were reviewed to establish the mechanism of injury, indications for surgical treatment, technique of fracture stabilization, and complications of surgical treatment. Anteroposterior and lateral radiographs were reviewed to evaluate fracture healing. Healing was defined as cortical contiguity in all four cortices seen on standard anteroposterior (AP) and lateral radiographs of the humerus. Patients with diaphyseal fractures of the humerus are routinely followed for approximately 3–6 months after healing and then on an as-needed basis. As part of this study, patients were contacted via the telephone to inquire about their

functional status. Several patients also returned for clinical evaluation.

Surgical technique

The surgical technique was based on the principles described by the originators of the flexible nail implants in France [18]. When retrograde insertion was utilized, a longitudinal incision is made laterally at the level of the lateral epicondyle. The cortex is opened with a 3.2- or 4.5-mm drill bit, depending on the size of the implant desired, and the drill is advanced under image intensification through the lateral column of the distal humerus into the medullary canal. The size of the implant is selected to be approximately 40% of the diameter of the canal, and two equally sized implants should be used to prevent asymmetric force on opposite cortices. In general, implants were in the range of 2.5–3.5 mm. The nail is prebent and driven to the fracture site, reduction is then obtained in a closed or open manner, and the implant is subsequently driven proximally to stabilize the fracture. A second small incision is then made over the medial epicondyle. This is extended adequately to both visualize and protect the ulnar nerve or to allow blunt dissection down to the medial epicondyle with a hemostat to assure that the ulnar nerve is not within the operative field. Again, a 3.2- or 4.5-mm drill is used to open the cortex and drill through the medial column into the medullary canal. A second nail is then selected, prebent and advanced to the fracture site, advanced across the fracture site, and impacted into the proximal humerus. The nails are driven proximally to within 1–2 cm of the proximal humeral physis, cut as close as possible to the insertion site, and impacted into place. Alternatively, both retrograde implants can be inserted through the lateral cortex to decrease risk of injury to the ulnar nerve as was done in two cases in this series (Figs. 1, 2).

When antegrade insertion is indicated, a longitudinal incision is made over the proximal humerus at the level of the greater tuberosity, and dissection is taken down sharply to the humeral metaphysis distal to the physis. The rotator cuff is incised in line with the fibers. Image intensification is used to confirm the starting point. The cortex is entered using a 3.2- or 4.5-mm drill bit and the opening subsequently enlarged using a clamp. A single flexible nail is inserted into the bone and passed into the distal fracture fragment as far as possible into the supracondylar area. The procedure is repeated to add a second implant. A small portion of the nail is left out of the cortex proximally to facilitate removal (Fig. 3). Closure is routine with the rotator cuff closed using absorbable suture.

The principles of elastic nail use would suggest that the ideal configuration is equally sized nails inserted retrograde

Fig. 1 **a** Anteroposterior radiograph of the humerus in an 11-year-old male showing a displaced diaphyseal fracture sustained in a motor vehicle collision. **b** Anteroposterior and lateral radiographs of the forearm in the same patient showing displaced diaphyseal fractures of the radius and ulna. **c** Oblique radiograph of the humerus showing retrograde intramedullary stabilization of the humerus fracture through the medial and lateral columns of the humerus with titanium elastic nails also visualized in the radius and ulna

Fig. 2 **a** Anteroposterior radiograph of the humerus in a 13.9-year-old female showing a displaced proximal third humerus fracture sustained as a pedestrian struck by a motor vehicle. The patient also sustained an ipsilateral clavicle fracture and a closed head injury. **b** Anteroposterior radiograph of the humerus in the same patient

4 months after injury showing complete healing of the fracture after stabilization using retrograde nailing, with both nails placed through the lateral column of the humerus. **c** Anteroposterior view of the humerus in the same patient 6 months after injury and 2 weeks after nail removal, showing a healed fracture in good alignment

through opposite cortices, thereby allowing for symmetric forces to be imparted by the flexible nails on the cortical bone [18, 19]. This is our currently preferred method for fractures in the distal half of the humerus and is the predominant method used in the series described.

Postoperative care

In patients with an ipsilateral radius or ulna fracture, the forearm fracture was stabilized with either Kirschner wire fixation or titanium flexible nails and placed into a

Fig. 3 **a** Lateral radiograph of the humerus in a 9.0-year-old female after a motor vehicle collision. Her arm went through plate glass, resulting in massive soft tissue injury with radial nerve deficit. The radiograph shows the contaminated soft tissue injury and midshaft fracture. **b** Anteroposterior radiograph of the humerus in the same patient 4 months after injury showing complete healing of the fracture after stabilization using antegrade nailing

posterior elbow splint. Patients without ipsilateral upper extremity fracture were either splinted or placed into a soft dressing and given a sling for comfort for 10–14 days. No routine physical therapy was prescribed. Mobilization out of bed without restriction was permitted for patients with isolated injuries. Patients with lower extremity fractures were permitted to bear weight on the upper extremity as tolerated. Radiographs were typically obtained 2 weeks postoperatively to check for loss of reduction, 6 and 12 weeks postoperatively to evaluate healing, and as needed after 12 weeks.

Patient demographics

We identified 13 patients (eight boys, five girls) who had humeral shaft fractures treated surgically with elastic nails at our hospitals between 1999 and 2006 (Table 1). The average age of the patient at the time of injury was 12 years (range 4.8–16.7 years). The mechanism of injury was motor vehicle collision (three patients), pedestrian struck by motor vehicle (three patients) or all-terrain vehicle (four patients), playground fall (two patients), and fracture due to gunshot wound (one patient). There were three open injuries; one each Gustilo and Anderson grade IIIA and IIIB and a fracture due to the gunshot wound [20]. Two of these patients had a radial nerve injury. One radial nerve injury was a neurapraxia, and the other involved transection of the radial nerve associated with an open

fracture. This latter patient underwent primary repair of the nerve. Associated injuries included four children with a closed head injury, five with pelvis and/or lower extremity long bone fractures, and five with either floating elbow or shoulder. Many had multiple associated injuries. The indications for surgical stabilization included two fractures that could not be maintained in acceptable alignment closed and were, therefore, treated operatively. The indications for surgery in the remaining 11 patients was to allow wound care for a severe open fracture (three patients), provide stability in the face of ipsilateral upper extremity fractures (five patients), and to allow mobility in the face of closed head injury or lower extremity fractures (three patients). The average follow-up was 29 months (range 1.5–90.8 months). Nine patients had elective removal of their implants after healing at an average of 8.3 months post-surgery (range 2.6–26.1 months).

Results

Two patients were treated with antegrade insertion of the nails, the remaining 11 with retrograde insertion. Of the retrograde insertions, nine had medial and lateral entry portals, and two had dual lateral entry portals. With the exception of the open injuries, all fractures were reduced with the closed technique. There were no immediate postoperative complications. All fractures united without

Table 1 Patient demographics, injury description, and indications for surgery

Patient	Gender	Age at injury (years)	Nail entry site	Open injury	Mechanism of injury	Associated injuries	Surgical indication	Complication	Follow-up (months)
1	F	13.9	Retrograde	No	Pedestrian struck by motor vehicle	Ipsilateral clavicle fracture, CHI	CHI	None	5.5
2	M	15.7	Retrograde	No	Fall from standing height	Pelvic fractures, CHI	Lower extremity fractures	None	90.8
3	M	15.8	Retrograde	No	ATV accident	Ipsilateral AC separation, contralateral forearm fracture	Bilateral UE fractures	None	28.3
4	F	10.2	Retrograde	Yes, IIIA	ATV accident	Ipsilateral both bone forearm fracture	Open injury, floating elbow	None	21.7
5	M	16.7	Retrograde	Yes, gunshot	GSW	Abdominal GSW	Polytrauma	Nail migration	16.3
6	F	9.1	Antegrade	Yes, IIIB	Motor vehicle collision	None	Open injury	None	14.0
7	F	13.2	Antegrade	No	ATV accident	Cervical spine fractures, pelvic fractures	Lower extremity fractures	None	7.9
8	F	4.8	Retrograde	No	Pedestrian struck by motor vehicle	Ipsilateral femur fracture, CHI	Lower extremity fracture	None	19.7
9	M	14.4	Retrograde	No	Motocross accident	CHI	Irreducible fracture	None	16.3
10	M	16.2	Retrograde	No	Motor vehicle collision	Abdominal organ injury	Irreducible fracture	None	26.1
11	M	8.1	Retrograde	No	Motor vehicle collision	Ipsilateral forearm fracture, Bilateral tibia fractures	Floating elbow, lower extremity fractures	None	52.3
12	M	9.7	Retrograde	No	Fall from jungle gym	Ipsilateral forearm fracture	Floating Elbow	Nail protrusion	1.4
13	M	8.7	Retrograde	No	Pedestrian struck by motor vehicle	Ipsilateral tibia fracture	Lower extremity fracture	None	79.3

ATV All-terrain vehicle, GSW gun shot wound, CHI closed head injury, AC acromioclavicular joint, UE upper extremity, M male, F female

an angular or translational deformity $>10^\circ$ within 12 weeks.

Two patients developed delayed complications: one had nail migration distally and required a return trip to the operating room to have his nails trimmed; the second missed his initial postoperative appointment, and when his dressing was removed 6 weeks after surgery in the clinic, both nails had migrated distally through the skin. There was no clinical evidence of infection in this latter patient, and the fracture was united radiographically. The nails were removed in the clinic, and the wounds left open to heal secondarily. The patient did not attend follow-up after that visit and was unable to be reached by telephone or mail thereafter.

One patient with a radial neurapraxia recovered function spontaneously within 4 months after injury. The other patient with radial nerve injury did not recover function after primary repair and was treated with tendon transfers approximately 1 year after the injury to restore wrist extension. She had sustained a grade IIIB open injury of her humerus when the plate glass from her vehicle's windshield sheared through her upper arm, transecting the radial nerve. The only patient with a limited range of motion following healing had sustained a gunshot wound and fracture and lacked 10° of extension and 25° of flexion at the last clinical evaluation. No patient developed a deep infection. Of the 13 patients, 11 had returned to all activities at the time of last follow-up. None of these 11 patients reported limitations or pain. The two patients who had not returned to full activities at the last follow-up included the patient with persistent radial nerve injury and the patient who was lost to follow-up 6 weeks postoperatively after the removal of his implants in clinic.

Discussion

Children with traumatic humeral shaft fractures require operative treatment only infrequently, primarily in cases where surgical stabilization of humeral shaft fractures is required to assist with patient mobilization, wound care, or the maintenance of adequate alignment. In many patients, more than one of these indications is present. The surgical technique of stabilizing humeral shaft fractures with titanium elastic nails is straightforward and can be performed in either a retrograde or antegrade manner. Establishing an antegrade entry is perhaps more straightforward; however, this approach requires that the rotator cuff be incised in line with its fibers. Retrograde entry is our current preference, although it also requires careful opening of the cortex to avoid iatrogenic distal humeral fracture and careful dissection to avoid iatrogenic nerve injury. Antegrade entry is used when severe soft tissue trauma about

the elbow contraindicates an entry point at the medial or lateral epicondyle. Stainless steel nails may theoretically provide increased rigidity in these fractures, with a lower incidence of migration and faster healing while maintaining a high union rate with minimal dissection, although we have not used stainless steel nails in this application.

The results presented here demonstrate that flexible nails provide the stability required to allow for timely fracture healing in children with traumatic humeral shaft fractures. Most of the children of our patient cohort have returned to full activity. While all fractures healed without delay or malunion, there were two significant cases of nail migration. Treating surgeons must be vigilant and regular in carrying out follow-ups to ensure that the nails remain in an adequate position throughout the healing period. Any child with evidence of nail migration and especially impending skin breakthrough should return to the operating room for revision of fixation or trimming of the implants. After healing, the removal of implants need not be done routinely; however, our experience suggests that many families prefer that the nails be removed.

Conclusion

Titanium elastic nail fixation is an ideal procedure for treating humeral shaft fractures in which stabilization is indicated as it provides stable fixation, with minimal soft tissue stripping at the fracture site, and allows early mobilization of the extremity. In addition, patients with concomitant lower extremity fractures can be mobilized more rapidly because of the increased ability to weight bear through the extremity. The surgical technique is straightforward and is familiar to most pediatric orthopedists due to its widespread use in the treatment of other fractures in children [18, 21–27]. Surgical stabilization of humeral shaft fractures in children, when indicated, can be safely performed using titanium elastic nails.

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