Evaluation of Pediatric Lower Extremity Fractures Managed With External Fixation: Outcomes in a Deployed Environment

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Abstract

External fixation of pediatric lower extremity fractures is usually reserved for severe, open fractures in poly-traumatized patients, but it is often the only available treatment option for deployed military surgeons. We analyzed the outcomes and complications of 17 consecutive pediatric long bone fractures treated with external fixation at a Forward Surgical Team facility in an austere environment during Operation Enduring Freedom in Afghanistan during a 12-month period.

Treatment consisted of uniplanar external fixation for 12 femoral shaft fractures (11 closed), 4 tibial shaft fractures (all open), and 1 subtrochanteric fracture (closed) in 14 males and 3 females with an average age of 7.4 years. All 17 fractures went on to union with no incidences of refracture. Complications included 1 broken pin and 3 pin site infections treated with wound care and oral antibiotics.

In a deployed environment, external fixation is the treatment method of choice for lower extremity fractures by virtue of patient, environment, equipment, and mission factors. This case series validates the usage of a simple, uniplanar external fixator for a variety of open and closed pediatric long bone fractures as evidenced by the successful union rate and low number of complications.

I n the study reported here, we retrospectively evaluated the outcomes and complications of external fixation of pediatric long bone fractures at a single Forward Surgical Team (FST) facility deployed to Afghanistan. We analyzed multiple factors, including age; fracture pattern; injury severity; time to union; and complications, including pin-site infections, refracture, nonunion, and need for additional procedures.

Management of pediatric lower extremity long bone fractures depends on a variety of factors, including age, fracture displacement, associated injuries, child size, surgeon experience, and implant and equipment availability.[1-3] In its guidelines for managing pediatric diaphyseal femur fractures, the American Academy of Orthopaedic Surgeons[1] (AAOS) recommended, depending on the factors involved, use of Pavlik harness in children aged less than 6 months, spica cast in children aged 6 months to 5 years, and operative fixation (with plates, flexible intramedullary nails, or rigid intramedullary nails) for children aged 5 years to 11 years. Surprisingly, the AAOS guidelines offer few details in regard to the option of external fixation, despite there being several studies demonstrating its efficacy.[4-6] The only external fixation study specifically cited in the guidelines is one that compared external fixation and spica casting.[7] That study showed that fewer malunions occurred with external fixation than with spica casting.

External fixation is an accepted method for managing diaphyseal femur fractures in Europe but is used less often in the United States. Use of external fixation is typically limited to severe polytrauma scenarios or open fractures with severe soft-tissue injuries.[8] The most

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Figure 1. Soft-tissue complications from hip spica casting.

Figure 2. Application of external fixation for closed femur fracture.

Figure 3. Patient ambulating on limb with external fixation.

Figure 4. External fixator construct with broken 3.0-mm half-pin.

significant drawbacks to use of external fixation, particularly for femur fractures, are pin-site infections and perceived risk for refracture.[9-11] Other complications are perceived difficulty of care, bulkiness, and undesirable appearance.[4,6]

Tibia fractures in the pediatric population most often are managed with cast immobilization. When operative fixation is used, it is usually in the form of plates, flexible intramedullary nails, and external fixation.[12] Primary indications for external fixation are for polytrauma and injuries with significant soft-tissue injuries.[12]

Our FST deployed to eastern Afghanistan for 12 months to provide trauma surgical care to US and coalition forces, as well as humanitarian and surgical care to host nation civilians. Injuries among the civilians included pediatric lower extremity fractures with a variety of causes, such as penetrating trauma, blunt trauma, and falls. Medical care in the region was lacking in surgical and orthopedic expertise. As part of our civil affairs and humanitarian mission, we provided care to the local nationals with the limited resources available.

Our ability to follow the AAOS guidelines for managing pediatric lower extremity fractures was limited by 2 major factors. First, FST inventory does not include anything 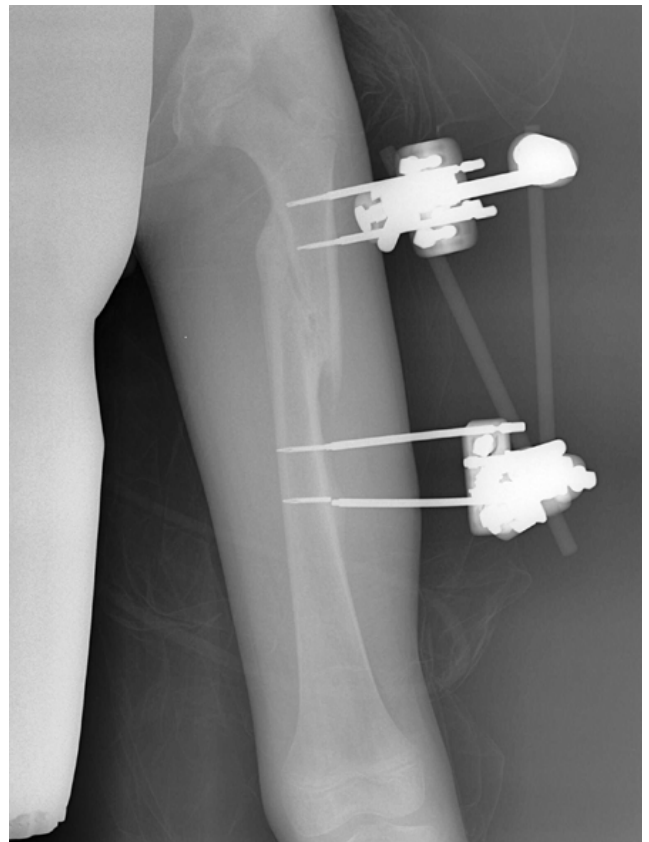other than external fixators and splinting materials, which is intended to meet the primary mission of damage control orthopedics followed by evacuation to where the next appropriate level of care can be provided. The second factor is the reported failure of hip spica casting for similar injuries in this patient population. FST facilities had been in the area for several years during the current operation, and surgeons in after-action reviews had reported on the complications and failures of plaster application and hip spica casting secondary to the inability to keep the casts clean. Living conditions in this part of the world presented obstacles not routinely encountered in the United States and resulted in recurring or persistent skin complications, including maceration, rashes, cellulitis, and skin breakdown (Figure 1). With these lessons learned, we used external fixation as the definitive management for lower extremity long bone stabilization for pediatric patients in whom surgical stabilization or hip spica casting would otherwise have been indicated according to the AAOS guidelines.

MATERIALS AND METHODS

Before initiating this study, we obtained institutional review board approval for analysis of a cohort of patients. Seventeen consecutive pediatric patients' lower extremity long bone fractures were managed with external fixation between February 2010 and February 2011 in Paktika Province, Afghanistan.

Figure 5. Pin sizes in Hoffman External Fixation Set (Stryker, Mahwah, New Jersey). Recommendation: use 4.0-mm or 5.0-mm half-pins only.

All fractures were stabilized with the Hoffman External Fixation Set (Stryker, Mahwah, New Jersey). Surgical management involved placing a unilateral Hoffman external fixator with 2 or 3 pins proximal and distal to the fracture site with the patient under general anesthesia (Figure 2). Standard pin-placement technique was used; there was no predrilling, and the pins were placed by hand using a t-handled chuck. Reduction was confirmed with use of a small fluoroscopy unit and postoperative plain radiographs.

With the assistance of interpreters, patients and their families were instructed about pin care, which involved using cotton-tipped applicators and bottled sterile water. Frame dynamization was not performed. Radiographs typically were obtained at 1-month intervals. Patients (and their families) were encouraged to ambulate once it became tolerable to bear weight on the involved extremity.

External fixators were removed on an outpatient basis once 3 to 4 cortices of healing were evident on radiographs. All patients had resumed independent ambulation by time of frame removal (Figure 3). Anesthesia was not required for fixator removal. No other immobilization or weight-bearing restrictions were used after fixator removal.

Patients who had pin-site drainage, but no frank purulence or cellulitis, were treated with povidone-iodine (Betadine) swabs and bacitracin ointment. Patients with purulent drainage or cellulitis also were treated with oral antibiotics for 1 week.

For each case, final follow-up included assessment and radiographs. Physical examination included assessment of joint range of motion (ROM) above and below the fracture, obvious deformity or leg-length discrepancy, and limp. Radiographs were evaluated for residual angulation or malunion. Mean values were calculated and recorded for each linear data point. Values were compared with historical values (values from other studies using external fixation).

RESULTS

Seventeen consecutive pediatric patients (14 boys, 3 girls) with lower extremity long bone fractures were treated over a 12-month period. Mean age was 7.4 years. The 17 fractures consisted of 12 femoral shaft fractures (1 open), 4 tibial shaft fractures (all open), and 1 closed subtrochanteric fracture (Table I). Most of the fractures were uncomplicated closed femoral shaft fractures. For

Table I. Management Results

Patient	Age, y	Sex	Fracture Location	Open/ Closed	Mechanism of Injury	Associated Injuries	Additional Surgery	Fixation Duration, d	Complications
1	6	F	Femoral diaphysis	Closed	Fall	None	None	47	None
2	5	M	Femoral diaphysis	Closed	Fall	None	None	35	None
3	6	M	Femoral diaphysis	Closed	Fall off donkey	None	None	50	None
4	13	M	Tibial diaphysis	Open	Fall in well	Pelvis fracture	EF adjustment	56	None
5	8	F	Femoral diaphysis	Open	Hit by motorcycle	Mandible fracture	None	61	Pin breakage
6	10	M	Femoral diaphysis	Closed	Run over by tractor	Pelvis fracture	None	55	Pin-site infection
7	9	M	Femoral diaphysis	Closed	Run over by tractor	None	None	94	None
8	2	M	Femoral diaphysis	Closed	Fall down stairs	None	None	41	None
9	7	F	Subtrochanteric	Closed	Fall in well	None	None	92	None
10	13	M	Tibial diaphysis	Open	Motor vehicle collision	None	None	98	None
11	7	M	Tibial diaphysis	Open	Fall	None	None	35	None
12	5	M	Femoral diaphysis	Closed	Fall	None	None	68	None
13	7	M	Femoral diaphysis	Closed	Run over by tractor	None	EF adjustment	96	None
14	10	M	Femoral diaphysis	Closed	Hit by boulder	None	None	112	Decreased Knee ROM
15	5	M	Tibial diaphysis	Open	Mortar blast	None	Knee I&D, EF revision, STSG	101	Pin-site infection
16	8	M	Femoral diaphysis	Closed	Fall from tree	None	None	112	None
17	5	M	Femoral diaphysis	Closed	Fall off roof	None	None	96	Pin-site infection

Abbreviations:EF, external fixation; I&D, irrigation and debridement; ROM; range of motion; STSG, split thickness skin grafting.

Table II. External Fixation Recommendations

- Avoid hip spica casting so as to prevent skin complications.
- Use external fixation for patients indicated for operative stabilization of fractures.
- Use half-pins with minimum diameter of 4 mm to avoid breakage complications.
- Consider laterally based external fixation frames for early knee range of motion.
- Encourage hip and knee range of motion during management.
- No need for frame dynamization.
- Provide pin-care instructions and supplies.
- Encourage ambulation once it becomes tolerable.

all fractures, the mean time to union was 73.5 days, which corresponded to total time spent in the external fixator. For femoral shaft fractures, mean time to union was 72.5 days. Except for the subtrochanteric fracture, which was spanned from the iliac crest to the femur, all fractures were managed with non–joint-spanning frames.

Two patients underwent an operation to revise the external fixator. One patient, who had an open tibia fracture and an open knee arthrotomy, initially was treated with an external fixator spanning the distal tibia and the distal femur. On postoperative day 3, this patient was transitioned to a tibia-only external fixator after it was determined that the soft tissues over the proximal tibia would be amenable to half-pin placement. The other patient, who had a femoral shaft fracture, required a simple frame adjustment to correct unacceptable angulation. The surgical adjustment was made 1 week after initial application of the construct. This patient required no further procedures, and healing was uncomplicated.

Six of the 17 patients were evaluated with C-arm fluoroscopy only at final follow-up. On the C-arm fluoroscopic images, visualization of the entire femur or tibia was inadequate for drawing conclusions about length, alignment, or rotation. Final radiographs were available for the other 11 patients. Their mean (range) sagittal plane deformity was 5.3° (0°-20°), and their mean (range) coronal plane deformity was 3.4° (0°-10°). Lack of resources prevented us from assessing limb-length inequality with formal radiographic imaging, such as scanogram or even bilateral full-length standing radiographs, but in no patient was there a clinically symptomatic leg-length discrepancy or limp at latest follow-up. In addition, no clinically symptomatic rotational malalignment was evident during examination, whether by dial testing, hip rotation testing, or assessment of foot progression angle.

There were 6 complications: 3 pin-site infections, 1 loss of reduction, 1 broken fixator pin, and 1 case of decreased knee ROM. The patients with pin-site infections were reeducated about pin-site care and given 7 days' worth of oral antibiotics; in each case, the infection resolved. The patient with loss of reduction underwent fixator revision. The patient with the broken fixator pin (the only component failure) had the pin removed when the external fixator was removed (this pin, a half-pin 3-mm in diameter, was found broken on fracture union; [Figure 4]. Thereafter, we began using 5-mm half-pins for larger children and half-pins no smaller than 4 mm for smaller children [Figure 5], and no additional pin failures were observed). Lastly, the patient with decreased knee ROM (the only such complication) had a closed femoral shaft fracture managed with a laterally based external fixator frame. On completion of healing and frame removal, knee ROM was 0° to 45°. This patient had been ambulating for approximately 3 weeks before frame removal. No associated injury was found on initial evaluation or during the immediate postoperative period. The presumed cause of loss of ROM was disuse, as the patient and family reported improved motion with ambulation during the weeks leading up to frame removal.

Mean follow-up after frame removal was only 6.3 days. Most patients did not return after frame removal—which is the major weakness of this study. However, as we represented the only medical assets within several hundred miles, we assumed that no refractures occurred during this year in theater. No disfigurement or excessive scarring was noted, even in the patients with pin-site infections.

DISCUSSION

The primary mission of FSTs is emergent surgical support of US and coalition forces during military operations, and FSTs are specifically equipped for that mission. However, civilian injuries and casualties are common, and the patients are often brought to FST facilities because the host nation's medical capabilities are lacking. In this environment, pediatric musculoskeletal injuries are common. We found that patient, environment, equipment, and mission factors dictated the use of external fixation as the primary method for managing lower extremity fractures in children.

While the usage of external fixation for pediatric lower extremity fractures is supported by current literature, its use represents a modification in practice methods over those used to treat children in the United States. We have found that this modification is necessary when conditions are austere. These modifications are summarized in Table II.

During military operations, orthopedic surgeons encounter many civilian injuries. Many of these injuries are war-related, and the patients are evacuated by military evacuation assets to military medical facilities. Other civilians with injuries, war-related or not, also are often evacuated to US medical facilities due to limited or lack of medical assets in the region of conflict. Whether for humanitarian reasons or mission requirements, management of these injuries is likely to continue. Even the smallest surgical units, such as fragmented FSTs, will need to be prepared to manage several types of injuries, war-related or not, for the duration

of required care. Evacuation to a higher echelon of care is not an option in many circumstances, which means that each medical unit must assess the host nation's local assets and capabilities while clearly understanding the inherent capabilities of their own medical assets. We have shown that, under austere conditions and with limited resources, management of pediatric lower extremity long bone fractures can yield safe and reliably good functional outcomes. It is important to analyze and understand how equipment limitations, indigent population and human terrain factors, and other variables affect management and outcomes. This kind of study not only is essential for the overall success of missions but also is beneficial to both surgeons and patients in regions of conflict.

AUTHORS' DISCLOSURE STATEMENT

The authors report no actual or potential conflict of interest in relation to this article.

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