Management of Pediatric Femur Shaft Fractures
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Background
The incidence of pediatric femur fractures is 19 in 100,000 patients and is more common in boys than girls.1-4 Femur fractures account for 1.4% to 1.7% of all pediatric fractures.1-4 In the 1990s it was reported as the leading cause for hospital stay (days/yr) longer than 5 days for pediatric patients.5 Etiology of injury includes falls, motor vehicle related, sports injuries and abuse. Abuse has been reported as the leading cause of femur fractures in children less than 1 year old and of significant concern in those up to 5 years old.1,2,6 Low socioeconomic status has been shown to be a risk factor for abuse related femur fractures, as well.2

Management of pediatric diaphyseal femur fractures has evolved significantly over the last 50 years. Nonoperative treatment with traction and immobilization was previously the mainstay of treatment. Due to the morbidity associated with prolonged immobilization and the development of fixation devices geared toward treatment of pediatric fractures, operative treatment is now more prevalent but is still age-dependent. Skeletal maturity and the potential for bony remodeling is a significant factor in guiding treatment.

Post-fracture growth acceleration is a special consideration. There is potential for 1 to 2 cm of overgrowth during fracture healing and remodeling.7 Accelerated growth can continue for up to 5 years but most occurs within the first 2 years after fracture.8 Fractures opposite to the dominant hand show more growth acceleration.9 Overgrowth is decreased by shortening and accelerated by distraction. Neither patient age nor fracture type/location significantly affects overgrowth.10

Fracture Classification
Historically, pediatric femur fractures were classified using descriptions of anatomic location and fracture characteristics. In 1963, Salter and Harris further described fractures involving the epiphyseal plate.10 In 2007 the AO Foundation published Fracture and Dislocation Classification Compendium for Children.11 This was the first comprehensive and anatomically descriptive classification system for pediatric fractures and includes both physeal and extra-physeal injuries. According to this system a pediatric diaphyseal fracture is classified as 32-D with further classification dependent upon fracture pattern and comminution.

AAOS Clinical Practice Guidelines
In 2009, the American Academy of Orthopaedic Surgeons (AAOS) released clinical guidelines for the management of pediatric femur shaft fractures.12,13

A summary of the 14 recommendations based on available evidence as of 2009 is listed below. Grade A recommendations are based on level I evidence. Grade B suggestions are based on level II or III evidence. Grade C options are based on level IV or V evidence. Grade I (incomplete) has no or conflicting evidence and therefore recommendations cannot be made for or against a given intervention.

Grade A Intervention:
• Recommend that children younger than 36 months with a diaphyseal femur fracture be evaluated for child abuse.

Grade B intervention:
• Suggest early spica casting or traction with delayed spica casting for children age 6 months to 5 years with a diaphyseal femur fracture with less than 2 cm of shortening.

Grade C interventions:
• Treatment with a Pavlik harness or a spica cast are options for infants 6 months and younger with a diaphyseal femur fracture.
• When using the spica cast in children 6 months to 5 years of age, altering the treatment plan is an option if the fracture shortens greater than 2 cm.
• It is an option for physicians to use flexible intramedullary nailing to treat children age 5 to 11 years diagnosed with diaphyseal femur fractures.
• Rigid trochanteric entry nailing, submuscular plating, and flexible intramedullary nailing are treatment options for children age 11 years to skeletal maturity diagnosed with diaphyseal femur fractures, but piriformis or near piriformis entry rigid nailing are not treatment options.
• Regional pain management is an option for patient comfort perioperatively.
• Waterproof cast liners for spica casts are an option for use in children diagnosed with pediatric diaphyseal femur fractures.
The committee was unable to recommend for or against the following Grade I (incomplete) interventions:

- Early spica casting for children age 6 months to 5 years with a diaphyseal femur fracture with greater than 2 cm of shortening.

- Using weight as a criterion for the use of spica casting in children age 6 months to 5 years with a diaphyseal femur fracture.

- Using any specific degree of angulation or rotation as a criterion for altering the treatment plan when using the spica cast in children 6 months to 5 years of age.

- Removal of surgical implants from asymptomatic patients after treatment of diaphyseal femur fractures.

- Outpatient physical therapy to improve function after treatment pediatric diaphyseal femur fractures.

- Use of locked versus non-locked plates for fixation of pediatric femur fractures.

**Nonoperative Management**

Indications for nonoperative management are classically described in Fractures in Children by Rockwood, Wilkins, and Beaty. Acceptable values for angulation and shortening decrease with advanced skeletal maturity, as there is less potential for remodeling of deformity. Patients from birth to 2 years can accept up to 30° of angulation in all planes and 15 mm of shortening. Patients aged 11 years to skeletal maturity can accept only 5° of varus/valgus, 10° of anterior/posterior degrees of angulation and up to 10 mm of shortening. Nonoperative stabilization options include Pavlik harness, early traction (skin and/or skeletal) with delayed spica casting, and early fracture manipulation with spica casting.

**Pavlik Harness**

Optimal positioning for affected limb is approximately 80° to 90° of hip flexion and 50° of hip abduction. A lateral pillow or blanket can also be used for comfort. Stannard et al. studied a series of 16 patients between 0 and 18 months treated with Pavlik harness and found that all femur shaft fractures united within 5 weeks without malunion or apparent complications. They recommend it as a good option for patients less than 4 months and for small patients up to 6 months when there is less than 2 cm of shortening. Podeszwa et al. compared Pavlik harness with immediate spica casting for femur fractures in infants less than 6 months and found that they all united within 5 weeks and the spica group had more skin complications.

**Early Spica Casting**

Optimal positioning for spica casting is approximately 40° to 60° of flexion and 90° of knee flexion. Wolff and James showed that the use of a waterproof liner significantly reduces loss of skin integrity and unexpected cast changes.

**Early Traction with Delayed Hip Spica Casting**

Various methods of skin traction include Bryant’s traction, Buck’s traction and Russell’s traction. Balanced skeletal traction with the hip and knee flexed at 90° is another option. Distal femoral transfixion pins have typically been utilized for balanced skeletal traction in these fractures. Once early bone healing has occurred patients can be transitioned into a hip spica cast. Rasool et al. compared immediate spica casting with skin traction and delayed casting and found more skin complications and hospital acquired infections in the traction group. There was also a significant difference in hospital expense favoring the immediate spica group.

**Operative Management**

Operative indications include unacceptable deformity, polytrauma, open fracture, neurovascular injury, pathologic fracture and body habitus not amenable to casting. Operative stabilization and fixation options include flexible/elastic intramedullary nailing, rigid intramedullary nailing, internal plate fixation and external fixation.

**Flexible/Elastic Intramedullary Nailing**

Implants include stainless steel flexible nails (Enders rods) and titanium elastic nails. The recommended diameter of each nail is 4/10 the diameter of the intramedullary canal at the isthmus. They should diverge at the fracture site and should avoid leaving cut ends resting on the physis. They offer minimal control over fracture rotation. Buechsenschuetz et al. compared traction with delayed casting to stabilization with elastic nailing and found no difference in complications. There was higher parent satisfaction for the elastic nailing group. A cost analysis showed that the average cost of care was less for the elastic nailing group as well. Flynn et al. performed a similar comparison and showed fewer malunions and complications in the elastic nailing group. Patients in the elastic nailing group also had shorter hospital stay, walked sooner and returned to school sooner.

Moroz et al. looked at predictors of complications and poor outcomes with the use of titanium elastic nailing of femur fractures in children. They found limb-length discrepancy, malunion and loss of fixation to be 5 times higher when patient weighed over 49 kg (108 lbs). These complications were also higher for patients older than 11 years and for fractures in the distal third of the femoral diaphysis.
Flexible interlocking intramedullary nails (FIIN) require a minimum 9 mm canal diameter and utilize a far lateral trochanteric entry to avoid disruption of the trochanteric apophysis and femoral head blood supply. It is not necessary to fill the canal and the nail should end approximately 1 to 3 cm proximal to the distal femoral physis. This device offers theoretically improved rotational and long axis stability compared to traditional flexible/elastic nails. The AAOS guidelines did not include studies reporting outcomes with this device. Jencikova-Celerin et al. compared FIIN with other types of fixation including elastic nails and found that the FIIN group has less blood loss and faster weight-bearing. Heterotopic ossification was the most common complication (13.8%) for the FIIN group. There were more complications with FIIN for patients weighing less than 45.5 kg (100 lbs) and for fractures in the distal fourth of the diaphysis. Keeler et al. performed a case-series of 80 patients and showed 100% union without malunion or avascular necrosis (AVN). These nails may be useful in patients too skeletally immature for use of a rigid nailing but too heavy for use of elastic intramedullary nailing.

Rigid Intramedullary Nailing

Trochanteric entry nails are the rigid nail of choice in appropriately developed pediatric patients. The recommended nail length should end 1 to 3 cm proximal to the distal femoral physis in order to prevent physeal injury. Piriformis nails are contraindicated in skeletally immature patients due to unacceptable risk of developing avascular necrosis (AVN). The reported rate of AVN with piriformis entry nailing was 4% according to Buford et al. In this study the authors performed intramedullary nailing with an entry just posterior to the piriformis fossa in an effort to avoid the retinacular vessels from the lateral ascending branch of the medial femoral circumflex artery, which is the primary blood supply to the femoral head. Kanellopoulos et al. reported no major complications and 100% fracture union after use of locked trochanteric rigid nailing in this population. Beaty et al. reported AVN as a complication after use of trochanteric entry nails but only in 1% of patients and is felt to possibly be related to the injury itself rather than the surgery. Greater trochanteric growth disturbance is a concern and, in general, rigid nailing is not recommended in patients younger than 11 years of age for this reason.

Internal Plate Fixation

Indirect reduction with submuscular bridge plating can be utilized to preserve fracture site biology in comminuted fracture patterns not amenable to intramedullary stabilization. This technique achieves relative fracture stability and relies on secondary bone healing. The ability for pediatric patients to remodel makes this an appealing option through minimal surgical exposure. Agus et al. reported a low rate (7%) of malunion and uncomplicated removal of submuscular plates after union.

Open reduction internal fixation with a direct reduction and compression plating is another option but requires more surgical exposure to obtain an anatomic reduction at the fracture site. This requires some amount of soft tissue devitalization around the fracture site, which may be less of a concern in the pediatric population as the reported rate of nonunion is rare for diaphyseal femur fractures.

External Fixation

External fixation is typically reserved for damage control situations where there is significant soft tissue and/or neurovascular injury. It can also be utilized for gradual correction of deformity. Pins are typically placed laterally and percutaneously. Barlas and Beg compared elastic nailing to external fixation for pediatric femur fracture stabilization. There was a higher reported rate of malunion and refracture in the external fixation group. Pin tract infections and pin loosening can also be problematic with external fixation.

Complications

Complications of operative stabilization and fixation include femoral head avascular necrosis, which has been reported uncommonly after rigid intramedullary nailing but can have devastating outcomes. Malunion is a risk of all forms of operative stabilization but is more prevalent with external fixation and flexible/elastic intramedullary nailing in heavier children. Nonunion is uncommon in children. Implant migration has been reported most with flexible/elastic intramedullary nailing. Infection, neurovascular injury, implant prominence and refracture are also risks of various operative stabilization techniques. Venous thromboembolism and fat-emboli syndrome are rare in children with isolated femur shaft fractures.

Other Considerations

Age and skeletal maturity are perhaps the most important factors to consider when determining appropriate management of femur shaft fractures. Fracture stability and the potential for accelerated growth can also affect the decision for operative versus nonoperative treatment. The potential for remodeling makes nonoperative treatment appealing in younger patients but soft tissue integrity, body habitus, medical comorbidities, confounding injuries and the ability of family to appropriately care for the patient are important considerations in guiding appropriate treatment.
**Patient Transportation**

Herman et al. evaluated the utilization of hip spica car seats for transportation of patients after casting. They reported that only 9% of caretakers used hip spica car seats even after formal recommendation. There are also proponents for hip spica casting without incorporation of the well limb (unilateral spica casting), which may improve the ability to transport patients safely after cast treatment as specialized car seats may then not be necessary. Transport for patients treated with surgical stabilization is less of an issue.

**Timing of Treatment**

The current trend is toward definitive stabilization within 24 hours whenever possible. Patient comfort and parent satisfaction are important considerations here. Buckley concluded that prompt stabilization and reduction can help to decrease pain, hospital stay and overall complications. Hedequist et al. concluded that the timing of stabilization of femur fractures had no apparent effect on pulmonary complications. Other factors that can influence the timing of definitive stabilization include soft tissue integrity, neurovascular status and poly-trauma. Early stabilization results in earlier mobilization and can decrease hospital length of stay. This may also reduce the risk of developing venous thromboembolism and fat-emboli syndrome.

**Venous Thromboembolism (VTE)**

Vavilala et al. performed a large retrospective study looking at prevalence and risk factors for VTE in trauma patients less than 16 years of age. They found that 0.08% (45/58,716) of patients developed VTE. Those that did were older and had higher injury severity scores (ISS). Patients who were more likely to have VTE included those who had central lines, severe vascular injuries, spinal cord injury, and pelvic injuries. They concluded that VTE chemoprophylaxis is not routinely recommended in pediatric population. An exception may be for those with ISS greater than 25. This ISS for an isolated femur fracture is 3.4

**Summary**

Nonoperative treatment options include Pavlik harness use for patients less than 6 months of age. Early closed manipulation and hip spica casting is the primary treatment for patients 6 months to 5 years old with less than 2 cm of fracture shortening. Traction is, in general, out of favor but is still an option for management.

Operative management options include the use of flexible/elastic nails for patients between 5 and 11 years old weighing less than 49 kg (108 lbs). Flexible interlocking nail (FIIN) is an option for patients between 5 and 11 years old weighing more than 45.5 kg (100 lbs) and too skeletal immaturity for rigid nailing. Rigid trochanteric nailing is an option for patients older than 11 years. Indirect reduction with submuscular bridge plating is an option for operative comminuted fractures for patients older than 5 years. Direct open reduction with compressive plating is an option for fractures not amenable to closed or indirect reduction. External fixation is useful when skin integrity is compromised and for damage control but has a higher rate of malunion and pin tract infection.

Other critical steps to appropriately manage pediatric femur shaft fractures are to rule out child abuse and strive for definitive stabilization within 24 hours. VTE chemoprophylaxis is not routinely recommended for pediatric patients with isolated femur fractures but may be considered in specific situations. It is important to evaluate the ability of caretakers to safely and appropriately transport and manage patients treated in hip spica casts. Future studies are needed to fill gaps in current AAOS treatment guidelines. There is no substitute for sound clinical judgment and individual patient factors must ultimately dictate the most appropriate management for these patients.

**References**


