Length, Alignment, and Rotation: Operative Techniques for Intramedullary Nailing of the Comminuted, Diaphyseal Femur Fracture

Matthew P. Sullivan, MD
Ryan M. Taylor, MD
Derek J. Donegan, MD
Samir Mehta, MD
Jaimo Ahn, MD, PhD

Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, PA

Introduction

Shortened and rotationally unstable femoral shaft fractures can be extremely challenging even for the very experienced. Orthopaedic surgeons taking trauma call should have the necessary technical skills to stabilize a femur fracture with an elementary pattern utilizing an intramedullary device, but they should also be prepared for the occasionally challenging case. This may occur in the high energy trauma patient, who is often young, healthy, and generally tolerant of surgery, but who also has many years of life ahead, making it critical to restore anatomic length, alignment, and rotation. Restoring normal anatomy gives the patient the greatest chance at normal long-term hip and knee function. Incidences of leg length discrepancy and angular malalignment following femoral nailing have been reported as 7% and 9%, respectively.[1,2] Significant rotational deformity occurs in up to 28% of femur fractures.[3] Historically, malrotation less than 15° was thought to be acceptable;[4] however, Karaman and colleagues recently showed that patients with rotational malunion greater than 10° demonstrated significantly worse WOMAC knee and hip scores at long-term follow- up.[5] Additionally, Lee *et al* demonstrated in a biomechanical study that patellofemoral contract pressures increase dramatically with both internal and external femoral malrotation greater than 30 degrees.[6] Finally, femur fractures are the most common cause of litigation in orthopaedic surgery.[7,8] For these and many other reasons, it is critical for those participating in trauma call to be familiar with multiple ways to restore length, alignment and rotation in a comminuted diaphyseal femur fracture. We will review tips and tricks used in order to ensure the best possible reduction following these complex injuries. We will take the reader through a complex case and the decision-making involved in arriving at the desired outcome.

Case Report

We present a 26 year-old male who arrived at our trauma center after sustaining an isolated, closed, high energy blunt injury to his left thigh. Primary and secondary surveys were carried out in the trauma bay, and the patient was cleared by the Trauma Service for surgery. Given the high energy nature of the injury, the availability of a ready orthopaedic trauma OR, and a full OR staff, including a trauma-trained orthopaedic surgeon with resident help, the patient was taken expeditiously to the operating room for intramedullary fixation of the femur fracture.

Preoperative Considerations

Imaging

Basic trauma series plain films were acquired in the trauma bay, which included lateral C-spine, chest, and pelvis Xrays. Limited AP and lateral plain films of the left thigh and knee were acquired as well. Radiographic evaluation of the ipsilateral knee and hip are essential, as abnormal native anatomy or intra-articular fracture extension will potentially alter the surgical plan. Our radiographic evaluation revealed a segmental, comminuted, diaphyseal femur fracture involving the subtrochanteric and mid-diaphyseal regions (Figure 1). Additionally, as is standard of care at our institution, this high energy trauma patient underwent a CT scan of the head, neck, chest, abdomen and pelvis, including the ipsilateral proximal femur to evaluate for an occult femoral neck fracture.

Equipment

Preoperative planning for this surgery should include choosing the appropriate operating room table, C-arm position within the room, and ancillary instruments that may be needed for reduction and fixation. The standard at our institution is to use a radiolucent flat-top (Jackson) table with the patient in the supine position with a bump placed under the ipsilateral hip. We utilize distal femoral skeletal traction with traction being applied longitudinally over a pipe-bender. (Figure 2)

Intraoperative Considerations

Length

It is critical to plan the strategies that will be used to restore length, alignment, and

Corresponding author:
Matthew P. Sullivan, MD
Department of Orthopaedic Surgery
University of Pennsylvania
3400 Spruce Street,
2 Silverstein Pavilion
Philadelphia, PA 19104
Matthew.Sullivan2@uphs.upenn.edu

Figure 1. Injury films taken in the trauma bay. The patient was initially placed in a Hare Traction splint (A), followed by skeletal traction (B).

Figure 2. Typical operating room setup depicting a radiolucent flat top table with a black foam ramp for proper positioning. The proximal apex of the triangle is placed at the gluteal fold. A pipe bender is attached to the end of the table on the contralateral side to the injury. Skeletal traction is applied longitudinally over the pipe bender with 10-15 lbs of weights attached to sterile rope.

rotation before the patient is prepped and draped. The first consideration should be restoration of length. When significant cortical comminution exists, length can be gauged from the contralateral leg. However, because of patient positioning on a bump as well as the sterile drapes, intra-operative comparison of the injured extremity to the uninjured extremity is unreliable. With the aid of fluoroscopy, the nail length can be accurately estimated from the uninjured leg before prepping and draping. There are several ways to accomplish this task.

Measuring Tape

One method for restoring length is to measure the distance from the nail entry point in the proximal femur (just distal to the cortex of the piriformis fossa or the tip of the greater trochanter) to where the distal tip of the nail will ultimately be seated (the distal femoral physeal scar or superior pole of patella). A common mistake when measuring this distance is to localize the precise locations with a radio-opaque marker over the extremity on the anterior skin surface. Because of fluoroscopic projection, placing the marker closer to the image intensifier will result in a false increase in the measured nail length. To prevent this, we prefer to use a hemostat placed lateral to the femur at the level of the femur in the anterior-posterior plane. One hemostat is placed proximally at the starting point, confirmed with fluoroscopy, and held in place. Another is placed distally, confirmed with fluoroscopy, and held in place. The distance between hemostat clamps is measured with a measuring tape. The final image of the distal hemostat should be saved and printed for future reference when determining where to ultimately seat the nail. Of note, when using any technique in which distance is being measured with the aid of fluoroscopy, the reference point must be centered in the C-arm field. Failure to properly center an image can alter a measurement by up to a centimeter.

Metal Ruler

Another method for measuring the nail length is with a metal ruler that occasionally comes in the instrumentation set for the implant system. A common mistake in measuring the length of the nail off of bony landmarks is to follow the contour of the lateral aspect of the thigh. Piriformis nails are straight in the coronal plane, and trochanteric nails have only a few degrees of built-in valgus bend. Measuring along the contour of the thigh will erroneously increase the measured length. Doing so will give the hypotenuse length as opposed to the long leg of the triangle. In general, in order to ensure proper measurement of length, the intraoperative position of the injured limb should be replicated in the uninjured limb. This involves using the same bump and angle of the hip.

Cortical Length

In certain situations, there will be enough cortical bone intact so that length can be assessed by lining up the intact cortices. This method has the potential to be problematic if the cortical read is out of the plane of the beam of the fluoroscope. In the situation in which a precise cortical read is not perfect, the above-mentioned steps should be carried out to ensure restoration of proper length.

Full-Length Imaging

Full-length imaging of the non-injured femur, if available, can be an excellent way to measure nail length. This is possible with plain radiographs or computed tomography. If full-length plain films are going to be used, it is essential to use a 25mm magnification marker at the level of the femur in order to account for radiographic projection. Another useful method to consider is using the CT scout view. All femoral shaft fractures should have a CT of the femoral neck to aid in identifying an occult femoral neck fracture. A scout view scan of the uninjured femur can easily be obtained at this time and used to accurately measure nail length.

Rotation

Along with assessment of length, proper rotation must also be addressed. Unfortunately, rotation is the most common parameter to be malreduced. Rotation, like length, requires careful consideration before the patient is prepped and draped. Additionally, there are intra-operative clues that can be used before the patient is woken up. In similar fashion to length, rotation can be planned from the uninjured extremity.

Lesser Trochanter Method

The lesser trochanter method relies on the rotational relationship between the distal femur and the proximal femur and uses the lesser trochanter to define this relationship. The first step is to evaluate the uninjured femur. The thigh should be bumped up in the standard fashion. We prefer to use a long, black foam ramp. (Figure 2) The C-arm is brought distally to the knee and the beam is oriented perfectly parallel to the floor. A perfect lateral of the distal femur is obtained. The thigh can be moved freely to obtain this view, but once it is acquired the thigh must be held perfectly still. The C-arm is then rotated up exactly 90° and translated up to the hip. Once at the hip, an image centered directly over the lesser trochanter is obtained. This image of the proximal femur centered over the lesser trochanter should be saved, printed, and posted in a visible location for reference later in the case (Figure 3). Once the nail has been passed, the proximal interlocking screw should be inserted. The C-arm is then centered directly over the lesser trochanter with the beam exactly 90° to the floor. Next the image of the lesser trochanter from the uninjured femur is referenced and replicated by gently rotating the proximal femur through the aiming jig. Specifically, the amount of lesser trochanter visible medial to the proximal femur must be perfectly reproduced. Once this is accomplished, the aiming jig is held perfectly still. The next step is to rotate the C-arm beam exactly 90° such that it is parallel to the floor. The machine is translated to the distal femur. With the proximal femur firmly being held in place through the aiming arm the distal femur is rotated until a perfect lateral of the distal femur is acquired. If done correctly, the entire femur will be locked in the equivalent rotation as the uninjured side.

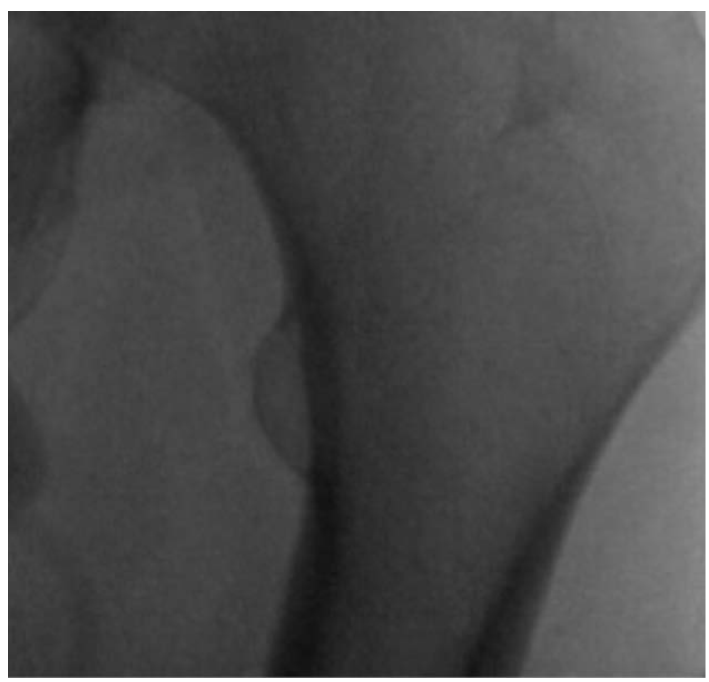

Figure 3. Preoperative fluoroscopic image centered over the lesser trochanter of the *uninjured* extremity. This image is saved and printed for later use in determining anatomic rotation once the nail has been placed. The image can be magnified over the lesser trochanter to more accurately set rotation.

Neck Version Method

The neck version method relies on the same principles as the lesser trochanter method for restoring femoral rotation. The primary difference lies in the anatomic landmark upon which rotation is referenced. In this method, instead of using an AP of the lesser trochanter, the version of the neck is used. As in the previous method, a perfect lateral of the distal femur is obtained. Then the C-arm is arced into a near lateral position until a perfect lateral is obtained of the native version of the neck, and this angle is noted. During the surgical repair of the injured side, the noted neck version can be recreated. These principles can in fact be applied to any two consistent landmarks on the femur, one proximal and the other distal to the fracture site.

Cortical Width Method

The cross sectional anatomy of the femoral diaphysis reveals a non-symmetric circumferential cortical width. In certain circumstances, this finding can be used to judge rotation. The ideal situation in which to use cortical widths to assess rotation is when there is little or no comminution of at least one cortex on AP or lateral imaging or there is a large wedge fragment that allows for assessment of cortical width. Once the nail has been passed and locked proximally, the distal segment may be rotated around the nail until the cortical width of the proximal and distal segments are perfectly equal. This may not be an appropriate method to use when there is significant circumferential comminution or a segmental injury.

Alignment

Limb alignment is critically important to the overall function of the traumatized limb, and restoration of the mechanical axis should be considered a high priority. Unfortunately, alignment is set well before the nail is placed and can be difficult to change once the nail has been passed. The most significant factor affecting alignment is starting point. For a piriformis entry nail, the entry point is constant regardless of the system being used. For a trochanteric entry nail, the starting point varies depending on the proximal bend of the nail. As a result, the technique guide should be consulted for the precise starting point before embarking on nailing a femur with a trochanteric entry nail. However, there are a few techniques that should also be considered to set alignment as anatomic as possible.

As mentioned above, the critical opportunity to set alignment is with the starting point. However, once the starting point has been identified and the femur has been open reamed, there are additional opportunities to adjust alignment. Upon successfully passing the guidewire across the fracture and into the distal segment, the mechanical axis can easily be evaluated. The C-arm is brought to the hip, and a Bovie cord with an attached hemostat is laid directly over the center of the femoral head. This is held perfectly in place. The Bovie cord is tensioned distally, clamped with another hemostat, and laid directly over the center of the ankle (just slightly laterally off center of the tibial plafond). Again, this is confirmed with C-arm, and the clamp/cord is held perfectly in place. Finally, the C-arm is brought proximally to the knee. If the mechanical axis is appropriate, the Bovie cord will lie slightly medially to the center of the knee (Figure 4). If the Bovie cord is translated medial or lateral to this spot, adjustments in alignment should be made prior to femoral reaming. Once the nail has been passed and prior to locking, the same steps should be repeated to ensure that alignment has been maintained.

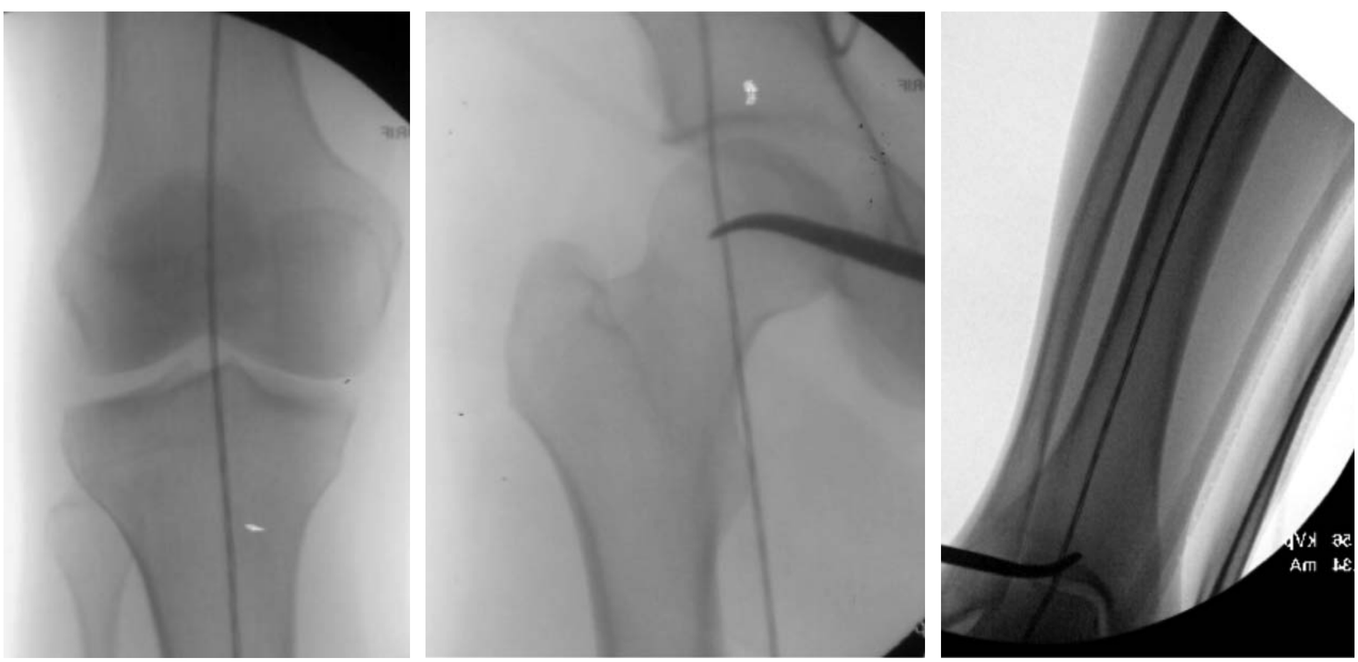

Figure 4. Bovie cord method used for restoring the proper mechanical axis of the limb. The Bovie cord is stretched from the center of the femoral head to the center of the ankle and held in place with clamps. An AP image at the knee is then taken. If the mechanical axis has been properly restored, the cord should pass directly through or slightly medial to the center of the knee.

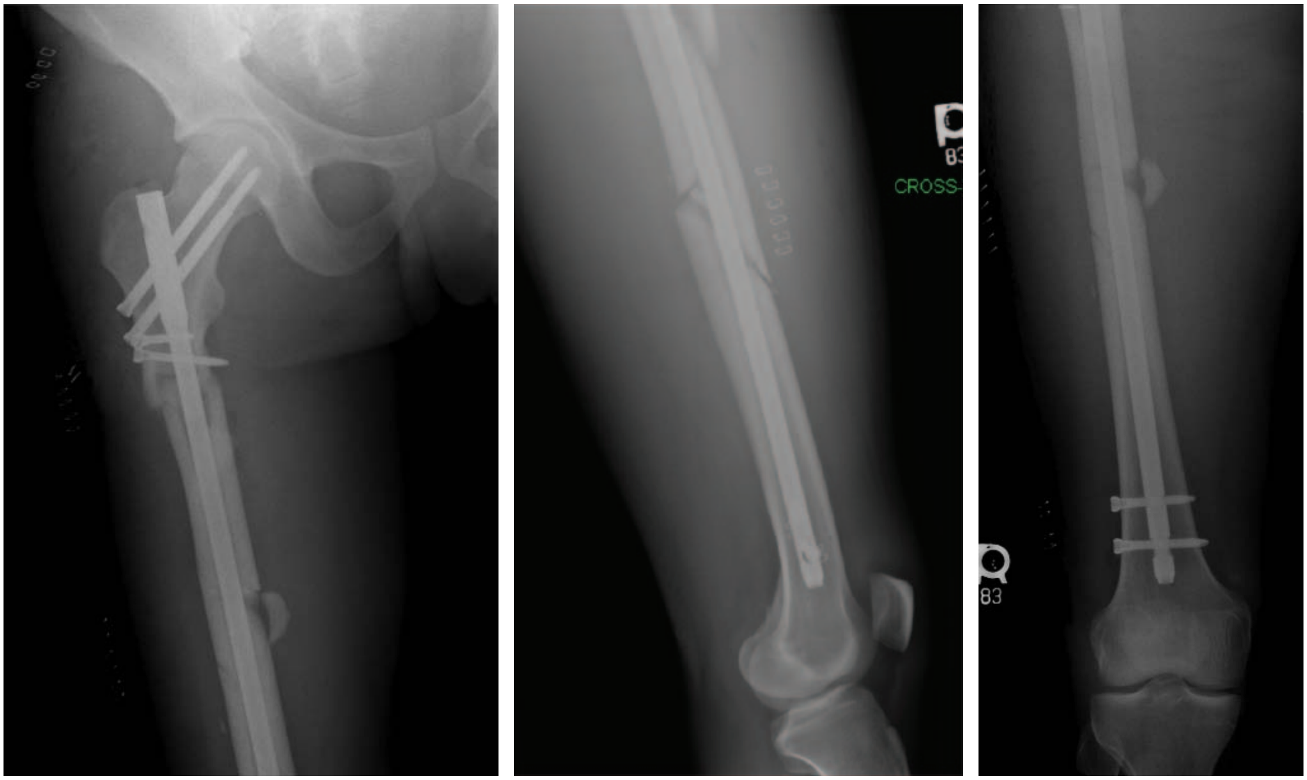

Figure 5. Intra-operative Xrays are performed prior to waking the patient and contaminating the surgical instrumentation. These are essential to ensure extra-articular placement of implants as well as gross alignment. Length and rotation are also evaluated clinically prior to waking the patient.

If the mechanical axis is markedly off due to a malpositioned starting point or loss of reduction of the unstable segment, the nail can be removed, and the starting point may be eccentrically reamed. This can be achieved by temporarily placing a one-third tubular plate into the proximal hole on the opposite side of which you choose to eccentrically ream. The plate will force the reamer in the opposite direction, allowing for the hole to be opened eccentrically. The nail can then be passed again, and alignment must be reevaluated. Another option for adjusting alignment once the canal has been reamed is to utilize cortical replacing screws (also known as Poller screws or blocking screws) in order to translate the bone relative to the nail.

Conclusion

The case presented above demonstrates a common senario that the orthopaedic surgeon may face while taking trauma call. Our management strategy includes many of the methods described above for restoring anatomic length, alignment, and rotation. Specifically, we utilize the measuring tape method for length restoration, the lesser trochanter and cortical width methods for restoring rotation, and the Bovie cord method for restoring alignment. Additionally, this fracture pattern required cortical replacing screws in order to control the mobile proximal segment during nail passage. Examination prior to waking the patient from anesthesia demonstrated anatomic restoration of the aforementioned parameters. Immediate intra-operative plain radiographs are shown in Figure 5. At 6-month follow-up, the patient demonstrated appropriate healing and excellent lower extremity function.

Intramedullary fixation of comminuted diaphyseal femur fractures is extremely challenging, and it is critically important to restore anatomic length, alignment, and rotation. Malreduction and malunion significantly affect long-term function. Here we describe several tips and tricks for restoring normal anatomy. As with nearly all orthopaedic procedures, preoperative planning and careful consideration are paramount.

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