Prevention of Cortical Breach During Placement of an Antegrade Intramedullary Femoral Nail

John A. Scolaro, MD; Christina Endress, MD; Samir Mehta, MD

Abstract: The radius of curvature of femoral intramedullary nails does not match the average radius of curvature of the human femur. Anterior cortical breach of the distal femur during nail placement has been reported in certain fracture patterns, in femora with a smaller radius of curvature, and at the starting point of the nail. The authors describe a novel technique used to prevent anterior cortical disruption of the femur using multiple percutaneously placed Steinmann pins. This technique ensures safe passage of medullary reamers and the femoral nail.

The average human femur has a radius of curvature between 114 and 120 cm.\textsuperscript{1,2} Most commercially manufactured femoral intramedullary implants have a radius of curvature between 150 and 300 cm,\textsuperscript{3} and the intramedullary devices are straighter than the anatomic curvature of the femur. This mismatch is not often clinically significant during antegrade femoral nailing with a proper starting point and surgical technique in non-pathologic bone.

Anterior cortical breach during nail placement is a rare occurrence. Ostrum and Levy\textsuperscript{4} reported 3 cases of penetration of the distal femoral anterior cortex during intramedullary nailing of subtrochanteric femur fractures. They suggested that fracture pattern and starting point, along with the femoral radius of curvature, may have contributed to this occurrence.\textsuperscript{4}

Pankaj et al\textsuperscript{5} suggested that Poller screws (ie, “blocking” screws or cortical replacing screws) be used to deflect an intramedullary nail posteriorly and protect the anterior cortex of the femur when indicated. The diameter of such screws was noted to be a concern within the narrow metadiaphyseal region of the femur and, therefore, could potentially be an issue with such a technique.\textsuperscript{5}

The current authors describe a technique that uses a modification of the concept of Poller screws to assist in the safe passage of a femoral nail in the clinical scenario with excessive anterior bow to the femur and concern that a standard femoral intramedullary nail may not be able to be passed safely. This technique requires minimal soft tissue disruption, is performed percutaneously, requires only a basic Steinmann pin set and power driver, and leaves only small-diameter cortical defects along the anterior femur (eventually bypassed with the intramedullary nail). Not to be used frequently, it is a technique reserved for cases in which safe passage of the nail is in question because of the patient’s anatomy or the fracture pattern. It is not meant to compensate for an improper starting point or other technical error.

Case Report

A 69-year-old woman reported right thigh pain. Her medical history was notable for obesity (height, 154.2 cm; weight, 84.4 kg; body mass index, 36.3), rickets, and hypertension, and her surgical history revealed prior gastric bypass surgery, bilateral total knee arthroplasty, and open reduction and internal fixation of a left periprosthetic femur approximately 3 years previously. The patient noted intermittent achiness and discomfort in the right thigh with prolonged weight bearing. Radiographs demonstrated cortical hypertrophy along the medial aspect of the proximal femur at the junction of the subtrochanteric/diaphyseal border, consistent with a stress fracture (Figures 1, 2). Of note, the patient had no history of bisphosphonate use. Protected
weight bearing vs prophylactic fixation of the stress fracture was discussed with the patient. Based on her desire to continue with her activities of daily living without concern for fracture, she elected to proceed with prophylactic fixation of her right femur.

**Surgical Technique**

The patient is positioned supine on a radiolucent flat-top table. All osseous prominences are padded, and antibiotic prophylaxis is given before the start of surgery. The ipsilateral hip is then bumped up to allow for adequate access to the proximal femur and for anteroposterior and lateral radiographs of the hip. The lower extremity is then prepped and draped.

Based on preoperative radiographs, one or two 2.0-mm Steinmann pins are placed percutaneously into the anterior aspect of the femur at a point that would approximate the initial point of contact of the intramedullary nail with the anterior cortex of the femur (Figures 3A, B). The pins are placed in a bicortical fashion to maximize stability within the bone so that they can successfully redirect a reamer or intramedullary nail.

The correct starting point for the femoral nail (piriformis or trochanteric entry) is then obtained, and the proximal entry portal is created according to the protocol of the specific nail. The ball-tipped guidewire, with a small bend approximately 1 cm from the distal tip, is then passed posterior to the Steinmann pins within the femoral canal (Figure 3C). The bend is placed in the wire to help guide its passage in the correct trajectory posterior to the Steinmann pins. Once the guidewire has been passed and the nail length approximated, preparation of the femoral canal for the nail occurs.

During reaming, care must be taken to not eccentrically ream the anterior cortex of the femur on sequential reamer passes. Frequently, multiple Steinmann pins must be placed in the femur at potential contact points to protect the anterior cortex. A Kocher (or similar) clamp is placed on the Steinmann pin and stabilized as the reamer is advanced past the pin. This prevents inadvertent advancement of the Steinmann pin into the medial soft tissues of the thigh as the reamer contacts the pin and advances. Biplanar fluoroscopy is used to confirm that the reamer passed safely.

After reaming is completed, the nail is then inserted into the femur and slowly impacted down the femur. Orthogonal fluoroscopic views are used to ensure correct passage of the nail down the femur. As the nail is advanced, additional 2.0-mm Steinmann pins are placed along the anterior cortex of the femur, if needed, to deflect the nail posteriorly. If the nail will not advance past 1 of the pins, it may be necessary to withdraw the guidewire proximal to the point of blockage so another distal pin can be placed that will deflect the guidewire more posteriorly and allow for safe nail passage (Figures 3D-F).

As the nail is advanced, the proximal-most Steinmann pin can be removed and placed in a more distal location at a point where the nail may contact the anterior cortex of the femur (Figures 3G-I, 4). Therefore, the Steinmann pins function as anterior rebar to protect the femoral cortex. Once the nail is advanced to its final position and after proximal and distal interlock fixation is secured, the multiple Steinmann pins are removed (Figure 5).

**Discussion**

The large variation in the anatomic radius of curvature of the human femur has been the subject of previous study. Egol et al performed an analysis of 948 femurs (892 from skeletal collections in 2 museums and 56 additional embalmed femurs) and determined that the average radius of curvature was 120±36 cm. Their conclusion was that age and femoral width had no effect on the length ratio.

![Figure 1: Preoperative anteroposterior (A) and lateral (B) radiographs of the right hip of a 69-year-old woman with right thigh pain during ambulation showing a stress reaction along the medial cortex and increased anterior femoral bow.](image1)

![Figure 2: Preoperative anteroposterior (A) and lateral (B) radiographs of the right distal femur of the same patient showing the findings described in Figure 1, as well as a total knee prosthesis.](image2)
on radius of curvature, but they observed that race has an effect on femoral bow. This overall variability in the radius of curvature of human femurs has been studied before, yielding similar findings. It has also been noted that with age, although generalized cortical thinning occurs in the femur, the greatest thinning occurs along the anterior femoral cortex.

The mismatch between femoral anatomy and orthopedic intramedullary femoral implants is a known problem. Harma et al reported the radius of curvature of 10 commercially available femoral nails and found values between 150 and 300 cm. The original Küntscher nail was a straight nail that relied on placing a large-diameter device in the medullary canal to obtain 3 points of fixation for stability. Since that time, the intramedullary nail has evolved from slotted to solid and from unlocked to interlocked. The rigidity of the solid nail decreases its ability to conform to the anatomic bow of the femur, increasing the risk of anterior cortical perforation during placement if a significant mismatch occurs in the radius of curvature of the implant and the bone. This mismatch has resulted in some manufacturers changing the specifications of their implants to more closely match the anatomic bow of the human femur.

In the setting of a femoral fracture distal to the intertrochanteric area, less difficulty often occurs in placing an intramedullary implant because the integrity of the medullary canal is already compromised and can be manipulated during nail passage. More difficulty may be encountered in the setting of a prophylactic nail or fixation of a proximal femur fracture because the diaphysis of the femur is entirely intact and the mismatch between the radius of curvature between the implant and bone is more relevant. Cortical replacing screws and Steinmann pins, later exchanged for larger-diameter screws, have been described during placement of intramedullary tibial and femoral nails to achieve reduction and resist later deformity. In the setting where the anterior cortex of the femur must be protected, multiple large-diameter screws are not necessary. The advantages of Steinmann pins are that they can be inserted in a percutaneous manner, do not leave a large osseous footprint, and can be reused as the nail is passed down the femur. In addition, all pins are removed at the end of surgery, and they are relatively inexpensive.

In the described case, other options discussed in preoper-
tive planning were the use of a smaller-diameter nail, overreaming proximally to allow for a more anterior proximal position of the nail, manually decreasing the nail’s radius of curvature with a table-top bender to more closely match the anterior bow of the femur, completing the stress fracture via an osteotomy, or performing open reduction and plate fixation of the femur.

**CONCLUSION**

In most instances, the mismatch between the anatomic radius of curvature and the radius of curvature of most commercially produced femoral nails results in a clinical problem. A proper starting point, as well as fracture reduction before passage of the implant, allows most nails to be inserted without danger of anterior cortical breach. In certain situations, because of unique patient anatomy or other circumstances, measures must be taken to avoid iatrogenic fracture of the anterior femur during intramedullary nailing. The authors presented a safe and novel technique based on the principles of Poller screws to aid in safe passage of a femoral nail in this situation. The use of large-diameter Steinmann pins is cost effective, does not involve soft tissue stripping or occlude the intramedullary canal, and results in only small defects in the femoral bone, which are eventually bypassed by the implanted nail.

**REFERENCES**