Complications After Hip Nailing for Fractures

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Abstract

Pertrochanteric fractures in elderly patients represent a major health issue. The available surgical options are fixation with extramedullary devices, intramedullary nailing, and arthroplasty. Intramedullary nailing for hip fractures has become more popular in recent years. Advantages of intramedullary nailing for hip fracture fixation include a more efficient load transfer due to the proximity of the implant to the medial calcar, less implant strain and shorter lever arm because of its closer positioning to the mechanical axis of the femur, significantly less soft tissue disruption and periosteal stripping of the femoral cortex, shorter operative time and hospital stay, fewer blood transfusions, better postoperative walking ability, and lower rates of leg-length discrepancy. Compromise of the posteromedial cortex and/or the lateral cortex, a subtrochanteric extension of the fracture, and a reversed obliquity fracture pattern represent signs of fracture instability, warranting the use of intramedullary nailing. However, the use of intramedullary nailing, with its unique set of clinical implications, has introduced a new set of complications. The reported complications include malalignment, cutout, infection, false drilling, wrong lag screw length and drill bit breakage during the interlocking procedure, external or internal malrotation (≥20°) of the femoral diaphysis, elongation of the femur (2 cm), impaired bone healing, periprosthetic fracture distal to the tip of the nail, fracture collapse, implant failure, lag screw intrapelvic migration, neurovascular injury, secondary varus deviation, complications after implant removal, trochanteric pain, and refracture. Many of these complications are related to technical mistakes. This article reviews intramedullary nailing for the treatment of pertrochanteric femoral fractures, with an emphasis on complications. [Orthopedics. 2016; 39(1):e108-e116.]

Hip fractures in elderly patients represent a health issue of global proportions. They are among the most common orthopedic injuries, with more than 250,000 cases occurring annually in the United States alone. In the United Kingdom, hip fractures have an annual incidence of 70,000 to 75,000, with a medical and social care cost of approximately £2 billion (€2.3 billion; $3.3 billion). Worldwide, it has been estimated that the total number of hip fractures could reach 2.6 million by 2025 and 4.5 million by 2050. Data show that 90% of these fractures occur in geriatric patients (65 years or older), usually as a consequence of a low-energy mechanism, typically a low-energy fall from a standing height. As the population ages, it is commonly believed that their incidence is due to increase exponentially within the next few decades.
few decades. The 1-month and 1-year mortality of patients with hip fractures is approximately 10% and 30%, respectively, usually resulting from comorbidities rather than from the fracture itself.4

Pertrochanteric fractures, defined as those occurring in the region from the extracapsular basilar femoral neck to the region along the lesser trochanter proximal to the development of the medullary canal, represent approximately 50% of all hip fractures.6-12 Surgical treatment is the treatment of choice, aiming to restore the preinjury level of independence and function within the shortest time possible. Traditionally, operative options for these fractures have been categorized into extramedullary fixation, intramedullary fixation, and arthroplasty.5-12 Arthroplasty is typically reserved as a salvage procedure for failed or complicated primary fixation of pertrochanteric fractures. Extramedullary fixation is the oldest and includes blade-plate, fixed-angle nail-plate, sliding nail-plate, sliding hip-screw, and locking-plate fixation constructs. Intramedullary fixation is newer and has become popular for the treatment of pertrochanteric fractures, increasing from 3% of all cases in 1999 to 67% in 2006 in the United States.7 Based on their design, intramedullary hip nails may be inserted through the piriformis fossa or the lateral or medial greater trochanter. In order of their invention, they have been classified into 4 classes: (1) the impaction class or “Y” nail class, originated with the Küntscher nail and currently represented by the trochanteric femoral nail (TFN); (2) the dynamic compression or gamma class, originated with the Stryker (Kalamazoo, Michigan) gamma nail with a single large lag screw into the femoral head; (3) the reconstruction nail developed by Russell and Taylor with 2 separate lag screws (Smith & Nephew, Memphis, Tennessee); and (4) the InterTAN class, comprising a medial trochanteric entry design and a trapezoidal cross-section similar to a hip arthroplasty femoral stem with an integrated 2-screw construct. Their evolution with time has resolved many technical issues.

Advantages of intramedullary nailing for hip fracture fixation include a more efficient load transfer due to the proximity of the implant to the medial calcar, less implant strain and shorter lever arm because of its closer positioning to the mechanical axis of the femur,8 significantly less soft tissue disruption and periosteal stripping of the femoral cortex,9-12 shorter operative time and hospital stay, fewer blood transfusions, better postoperative walking ability,11 and lower rates of leg-length discrepancy.12 Compromise of the posteromedial cortex and/or the lateral cortex, a subtrochanteric extension of the fracture, and a reversed obliquity fracture pattern represent signs of fracture instability, warranting the use of intramedullary nailing.9,12

However, the use of intramedullary nailing has introduced a new set of complications with unique clinical implications.13-15 Although intramedullary implants became increasingly popular in recent years for the internal fixation of unstable (AO/OTA 31-A2.2, 31-A2.3, and 31-A3) and stable (AO/OTA 31-A1 and 31-A2.1) pertrochanteric fractures,13,15 in the latter case intramedullary fixation does not seem to be an advantage when compared with extramedullary fixation due to a higher complication rate.14 Therefore, the current authors performed this study to review these complications, describe the circumstances under which they occur, and clarify the strategies implemented to avoid or minimize them.

**Materials and Methods**

An Internet-based search was conducted using the PubMed search engine for articles in the medical literature published until February 2015. The search terms hip nailing, complications, and pertrochanteric were entered, and related results were retrieved. Editorials, letters to the editor, and publications in languages other than English, German, and French were excluded. After locating a sufficient number of individual complications, the literature search was restricted, combining the term hip nailing with each individual complication identified. In addition, the references from the resulting manuscripts were reviewed to identify further suitable articles. Major relevant textbooks were also used as a reference. The resulting complications were grouped as those relevant to intramedullary nailing in general; those inherently related to hip nailing were studied in depth if they were deemed relevant.

**Results**

The literature search resulted in numerous reports regarding intraoperative and postoperative complications and technical errors with intramedullary hip nailing for fractures.16-69 The reported complications include malalignment, cutout, infection, false drilling, wrong lag screw length and drill bit breakage during the interlocking procedure, external or internal malrotation (≥20°) of the femoral diaphysis, elongation of the femur (2 cm), impaired bone healing, periprosthetic fracture distal to the tip of the nail, fracture collapse, implant failure, lag screw intrapelvic migration, neurovascular injury, secondary varus deviation, complications after implant removal, trochanteric pain, and refracture.16-69

Malalignment of the hip fracture in the setting of intramedullary nailing may result from different types of mechanical failure, such as loss of reduction, techni-
cally inadequate fixation (Figure 1), varus deformity, lag screw cutout, and periprosthetic femoral fractures distal to the tip of the nail (Figure 2). Any deviation in the coronal plane (>5°), the sagittal plane (>10°), or the axial plane (>15°) may produce uneven distribution of contact pressures within the joint, leading to premature joint degeneration. A lateral entry point for trochanteric entry nails may induce gapping of the lateral cortex and varus malalignment (Figure 3). Subtrochanteric fractures are more susceptible to varus or rotational malreduction and leg-length discrepancy.

Cutout has been associated with multifactorial variables, including patient age, bone quality, fracture pattern, reduction adequacy, lag screw position, implant design, and choice of nail angle. Four factors were the most important predictors for the development of this complication: suboptimal fracture reduction, nonideal femoral head lag screw position, unstable fracture pattern, and intramedullary implant design. The combination of the first 3 of these factors further increased the risk of cutout because complex fracture patterns may be difficult to reduce anatomically, which in turn can lead to difficulty in achieving an acceptable lag screw position (Figure 4).

Periprosthetic femoral fractures usually occurred distal to the tip of the intramedullary nail (Figure 5). Early-generation intramedullary nails and dynamic interlocking have been associated with a significantly higher risk for iatrogenic femoral fractures after intramedullary nailing for hip fractures. Impinging and penetration of the anterior femoral cortex may occur during nail insertion in shorter patients, use of long hip nails, and inappropriate entry point. Varus malreduction of the fracture, improper entry point selection, severe osteoporosis, and medial comminution were the most important related factors for z-effect and reverse z-effect after hip nailing for fractures. Medial migration into the pelvis of the femoral head lag screw has been related to suboptimal femoral head lag screw positioning. This phenomenon has been associated mostly with proximal femur nails (PFN; Synthes, Paoli, Pennsylvania), but it was recently demonstrated in a study of 5 different nails (TFN, PFN, and PFNA; Synthes; and Gamma-3; Stryker; and IMHS; Smith & Nephew) in a biomechanical model of an unstable pertrochanteric fracture. The nails were examined to an endpoint of 9 mm of medial migration on completion of 5000 loading cycles. Results showed that medial migration occurred in all implants with no statistically significant difference between them.

Implant breakage usually occurred at the interface between the interlocking screws and the nail, although breakage of...
the nail itself has also been reported (Figures 7-9). Risk factors for periprosthetic infection after hip nailing included open hip fractures, lack of thorough debridement, delay in administration of perioperative antibiotics prophylaxis, low socioeconomic status of the patients with limited access to health care systems, delay in soft tissue coverage or wound closure, prolonged operative time, and prior stabilization with external fixation (Figure 10). Risk factors for delayed union and nonunion after hip nailing included complex fracture patterns, poor bone quality, suboptimal implant position, open fractures, poor surgical technique with disruption of the soft tissue and compromise of the blood supply, smoking, and unreamed nailing (Figure 11). Fracture dynamization through removal of the distal interlocking screw has not always been successful.

Neurovascular structures were susceptible to iatrogenic intraoperative injury during percutaneous insertion of implants such as pins (Figure 12), drill bits (Figure 13), screw tips, and blades, or by a displaced bone fragment during the fracture or repair. The most common vascular structure was the profunda femoris, followed by the superficial femoris, superior gluteal, and inferior epigastric arteries. Compression of the femoral nerve by a secondarily displaced fragment of the lesser trochanter, late (7 years) sciatic nerve injury from heterotopic ossification, and superior gluteal nerve compression from positioning of the patient on the fracture table have also been reported after intramedullary nailing for hip fractures. In a case report, femoral nerve compression was relieved with removal of the bone fragment through the anterior approach to the hip. In another report, removal of the intramedullary hip nail and the heterotopic bone and external neurolysis of the sciatic nerve were performed, but without improvement of the motor power for the patient.

**DISCUSSION**

Intramedullary nailing for pertrochanteric fractures has become popular in recent years. However, implant-related complications may occur. The evolution of hip nails over time has resolved many technical issues, but many of these complications are related to technical mistakes. Malalignment of the hip fracture in the setting of intramedullary nailing for hip fractures can occur primarily or secondarily; both are equally important to ensure successful intramedullary osteosynthesis. Primary malalignment is the deformity that occurs immediately after the patient has left the operating room; this is under the direct control of the surgeon and should be considered preventable with meticulous surgical technique because it is largely a consequence of either an inappropriate entry point or malreduction of the fracture. It is critical for the orthopedic surgeon to understand that the nail will not...
simply perform the fracture reduction by itself upon insertion. Care must be taken to ensure that fracture reduction and entry point are appropriately established to prevent malalignment. A lateral entry point for trochanteric entry nails should be avoided. This is even more important for fractures with subtrochanteric extension, probably because of the anatomy of the subtrochanteric region. Significant fracture displacement occurs secondary to the pull of the iliopsoas, gluteus medius, and short external rotators muscles on the proximal fragment, which is consequently pulled in flexion, abduction, and external rotation. In the meantime, the unopposed force of the adductors on the distal fracture fragment leads to femoral shortening. This underscores the importance of a proper surgical technique and anatomical reduction of the fracture.

Secondary malalignment occurs at some point during the postoperative period as a result of change in position of the fracture fragments. It is usually attributed to a loss of fixation in poor quality bone or to technically inadequate fixation in combination with an unstable fracture pattern, premature dynamization, or noncompliance with appropriate weight-bearing restrictions. Secondary malalignment of hip fractures treated with intramedullary nailing can be minimized by applying the standard intramedullary nailing principles, including static interlocking of sufficiently sized nails and implementation of weight-bearing restrictions, as necessary.

Cutout is defined as the collapse of the neck-shaft angle into varus, leading to extrusion of the lag screw from the femoral head. In a large study of 3066 hip fractures, the prevalence of cutout was 1.85%; the most important predictors were suboptimal fracture reduction, nonideal femoral head lag screw position, unstable fracture pattern, and intramedullary implant design. The importance of an optimal position of the lag screw in the femoral head should be emphasized. Two locations have been described as being optimal: the central-central zone and central-inferior zone as seen on the lateral and anteroposterior views. Central placement in the lateral radiograph has been reported to be more crucial. This is the same concept represented by an ideal tip to apex distance of less than 25 mm (more recently less than 20 mm) and its proven repercussions to the rates of fixation failure. To avoid cutout, careful preoperative planning with correct fracture geometry assessment and fracture pattern classification, as well as a correct operative technique, are necessary. Because these factors can be controlled by the surgeon, they are considered fundamental to achieving optimal surgical results and obviate the need for revision procedures.

Intraoperative or postoperative iatrogenic periprosthetic femoral fractures are a notorious complication of intramedullary nailing for hip fractures. A high incidence of variable types of intraoperative iatrogenic femoral fractures has been reported. A meta-analysis performed to identify the risk of femoral fractures associated with short intramedullary hip nails for pertrochanteric hip fractures showed that in studies published between 1991 and 2000, gamma nails increased the risk of femoral fracture by 4.5 times when compared with extramedullary implants using compression screws. However, studies published between 2000 and 2005 showed that the incidence of iatrogenic periprosthetic femoral fractures was similar between intramedullary and extramedullary implants, suggesting that the increased risk of femoral fracture associated with early-generation intramedullary implants has been resolved by the improved implant design and surgical technique. Currently, modern trochanteric intramedullary nail designs have moved to a 4- to 6-degree proximal bend positioned above the region of the lesser trochanter (similar to the Herzog bend in tibia nails) for improved fit in the femoral metaphysis.

Figure 11: Nonunion of a pertrochanteric fracture after disengagement and lateral migration of single (A) and dual (B) femoral head lag screws.

Figure 12: Medial migration (A) and breakage (B) of the guidewire of the femoral head lag screw.

Figure 13: Intraoperative vascular injury of an arteriosclerotic profunda femoris artery (arrows) from the drill bit of the distal interlocking nail screw.
the rate of periprosthetic fractures has been similar for short and long nails and significantly lower with static compared with dynamic interlocking. To avoid iatrogenic periprosthetic femoral fractures, the surgeon should not force the nail into the femur. If the nail does not advance by hand, it should be extracted, and the femoral canal should be overreamed and reinsertion attempted.

A rare intraoperative iatrogenic complication of hip nailing is impingement and penetration of the anterior femoral cortex during nail insertion. This complication may occur in shorter patients (height less than 160 cm) with increased femoral bowing and when a long hip nail is used with an improper trochanteric entry point. Careful preoperative planning and selection of a more posterior trochanteric entry point are necessary to obviate this major complication.

The z-effect and reverse z-effect are unique phenomena that were first described in 2002 with the use of hip nails comprising 2 interlocking head screws; the terms refer to the migration of the femoral head lag screws in opposite directions with consequent varus collapse of the fracture. The z-effect is characterized by lateral migration of the inferior screw, varus collapse of the fracture, and perforation of the femoral head by the superior screw. The reverse z-effect is characterized by lateral migration of the superior screw and medial migration of the inferior screw. Although the biomechanics of this complication remain unclear, it seems that varus malreduction of the fracture, improper entry point selection, severe osteoporosis, and medial comminution are the most important related factors.

Medial migration into the pelvis of the femoral head lag screw, similar to the reverse z-effect, may occur with hip nails comprising a single femoral head lag screw. Sporadic cases of this complication have been reported in the setting of suboptimal femoral head lag screw positioning. Intrapelvic complications from medial migration of the femoral head lag screw may be significant, including sigmoid perforation, retroperitoneal abscess formation, and neurovascular injuries. Medial migration of the femoral head lag screw has been explained by a defective mechanism of the set screw or by the z-effect phenomenon itself. In the latter case, the hypothesis was that as rotation and axial loading occurred with the initiation of weight bearing, the lag screw disengaged from the nail and migrated medially rather than laterally.

Implant breakage may occur when the implant sustains more load than intended because of early excessive weight bearing or prolonged cyclical loading, as in the case of nonunion. Failure may occur at the weakest portion of the construct, which is the interface between the interlocking screws and the nail, or at the nail itself. It has been suggested that increasing the number, diameter, and type of interlocking fixation may increase the fatigue strength of the construct.

Periprosthetic infection may occur in 1.1% to 3.2% of patients with pterrochanteric fractures treated with intramedullary hip nailing. The rate is lower compared with other sites of intramedullary nailing, probably because of the more generous soft tissue envelope and lower incidence of open fractures. Management of the infection is challenging. In the acute postoperative period, a strategy of irrigation and debridement, systemic antibiotics administration, and implant retention has been recommended for bone stability that is a prerequisite for successful eradication of infection. However, the presence of an intramedullary implant (rather than an extramedullary plate and screw construct) places this strategy at a higher risk of failure.

Therefore, nail removal and bone reconstruction in a staged procedure should be pursued. Delayed union and nonunion may occur in 1% to 2% of the patients with pterrochanteric fractures treated with intramedullary hip nailing. The rate is low because of the excellent blood supply and good cancellous bone in the intertrochanteric region of the femur and the fact that the fracture is reduced in a closed fashion that creates minimal disturbance to the blood supply and soft tissue envelope of the area. Management should be considered on an individual basis. Any underlying metabolic and endocrine abnormalities should be corrected, and revision surgery should be performed. Fracture dynamization through removal of the distal interlocking screws has been controversial for the treatment of delayed union and nonunion of pterrochanteric fractures after hip nailing. Dynamization is based on the principle that an increase in load and compression across the fracture site may promote and enhance fracture union. In the presence of nonunion, reaming and exchange nailing with a larger-diameter nail is recommended.

Iatrogenic neurovascular injuries may occur intraoperatively during intramedullary hip nailing for fractures from percutaneous implants insertion or by a displaced bone fragment during the fracture or repair. It has also been suggested that manipulation of atherosclerotic vessels of the leg on the fracture table may injure brittle endothelium, rupture plaques, and dislodge emboli, leading to an acute ischemic lower extremity necessitating prompt vascular intervention. Iatrogenic vascular injury can be distinguished into hemorrhagic (caused by sharp items such as pins, drill bits, screw tips, and blades) and thrombotic (caused by compression by retractors and forceps). Presentation may be acute (hemorrhage) or delayed (pseudoaneurysm formation). The profunda femoris is most commonly injured. The artery typically gives rise to 3 perforating arteries that lie close to the linea aspera of the femur and therefore are vulnerable to traumatic or iatrogenic injuries related to femoral fractures and their surgical repair. Selective embolization of the pro-
in the case of a femoral pseudoaneurysm, an endovascular or open repair is necessary. Superficial femoris artery injury is less frequent; soft tissue compression at the perineal post and traction of the limb in adduction and internal rotation have been reported as risk factors for iatrogenic superficial femoris artery injury. Release of lower limb traction and return of the leg to a neutral position as soon as the femoral head lag screw is in place should be performed to withdraw compression, increase superficial femoris artery mobility, and reduce the risk of inadvertent iatrogenic injury. Inferior epigastric vessel avulsion from traction of the leg on the fracture table and superior gluteal artery injury from a threaded guidewire used to locate the trochanteric entry point have been reported. To avoid iatrogenic vascular injuries, blunt dissection to bone prior to drilling and instrumentation should be performed; if any concern for neurovascular injury exists, a limited open approach should be performed, reduction maneuvers on the fracture table should be delicate, and the leg should be returned to the neutral position after optimal insertion of the femoral head lag screw.

The femoral, sciatic, and superior gluteal nerves are more commonly injured or compressed by bone fragments, heterotopic ossification, or positioning of the patients on the fracture table. Decompression of the nerve with removal of the bone fragment and the nail is necessary. The risk of iatrogenic injury to the superior gluteal nerve seems to be higher with the patient in the standard supine position on the fracture table than it is with the patient in the lateral position on the fracture table with greater hip flexion and adduction.

**Conclusion**

Intramedullary hip nailing for pertrochanteric fractures provides a minimally invasive, biologically friendly, and relatively safe surgical option for fracture reduction and fixation. It permits early weight bearing and allows fast rehabilitation; however, it is not without complications. The treating surgeons should be aware of these complications, most of which can be precluded and/or corrected intraoperatively. They also should consider the fact that nailing for pertrochanteric fractures is frequently performed by junior staff members; in these cases, close supervision and guidance are necessary for a proper and meticulous surgical technique. The operative setting should be ideal, preferably in a working-hours operating list under senior supervision with the correct equipment readily available, and with image intensification performed by an experienced radiographer. The patient should be properly and gently positioned on the fracture table, and an optimal reduction should be obtained by closed means prior to proceeding with implant placement. An optimal entry point should be obtained, and the nail should be gently advanced in the medullary canal. The surgeon should not hesitate to perform a limited open reduction when needed, with the soft tissues around the hip respected. The femoral head lag screw should ideally be positioned central-central in the femoral head, and drilling for the distal interlocking screw should be performed with subtlety. Complete intraoperative imaging with fluoroscopy should be obtained without technical compromise in every step of the procedure. Being proactive rather than reactive is necessary.

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