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Intramedullary Nailing of Tibial Fractures: Review of Surgical Techniques and Description of a Percutaneous Lateral Suprapatellar Approach

by Max Morandi, MD; Trevor Banka, MD; Guilherme P. Gaiarsa, MD; S. Trent Guthrie, MD; Jad Khalil, MD; Joseph Hoegler, MD

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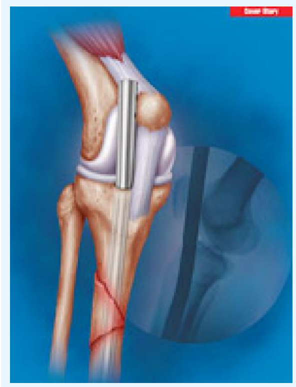
The lateral percutaneous suprapatellar approach in a semi-extended position is an excellent approach for intramedullary nailing of tibia fractures.



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Fractures of the tibia are among the most serious long bone fractures, due to their potential for nonunion, malunion, and long-term dysfunction, as well as their propensity for open injury. Intramedullary nailing is the gold standard treatment option for displaced closed or open tibial diaphyseal fractures.[1-7] Intramedullary nailing acts as an internal splint and permits early weight bearing along with fracture healing.[8]

The evolution of tibial intramedullary nails dates back to the work of Gerhard Kuntscher during World War II. Nail design and instrumentation have advanced greatly since Kuntscher's nail, yet the surgical technique has changed little. Tibial intramedullary nails are still largely inserted through a patellar tendon-splitting or parapatellar tendon approach. This article presents a summary of the evolution of tibial intramedullary techniques and describes a different surgical approach: the percutaneous lateral suprapatellar approach in semi-extended position. This approach has been used in >124 cases in the past 3 years, performed by 2 of the authors (M.M., G.P.G.).

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History

Gerhard Kuntscher, from Germany, was a pioneer in the development of the intramedullary nail. He initially described intramedullary nailing for the treatment of femoral fractures and subsequently for tibial fractures. He experimented with a straight, unreamed, V-shaped, stainless steel intramedullary nail in the 1930s and 1940s during World War II.[9,10] Like many other pioneers, the medical community did not approve of his work; however, he was permitted to continue practicing outside Germany on the Finnish/USSR war front in Karelia. There, with the help of the allied Finnish Medical Army Forces, he continued inserting nails and published a report of 105 cases of the V-shaped nail in human femora.[8] He later modified the V-shape to a cloverleaf pattern to resist torsion.

Although Kuntscher also experimented with straight nails in human tibiae, little is published on results of his early tibial nails. The results of this technique became known in the 1950s, when Lottes[11,12] developed a flexible, unreamed triflanged nail, in contrast to Kuntscher's V-shape. Lottes' nails were designed to conform to the shape of the tibia and had different flexibilities and hardnesses. The theory was the nail would conform to the shape of the tibia during insertion into the medullary canal, then spring back to its original shape, reducing and stabilizing the fracture. In his original series of 534 tibial fractures, Lottes reported a union rate of 97%.[11] His nail was inserted through a medial parapatellar approach, and the starting point was at the junction of the tibial plateau and the anterior cortex, allowing the nail to enter the medullary canal.

Almost a decade later, Zucman and Maurer[13] reported on 36 cases of straight Kuntscher nails in segmental tibial fractures. They reported 88% union in closed fractures and 95% union in open fractures. Of the 36 patients, there were no cases of malunion. In this study, a medial parapatellar incision was used and the nails were not locked or reamed. Five years later, D'Aubigne et al[14] published their results with Kuntscher tibial nails. They reported a nonunion rate of 1.04% in closed fractures and 2.4% in open fractures. In this study, again, the nail was inserted through a medial parapatellar incision with the knee flexed 150° over a padded bar. The starting point was as far posterior on the tibial plateau as possible and locking screws were not used. The authors reported a malunion rate of up to 22% depending on the fracture location.

Posterior cortical perforation proved to be a complication with straight Kuntscher nails. If the starting point was too anterior on the tibial plateau, it would not place the nail in line with the medullary canal and would abut the posterior cortex, risking iatrogenic fracture. The proper, far posterior starting points would risk intra-articular cartilage, ligamentous and/or meniscal damage. To address this issue, Herzog modified the Kuntscher nail by adding a 20° apex posterior curve to the proximal nail and 5° apex posterior curve to the distal nail to allow negotiation of the nail into the medullary canal.[15] This Herzog curve allowed for an eccentric anterior starting point on the tibial cortex between the tibial tubercle and the plateau avoiding insertion though articular cartilage. This proximal curve is still used in modern nails.

D'Aubigne et al[14] noted that intramedullary nailing of the tibia offered poor fixation in the upper and lower ends of the bone. In 1978, to overcome this problem, Grosse et al[16] added interlocking screws that could be inserted through the bone and nail, above and below the fracture site. These locking screws prevented rotational movement and telescoping, adding fracture stability and allowing earlier motion and weight bearing. Interlocking nails also extended the indications for nailing to include proximal and distal fractures as well as comminuted and segmental fractures.[16-18] Interlocking nails had either dynamic holes, which allowed for fracture compression during weight bearing, or static holes, which offered greater stability but no compression.[16] The Grosse-Kempf nail used the Herzog curve proximally, and the approach and starting points were unchanged.

Until now, tibial intramedullary nails were largely inserted on fracture tables with the patient's hip and knee flexed and a padded bolster placed beneath the popliteal fossa. Traction was applied via a calcaneal pin or foot holder. With the advent of locking screws, the fracture bed setup obstructed the proximal or distal aiming jigs. Even freehand techniques, popularized in North America, had difficulties placing the locking screws. A popular solution was to abandon the traction devices to avoid the cumbersome traction holder. Surgeons would hang the leg off a regular tower table with gravity providing the traction force. An assistant would hold the tibia while squatting until the nail had traversed the fracture site. The distal end of the surgical table could then be elevated and the locking screws drilled. This technique was described as challenging, and exposure for adequate intraoperative radiographs was difficult to achieve.

To avoid these problems, surgeons began inserting tibial nails on flat, radiolucent tables with the knee in extreme flexion over a padded bar or radiolucent triangle. The leg would be in the near-vertical position.[14] Traction was applied manually by an assistant pulling down on the foot.

In 1991, Moed and Strom[19] discouraged the use of traction during tibial intramedullary nailing. Their canine study of closed reamed tibial shaft fractures demonstrated increased compartment pressures when traction was applied during nailing. This study, along with the difficulties that traction beds posed to insertion of locking screws, led most surgeons to abandon the use of skeletal traction when inserting tibial nails.

In 1996, Tornetta and Collins[20] offered a new approach to tibial nailing in proximal fractures aimed at solving the problem of malalignment for this kind of injury. They used a semi-extended position of the knee with an open medial parapatellar arthrotomy rather than the more common patellar tendon-splitting approach, which had the knee flexed >90°. They noted that knee flexion in proximal fractures led to apex anterior angulation secondary to over-pull of the quadriceps muscle. The semi-extended technique, however, with the knee positioned in 15° of flexion, relaxed the quadriceps muscle, preventing the procurvatum deformity. They also initially used a large medial incision from the upper pole of the patella to the tibial tubercle with a medial parapatellar arthrotomy. This open approach allowed direct visualization of the starting point and facilitated lateral patellar subluxation, eliminating the impingement created by the presence of the patella. It uses the femoral trochlear groove as a guide to the starting point. This was the first time in decades that a series of cases was published using a novel approach to insert a tibial nail.

In late 2007, Tornetta and Ryan[21] revised the semi-extended positioning from an open approach to a minimal skin incision of 2.5 cm medial, proximal to the patella, into the intermedius. They prefer a medial arthrotomy to subluxate the patella to position the cannula to be in the trochlea groove, and the patella subluxates laterally more easily due to the less-deep groove on that side. They routinely use a cannula or metal trocar and do not advocate washing out the knee, since the reamings come out the cannula. The knee pain rate was compared to the classic, standard 1-cm poke hole next to the tendon for flexed nailing, and it was found to be identical.[22]

In 1998, Cole[23] published his technique of nailing proximal tibial metaphyseal fractures. He described a new approach to nailing, as the classic patellar tendon-splitting or medial/lateral parapatellar approaches resulted in unacceptable deformities in proximal third fractures. In a proximal tibial metaphyseal fracture, the medial parapatellar approach directs the nail in a medial-to-lateral direction, resulting in a valgus deformity. A lateral parapatellar approach results in the opposite deformity.

The patellar tendon-splitting approach allows the nail insertion angle to be in line with the medullary canal, avoiding varus or valgus deforming forces. However, the inferior pole of the patella directs the nail posteriorly, resulting in a procurvatum deformity. To avoid these potential malpositions, he advocated a limited medial parapatellar arthrotomy and retraction of the patella lateral to the femoral sulcus. As a protective sleeve, he took advantage of a disposable plastic trocar from the surgical endoscopy set. This technique prevents patellar contact with the nail during introduction, allowing direct insertion into the medullary canal. He also avoided distal skeletal tibial traction; however, the leg is hung from an overhead chain attached to a distal femoral traction pin and uses gravity traction to maintain knee flexion.

Current nails have various degrees of proximal curve and location of locking screws.[10] The choice of reaming and interlocking is based on characteristics of the fracture and surgeon preference. The approach to insert the nail is standard—either a patellar tendon-splitting or medial/lateral parapatellar approach—unless it is a proximal fracture, in which case either Tornetta's[22] or Cole's[23] techniques may be used.

The Classic Parapatellar/Patellar Tendon-Splitting Approach

The accepted approach to tibial nailing that follows highlights techniques from selected texts.[10,24,25] Three positioning options are used to facilitate nailing: (1) a traction table with the patient's hip and knee flexed, (2) the patient supine on a radiolucent operating table while the fracture is reduced with an external fixator, or (3) manual traction with the patient supine on a radiolucent table with the ability to flex the knee >90° over an aluminum triangle or pile of blankets. This method avoids the use of traction pins, which reduces operative time and removes the risk of iatrogenic nerve injury or nerve compression from the bolster. It also avoids elevated compartment pressures seen with prolonged traction.[19,26]

After appropriate fracture reduction, 1 of 2 skin incisions may be used: a 5-cm longitudinal incision made medial to the patellar tendon between the tibial tubercle and the inferior border of the patella, or a transverse incision midway between the joint and tibial tuberosity. The transverse skin incision has the advantage of minimizing scar formation, particularly in keloid-prone patients. The skin incision must be in line with the central axis of the medullary canal. The starting point may be accessed either medially, laterally, or through the patellar tendon. Patellar tendon-splitting approaches have been associated with increased knee pain, although this point remains controversial.[27]

The location of the starting point varies depending on the type of nail used. Slotted nails are less stiff than solid nails, allowing the starting point to be more distal on the anterior tibial cortex. In the anteroposterior (AP) view, the entry point is in line with the axis of the intramedullary canal and with the lateral tubercle on the intercondylar eminence. In lateral view, the entry point is at the ventral edge of the tibial plateau. The appropriate starting point of a slotted nail is 1 to 1.5 cm distal to the knee joint in line with the medullary canal on AP radiographs, at the level of the fibular head. Tornetta et al[28] defined the appropriate starting point for solid rigid nails as the "safe zone" on the anterosuperior plateau. The safe zone is 9 mm lateral to the center of the plateau and 3 mm lateral to the center of the tibial tubercle. An awl is inserted perpendicular to the cortex and the position is gradually adjusted more parallel to the cortex as it is advanced. Alternatively, a Kirschner wire may be placed at the appropriate starting point and over-reamed with a rigid reamer to obtain entry into the medullary canal.

A ball-tipped guide wire is placed through the entry portal into the medullary canal. The guide wire is advanced across the fracture site with C-arm assistance and impacted into the distal subchondral bone. If a reamed technique is desired, sequential reaming takes place with the knee in flexion to avoid damage to intra-articular structures or the anterior cortex. If an unreamed technique is used, only the cancellous bone about the entry portal is reamed. After reaming, the nail length is measured appropriately.

The nail is attached to the introducer and aiming guide for the proximal locking screws and inserted over the guide wire. The nail should be countersunk 0.5 to 1 cm to allow nail backslap and fracture compression and avoid soft tissue irritation. The proximal locking screws are placed with the assistance of a jig and soft tissue protector. Distal locking screws are inserted using a freehand technique.

Pain

Anterior knee pain is one of the most common complaints after tibial intramedullary nailing. This has a significant economic impact, since the majority of tibial fractures that require nailing are sustained by men with an average age of 31 years.[29] Court-Brown et al[30] found the incidence of anterior knee pain to be 56%. The only difference between patients who developed pain and those who did not was that patients with pain were younger. Ninety-one percent of these patients experienced pain with kneeling and 33% had pain at rest. Possible explanations for this include nail protrusion leading to soft tissue irritation or damage to the gliding tissues in front of the knee during nail insertion. It has been suggested that the patellar tendon-splitting approach may be associated with increased pain due to lateral retraction of the tendon, compared to paratendinous approaches.[31,32]

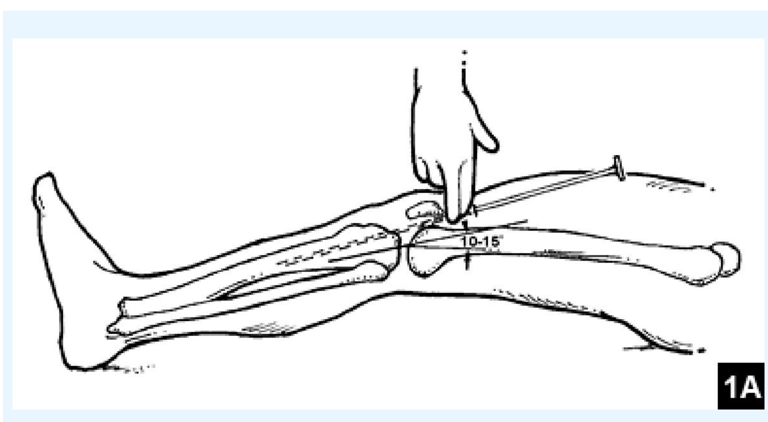
Keating et al[27] compared knee pain after parapatellar and patellar tendon-splitting approaches. They found that 77% of patients developed knee pain after a tendon-splitting incision, whereas only 50% developed pain with a parapatellar approach. This led them to abandon tendon-splitting incisions. In their series, there was no correlation between nail protrusion and knee pain, suggesting that pain is secondary to tissue disruption during nail insertion.

Toivanen et al[32] performed a prospective randomized, controlled study comparing anterior knee pain in transtendon and paratendinous incisions. Contrary to the study of Keating et al,[27] they found no significant difference in pain between the approaches. However, like Keating et al,[27] they were unable to demonstrate a relationship between anterior pain and nail protrusion from the cortex. They concluded that other than surgical approach, anterior knee pain has a multifactorial etiology including infrapatellar nerve damage and surgically induced scar formation.

A suprapatellar approach has the potential to reduce the incidence of anterior knee pain. The infrapatellar nerve is well protected and not at risk of injury when using this approach. Additionally, soft tissue scar formation will not be located on the anterior knee, but rather superior to the patella, which may reduce flexion-related pain and pain with kneeling.

The Percutaneous Lateral Suprapatellar Approach in a Semi-extended Position

In this approach, the patient is positioned supine on a radiolucent table with a radiolucent foam support under the leg. The knee is placed in 10° to 15° of flexion to relax the quadriceps muscle, preventing a procurvatum deformity. A 1.5-cm transverse skin incision is made 2 finger breadths above the superolateral corner of the patella (Figure 1). The interval between the vastus lateralis and rectus femoris is bluntly dissected. There is no internervous plane, as the femoral nerve supplies both these muscles; however, there is no risk of denervating them, as the femoral nerve enters both well proximal in the thigh.



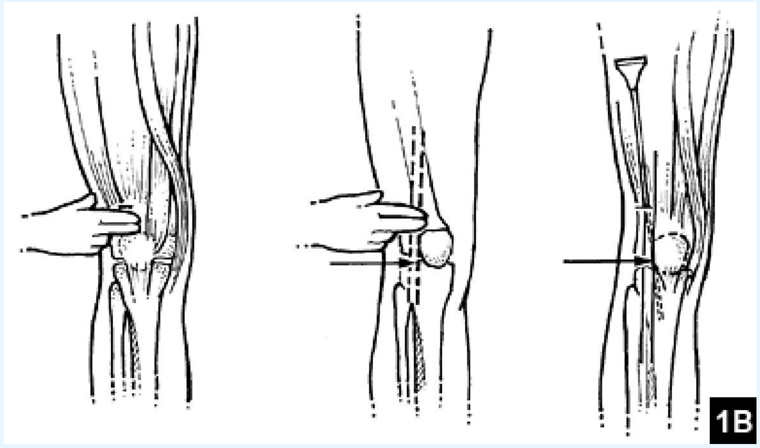
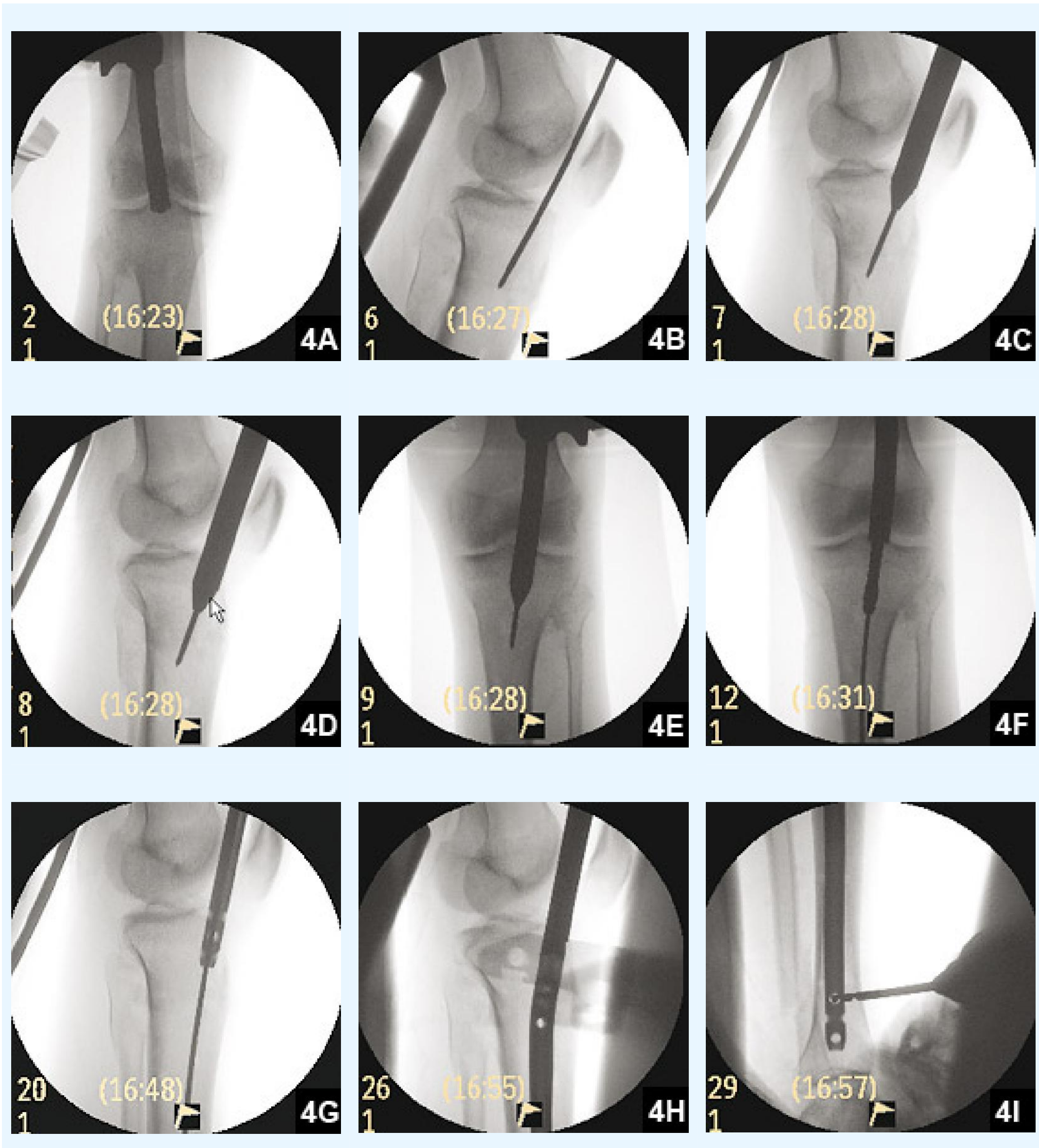


Figure 1: Lateral illustration of appropriate positioning of the knee in 10° to 15° of flexion (A). Anterior illustration of incision placement 2 finger breadths superior to the superolateral corner of the patella, subluxation of the patella medially (B).

Blunt dissection is carried out inferomedially to the joint capsule, and a trocar is inserted posterior to the patella, into the knee joint. The patella is subluxated medially as the trocar is directed toward the safe zone[28] on the tibial plateau, using the femoral trochlear groove as a guide (Figure 2). A 3.2-mm guide pin is inserted through the trocar/entry tube complex and placed in the starting portal. The trocar is removed, and biplanar C-arm imaging confirms the starting point. After definitive placement of the guide pin, a rigid entry reamer is advanced over the guide pin, through the entry tube, to a depth of 4 to 6 cm in the tibia. After positioning of the entry reamer is checked radiographically, the reamer and guide pin are removed. A ball-tipped guide wire is then introduced into the medullary canal, advanced across the fracture site, and impacted into the subchondral bone of the distal tibia.

Figure 2: Photograph demonstrating the trocar placed through the incision and arthrotomy directed toward the tibial safe zone. Note the challenging soft tissue lesions that can preclude an open reduction/internal fixation or conventional intramedullary nail. Figure 3: Lateral C-arm radiograph after the tibial nail has been placed in the medullary canal. The arm to connect the proximal locking screw gig can be seen on the left.

If reaming is desired, sequential reamers are placed through the entry tube to protect intra-articular structures, and the canal can be reamed. Once reamed to the appropriate size, the tibial nail is placed down the canal; the protective entry tube can be used to avoid potential intra-articular damage. An extended proximal jig is used to place the proximal crossed locking screws (Figure 3). This jig is longer than the similar device used in the tendon-splitting or parapatellar approaches. It extends from the incision to the proximal tibia. The distal locking screws are placed freehand under biplanar C-arm guidance (Figure 4).



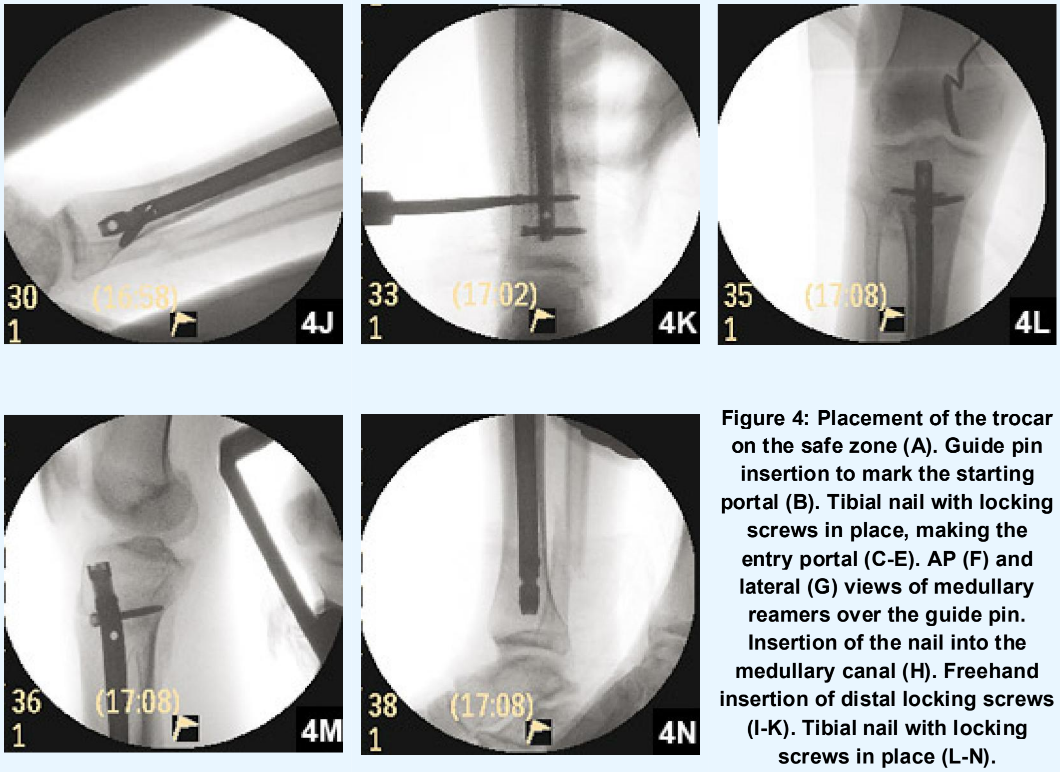


Figure 4: Placement of the trocar on the safe zone (A). Guide pin insertion to mark the starting portal (B). Tibial nail with locking screws in place, making the entry portal (C-E). AP (F) and lateral (G) views of medullary reamers over the guide pin. Insertion of the nail into the medullary canal (H). Freehand insertion of distal locking screws (I-K). Tibial nail with locking screws in place (L-N).

Discussion

Intramedullary nailing of tibial fractures has evolved since the 1940s. Advances have been made in metallurgy and nail design, which have expanded the indications for intramedullary stabilization of tibial fractures; however, the approach to nailing a diaphyseal fracture has remained largely unchanged: either a patellar tendon-splitting or medial or lateral parapatellar approach. Tornetta[22] and Cole[23] have described the use of medial patellar arthrotomies for nailing proximal tibial fractures. These techniques are helpful in reducing the deforming forces, allowing proper reduction of proximal fractures, and preventing a procurvatum deformity. However, they require large incisions for nail insertion.

The classic parapatellar and transtendon approaches are associated with postoperative knee pain. The etiology of this pain is likely multifactorial, including stretching the tendon intraoperatively, damage and scarring to the soft tissues, and infrapatellar nerve injury. This pain has a significant impact on patient outcome, particularly in young manual laborers, who are most commonly affected by tibial shaft fractures. The percutaneous lateral suprapatellar incision theoretically avoids these potential causes of pain, likely improving patient outcome and increasing patient satisfaction. It also allows the patient to avoid periods of limited activity due to the healing of a split tendon. This can be particularly important for athletes.

In proximal oblique metaphyseal fractures with posterior cortical extension, the suprapatellar technique reduces the risk of posterior cortex perforation by placing the starting point in line with the medullary canal. It also relaxes the quadriceps muscle, preventing malreduction. This technique helps to reduce varus and valgus deformities by using the femoral trochlear groove as a guide to the starting point. This maintains the mechanical axis of the lower extremity. Additionally, the suprapatellar approach is easily mastered, gives the orthopedic surgeon convenient access to the safe zone on the tibial plateau, and helps obtain more consistent starting portal placement in a closed fashion. Nail removal can be easily achieved via a regular tendon-splitting technique.

A potential criticism of this approach is the intra-articular involvement and the potential for patellar or trochlear chondral injury. Although this approach transverses the patellofemoral joint, the entry sleeve is in place at all times, protecting the chondral surfaces during reaming. Furthermore, the sleeve will easily collect the bone debridement that would be rapidly suctioned out.

During the course of our experience with this approach, we have implemented different designs of trocars and sleeves (Figures 5-7). The sleeves can be disposable plastic from endoscopy sets or custom made in stainless steel or carbon fiber. They reach a maximum diameter of 12.5 mm to accommodate a reamer. All the jigs, including reaming and measuring devices, have to be appropriately fabricated to accommodate the extra length of the set. Only the ball-tipped guide wire can be a short 80 cm instead of the usual 100 cm. We have been pleased with a stainless steel trocar that can be screwed in the outer sleeve and has minimal tip distance between the apex of the trocar and the circumference of the sleeve. Furthermore, a three-quarter outer sleeve completes the set and is used in the insertion of the nail to maintain protection between the nail itself and the cartilaginous surface of the throclear knee.

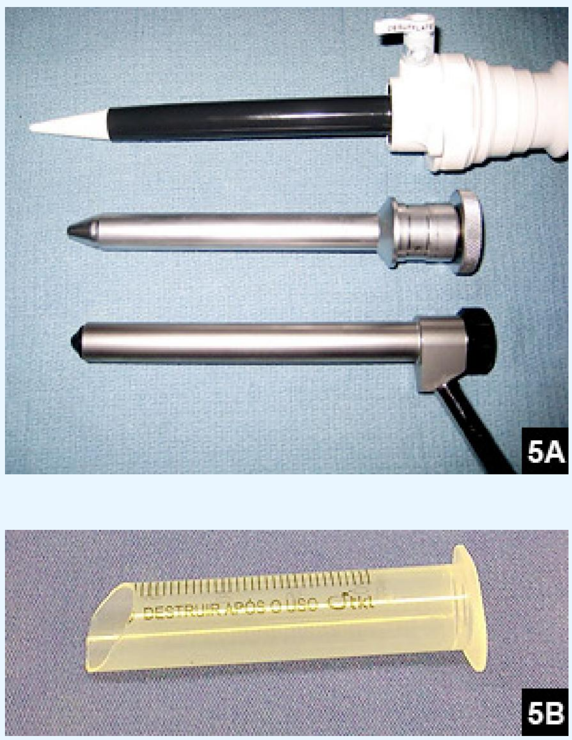


Figure 5: Different trocars used for the reamers during the percutaneous lateral suprapatellar approach. A plastic disposable abdominal endoscopy trocar (A). A regular 20-cc syringe, properly cut and used as a protective sleeve (B).

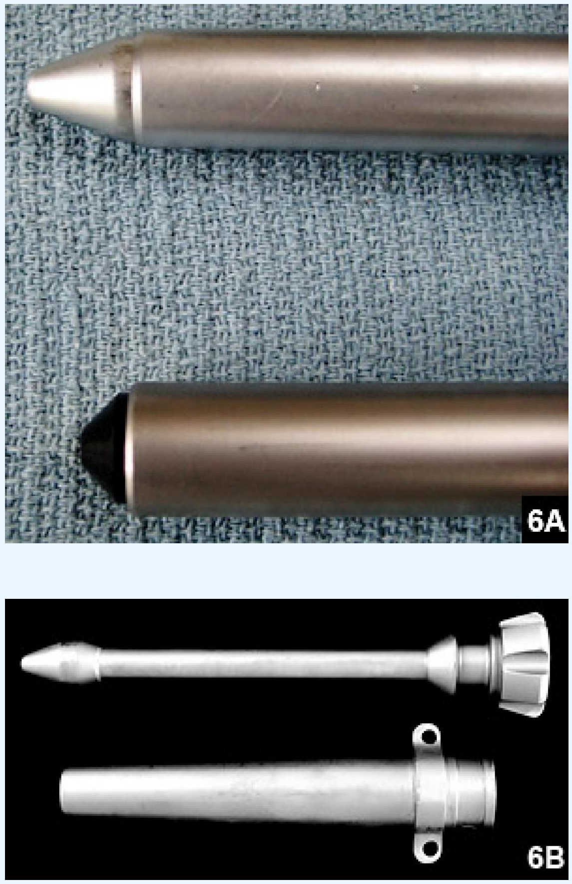


Figure 6: Stainless steel trocars and sleeves. Note the different protruding tips (A, B).

Figure 7: Custom-made trocar with short point to minimize the distance between protective sleeve and cartilage and therefore the potential for damage of the cartilaginous structures. The three-quarter outer sleeve (black) can remain in place during the introduction of the nail for extra protection.

It remains to be determined if contact between the protective sleeve and articular surfaces causes any clinically significant sequelae. Further research is necessary to completely evaluate this approach and the related instrumentation. A cadaver study comparing starting points between the different approaches would be helpful, as well as clinical assessment of intra-articular damage after nail placement.

Conclusion

We consider the lateral percutaneous suprapatellar approach in a semi-extended position to be an excellent approach for intramedullary nailing of tibia fractures. Combined with easy stabilization and fixation of proximal tibia fractures, it can be implemented in all kinds of diaphyseal or metaphyseal fractures due to the direct internal alignment obtained. There is no need for fracture tables or bulky, expensive surgical aids to prevent malalignment.

The use of poller screws can be furthermore eliminated. The approach must be combined with a nail set that includes particular requirements, specifically appropriate targeting and measuring devices. A future nail design may not feature a proximal Herzog curve. The use of protective sleeves and a trocar is recommended. The association of a transverse small skin incision and avoidance of direct contact with the patellar tendon make this surgical approach particularly prone to early mobilization of the knee joint, and it is well tolerated by athletes or patients who kneel frequently.

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Authors

Drs Morandi, Banka, Guthrie, Khalil, and Hoegler are from the Department of Orthopedics, Henry Ford Hospital, Detroit, Michigan; and Dr Gaiarsa is from Hospital Dr Moises Deutsch, San Paulo, Brazil.

Drs Morandi, Banka, Gaiarsa, Guthrie, Khalil, and Hoegler have no relevant financial relationships to disclose.

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Correspondence should be addressed to: Max Morandi, MD, Department of Orthopedics, Henry Ford Hospital, 2799 W Grand Blvd, Detroit, MI 48202 (maxmorandi@aol.com).

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