Original Article

Triple Nerve Injection for Open Reduction and Internal Fixation of Fracture Tibia and Fibula – A Feasibility Study

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Abstract

Background: Targeting femoral, obturator, and sciatic nerves with an anterior approach is a daunting task. Surface landmarks have been described but with limited success. This feasibility study describes a single-puncture approach to the three nerves in real time under the guidance of a curvilinear probe and investigates the feasibility in the proximal thigh for patients undergoing bicondylar fixation with fractures of the proximal tibia. **Methods:** Forty patients with fractures of the proximal tibia planned for a bicolumnar open reduction and fixation with a plate were recruited in this feasibility study. We named this unique approach the "triple nerve injection" (TNI) block. These blocks were injected with 40 mL of 0.2% ropivacaine injected in the vicinity of the branches of the femoral nerve (10 mL), the sciatic nerve (20 mL), and between the adductors targeting the anterior and posterior division of the obturator nerves (5 mL each). **Results:** The pain was perceived at a mean of the 12th h on the medial side as against a mean of the 13th h on the lateral aspect. The time to rescue analgesia was 12 h. An optimal spread was visualized in 90% of blocks, while the diffusion in 10% of sciatic blocks was inadequate. **Conclusion:** A TNI block facilitates a single-puncture and a single-probe placement technique enables a satisfactory visualization of three fascial planes, together with a single needle redirection.

Keywords: Femoral nerve, nerve block, obturator nerve, sciatic nerve, ultrasonography

Introduction

Tibial plateau fractures are common fractures that constitute approximately 1% of all fractures.[1,2] These fractures are significant because of its intra-articular nature and associated meniscal and medial collateral ligament tears. However, AO/OTA type C or Schatzker type V and VI accounts for 35.8% of all tibial plateau fractures.[3] Open reductions and internal fixation for bicondylar tibial fractures with a medial and lateral incision have generally shown good functional results.[4,5] A meta-analysis questioning the role of single versus dual plate concluded that the dual plate has the advantage of maintaining anatomic alignment compared to a single plate.[6] A study investigating patient's expectancy following surgery on fractures of the proximal tibia committed that "pain relief" and "being able to walk" were the highest priorities.[7] The pain scores Numeric rating scale (NRS) were a mean of 4.5 following surgeries on the proximal tibia. However, the residual pain following surgeries on proximal tibia was at 47% and 77% in two separate studies.[8,9] A prospective study revealed tibial fractures that had an incidence of complex regional pain syndrome after surgery of 31%, with 33.3% treated with intramedullary nailing, 28.6% treated with screws, and 28.6% treated with external fixation.[10] A task force guideline recommends using a continuous catheter over a single shot when administering a nerve block. They report better pain control with a decreased chance of rebound pain often associated with lower extremity blocks. It is hypothesized that reduced postoperative pain may allow earlier mobilization, better rehabilitation, and higher patient satisfaction, findings that have been reported in patients undergoing total knee arthroplasty.[11] Neuraxial techniques and general anesthesia both can be implemented for lower limb surgeries. A comparative study concluded that spinal anesthesia was associated with decreased pain scores in the immediate postoperative period.[12] However, the regional

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Abbreviations

NRS	Numeric rating scale
b-FN	Branches of femoral nerve
TNI	Triple nerve injection
US	Ultrasound
AP	Adductor plane
CTRI	Clinical Trials Registry-India
LA	Local anesthetic
TTFA	Time to first analgesia
ACL	Anterior cruciate ligament
FOS	Femoral, obturator, sciatic

nerve blocks may have the ability to reduce central pain sensitization and modify spinal pain pathways that can lead to postoperative hyperalgesia and chronic pain syndromes. Blocks for surgeries in and around the knee joint involve the innervation of lateral femoral cutaneous femoral, sciatic, and obturator nerves. Sensory innervation of the proximal tibia is through the nerves innervating the knee joint (saphenous, branches from the anterior and posterior obturator nerves, and the sciatic nerve).[13] Thus, intense pain after surgical procedures on the knee and tibia requires the blockade of "3" nerves (femoral, obturator, and sciatic).[12,14-16]

Individual lower limb nerve blocks are time-consuming and also lead to patient discomfort in an awake state.[17] However, procedural discomfort was uncommon with ultrasound-guided block. Discomfort during the peripheral nerve block procedure was uncommon with only 1% (11/977) of patients reporting severe procedural discomfort and 6% (56/977) of patients reporting moderate procedural discomfort.[18] It is therefore important to have a technique that covers multiple nerves with a single injection entry point.

In 40 patients, we studied the feasibility of an ultrasound-guided single-puncture approach to the branches of the femoral nerve (b-FN), obturator nerve, and sciatic nerve (triple nerve injection [TNI]).

Materials and Methods

The study was conducted in accordance with the Declaration of Helsinki and was approved by Institutional Ethics Committee—Sancheti Institute for Orthopedics and Rehabilitation (approval number: SIOR/11-03-2021; approval date: 03/11/2021) and was registered with the Clinical Trials Registry-India (CTRI) (CTRI/2021/09/036715). Informed written consent was obtained from 40 patients with fractures of the proximal tibia planned for a bicolumnar open reduction and fixation with a plate. The inclusion criteria were patients aged 18–80 years, the American Society of Anesthesiologists physical status I to III, elective surgical fixation of proximal tibia qualified for inclusion, and a body mass index of <30 kg/m^{-2}. The exclusion criteria were bilateral lower limb surgery, lower and upper limb surgery, contraindications to regional anesthesia, pregnancy, known allergy to local anesthetics, bleeding diathesis, and preexisting neuropathy.

All patients were monitored with electrocardiogram, noninvasive blood pressure, and pulse oximeter. Ringer's lactate 1000 mL was infused through a 20G intravenous cannula. In a sitting position, all patients were administered spinal anesthesia through a 27G spinal needle. Following a free flow of cerebrospinal fluid, 0.5% bupivacaine 3.5 mL was injected. All fractures underwent open reduction and internal fixation with incisions on the lateral and medial aspect of the proximal leg. In the immediate postoperative period, the block was administered in all patients with 0.2% ropivacaine and 1 μg/kg of clonidine.

With the leg in slight external rotation, a curvilinear Ultrasound (US) probe was deployed on the inguinal crease in the axial

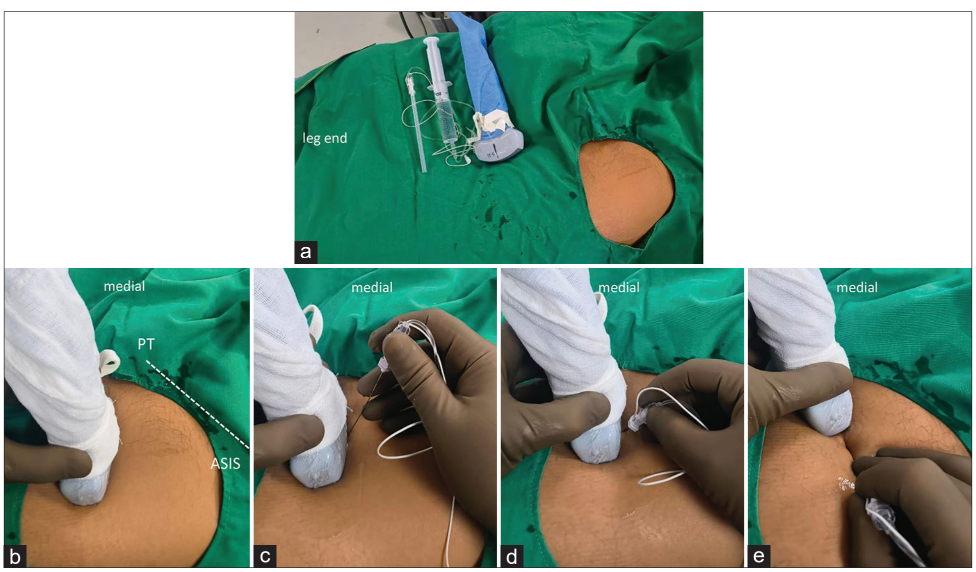

Figure 1: (a) Block requirements (curvilinear probe, 100 mm needle, and local anesthetic-filled syringe) with the patient in the supine position, (b) Axial probe placement in the proximal thigh at the level of the lesser trochanter, (c) Needle placement, out of plane at the branches of the femoral nerve, (d) Needle inserted deep, and out of plane with tip in the vicinity of the sciatic nerve, (e) Probe slides medially toward the adductor planes and needle in plane for obturator nerve block. ASIA: Anterior superior iliac spine, PT: Pubic tubercle

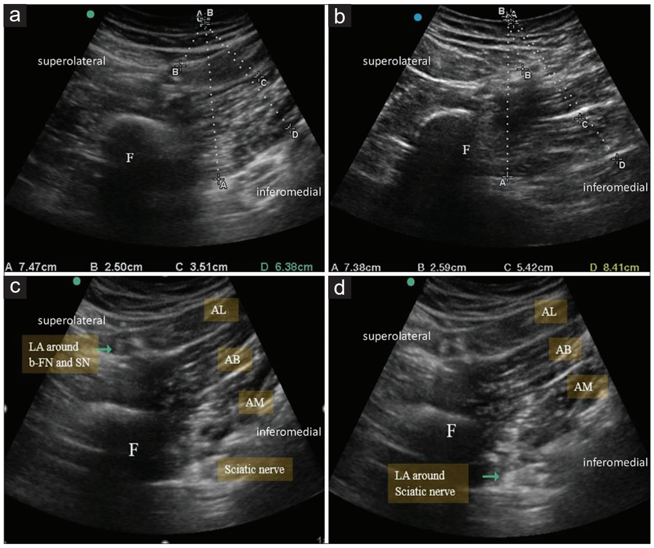

Figure 2: (a) Out-of-plane approach to all nerves, (b) Out-of-plane approach to all nerves, (c) Local anesthetic in vicinity of branches of femoral nerve and saphenous nerve, (d) Local anesthetic in vicinity sciatic nerve; AL: Adductor longus; AB: Adductor brevis, AM: Adductor magnus, b-FN: Branches of the femoral nerve, F: Femur

plane to identify the FN and vessels [Figure 1a-e]. The transducer was shifted caudal to identify the lesser trochanter; subsequently, the target planes were identified in respective fascial planes mentioned below [Figure 2a and b]. Figure 2c and d shows the b-FN lateral to the femoral artery beneath the sartorius. The adductor planes (APs) between the adductor longus and brevis and the brevis and magnus host the anterior and posterior divisions of the obturator nerves, respectively, and the sciatic nerve between the gluteal and adductor magnus [Figure 2c and d]. Needle trajectories were plotted engaging the FN, sciatic nerve, and AP. The distance from the needle entry point to the[1] b-FN,[2] sciatic nerve, and[3] both the AP was measured during all blocks [Figure 2c and d].

With a 10 cm insulated needle (PAJUNK®, Germany) and using an out-of-plane approach, the needle was inserted in the vicinity of the femoral artery. A total of 10 mL LA solution was injected lateral to the femoral artery after identification of the b-FN [Figure 3a]. Once the needle tip was confirmed in the paraneural sheath, 20 mL of LA was injected which engulfed the sciatic nerve (complete or at least three-fourths of the circumference) [Figure 3b].

The probe was tilted medially in the same plane to recognize the planes between adductors. The needle was withdrawn superficially and redirected to the femoral artery, targeting the two planes between the three adductor muscles. With the needle tip in the plane between the adductor longus and brevis, 5 mL LA was injected. Advancing needle tip between brevis and magnus further 5 mL LA was injected [Figure 3b]. The access to each of the target areas:[1] b-FN,[2] sciatic nerve, and[3] both the APs was evaluated in each block. The performance time (scan and needling time) was monitored. Upon injection, the spread of LA was scrutinized. A three-fourth spread around the b-FN and the sciatic was considered adequate spread while an elliptical spread in the AP was contemplated as successful diffusion.

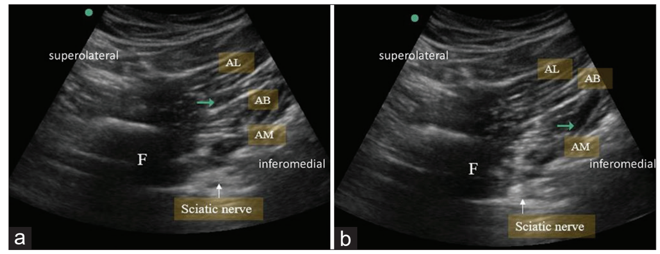

Figure 3: (a) Local anesthetic in the adductor plane between the adductor longus and adductor brevis (AB), (b) Local anesthetic in the adductor plane between the AB and adductor magnus. The Friedman test for repeated measures with *P* value adjustment has been done, and results are presented in the figure. AL: Adductor longus, AB: Adductor brevis, AM: Adductor magnus, F: Femur

Postoperatively, the time to first analgesia (TTFA) was identified as a complaint of pain either on the medial or lateral aspect of the leg. Intramuscular diclofenac sodium 75 mg was administered on this occasion and thereafter every 8 h. Rescue analgesia was in the form of intravenous tramadol 50 mg infusion for the first 48 h. NRS was measured at various time points for the first 48 h. Oral analgesics in the form of diclofenac 75 mg and tramadol 50 mg were prescribed after the first 48 h. Postoperatively, all patients were examined for foot drop secondary to prolonged duration of motor sciatic nerve block. After a change of dressing, isometric exercises were initiated by physiotherapists for the quadriceps on the 3^{rd} postoperative day. Before hospital discharge, all patients were evaluated for residual effect of nerve blocks. From day 5 until the 2^{nd} week, knee range of motion exercises was commenced. Surgeons assessed the range of motion at the end of 1^{st} and 3^{rd} months. Data were summarized as medians and interquartile ranges for continuous variables and as frequencies and percentages for categorical variables. Data were analyzed using the R-Project for Statistical Computing Version 4.3.0, R Core Team (2023), for MS Windows, PAJUNK® GmbH Medizintechnologie, Geisingen, Germany.[19]

Results

Demographics and other relevant information are detailed in Table 1. The pain was perceived at a mean of the 12^{th} h on the medial side as against a mean of the 13^{th} h on the lateral aspect. The NRS at 0^{th}, 4^{th}, 8^{th}, 12^{th}, 18^{th}, and 24^{th} h are illustrated in Figure 2c. The request for analgesia for the TTFA after the block was a mean of 12 h. Figure 4 depicts a Kaplan–Meier curve showing TTFA from the time of the block (X-axis: Time, in hours) along with a risk table. The number of rescue analgesic (tramadol) injected was 7%. Transient quadriceps weakness in 1 and foot drop in 2 were reported at the 24^{th} h. However, at the time of discharge on the 5^{th} postoperative day, none of the patients complained of residual effects of nerve blocks. Isometric exercises for the quadriceps confirmed a 90° knee flexion on 3^{rd} and 5^{th} day. Surgeons confirmed adequate

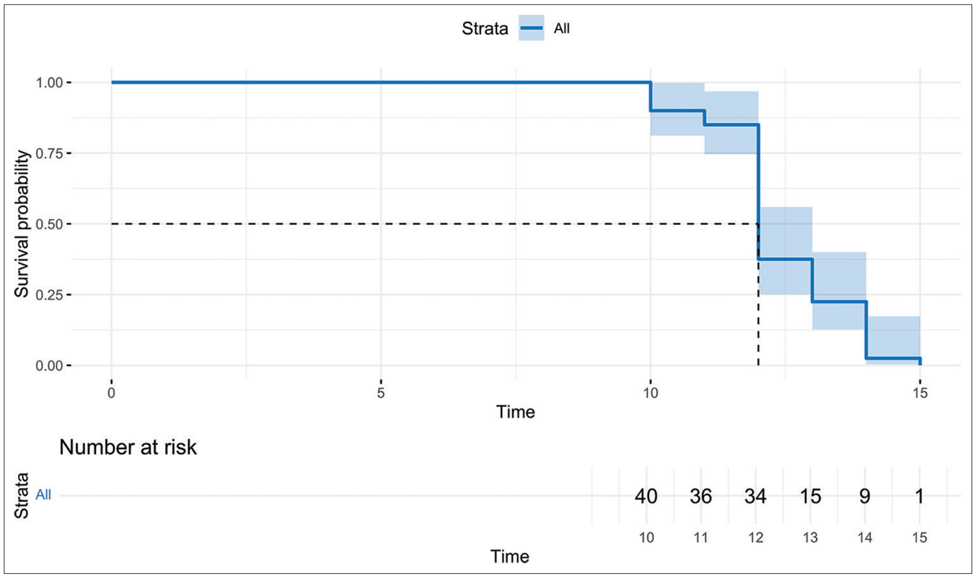

Figure 4: Kaplan–Meier curve depicting time to first analgesia in the X-axis

Table 1: Demography and block characteristics

Variable/characteristic	n=40[a]
Median age (years)	49 (40.5–60)
Gender (male/female)	20/20
ASA-PS (I/II/III)	20/19/1
Skin to b-FN distance (cm)	4.00 (3.00–5.00)
Skin to sciatic nerve distance (cm)	10 (8–10)
Skin to AP distance (cm)	6.00 (5.00–7.00)
b-FN	
Successful	40 (100)
AP	
Successful	40 (100)
Sciatic access	
Successful	36 (90)
Unsuccessful	4 (10)
Scan performance time (min)	5 (4–6)
Needling performance time (min)	12 (10–12)
Inadequate LA spread	4 (10)
Vascular aspiration	2 (5.0)
Medial leg (time of first pain occurrence)	13 (12–14)
Missing data (count)	22
Lateral leg (time of first pain occurrence)	12 (8–12)
Missing data (count)	18
NRS 4 h	0 (0–0)
NRS 8 h	1 (1–2)
NRS 12 h	6 (5–7)
NRS 18 h	4 (4–4)
NRS 24 h	4 (3–4)
Time to first analgesia (h)	12 (12–13)
Rescue analgesia	7 (18)
Quadriceps weakness	
No	40 (100)
Foot drop	2 (5.0)

[a]Median (IQR); n (%). IQR: Interquartile range, AP: Adductor plane, ASA-PS: American Society of Anesthesiologists-physical status, b-FN: Branches of the femoral nerve, NRS: Numeric rating scale, LA: Local anesthetic

range of motion at the 1st and 3rd month in all patients except one who suffered from knee stiffness.

Discussion

Our pilot study illustrates that the block was feasible in all patients (100%). However, in 4 out of 40 (10%) patients, the analgesic block was inadequate, requiring tramadol in 7% of patients.

Innervation of the tibial subchondral plate and trabecular bone within the tibial epiphysis carries pain signals from the knee joint to the brain through intercondylar foramina.[20] The saphenous nerve through the infrapatellar branch and the nerve to vastus medialis innervate the anteromedial knee (capsule and retinaculum). The anterior obturator nerve anastomoses with the saphenous nerve (subsartorial plexus) while the posterior obturator nerve forms a part of the popliteal plexus and innervates anterior and posterior knee joints, respectively. Interestingly, the branches to the anterior cruciate ligament (ACL) originate from the branches to the anterior capsule, and the branches to the posterior cruciate ligament come from the branches to the posterior capsule.[21]

The nerves embroiled in knee joint penetrate the anterior capsule and innervate the proximal tibia and fibula (saphenous, anterior obturator, common fibular nerve invigorates the tibia) and popliteal plexus (articular branches of the tibial, posterior obturator, and the posterior branch of the sciatic nerve) supplying the superior tibiofibular joint and fibular periosteum.[22,23] Thus, pain originating from the tibia would be relayed through nerves arising from the four quadrants through the three nerves (femoral, obturator, and sciatic nerves).[24]

A couple of combinations of nerve blocks exists for the knee joint. In particular, are the femoral and the sciatic, a three-in-one and sciatic, and the posterior lumbar plexus and sciatic. Comparative studies concluded that an additional obturator nerve block to femoral and sciatic blockade improved postoperative analgesia following ACL tear and total knee replacement.[25-27] Based on the fact that an obturator nerve block improves analgesic efficacy, a novel technique was recently published, the "femoral, obturator and sciatic (FOS)" technique. The obturator and FN were identified separately with dual guidance, and the sciatic nerve was approached through a subgluteus technique.[28] In contrast to our technique where all the three nerves were approached successfully through a single puncture, in earlier studies, the nerves were approached separately. Likewise, our study includes the obturator nerve block for the compelling reason that it innervates the proximal tibia with other nerves of the lumbar plexus, femoral and obturator nerves.

External rotation of the lower limb with slight flexion allows better sciatic nerve visibility, decreases the depth of the skin to the sciatic nerve, and facilitates needle insertions.[29] As against the perspective that the advancing needle (out of plane) encounters the deep femoral artery and b-FN which needs to be avoided, we take this advantage to inject local anesthetic lateral to the artery. Decreasing the depth of the image will allow better vitalization of the b-FN (saphenous nerve). As the neural elements move away from the advancing needle, the sciatic nerve is targeted (out of plane), which is known for anisotropy. Slight angulation will improve the visibility of the needle tip in approximation with the sciatic nerve. Following this, a slight medial shift of the curvilinear probe, and bringing in line with the needle shaft and medial to it, the inter-APs for the obturator nerves are visualized. Withdrawing the needle from the femoral target (out of plane), the needle is redirected (in plane) above the artery toward the AP for the obturator nerves. The spread of local anesthetic circumferential or noncircumferential does not determine block failures; however, in the sciatic nerve, a circumferential spread is associated with rapid sensory block onset times.[30] The injection in the AP produces an elliptical swelling as it dissects the fascia.[31]

A meta-analysis confirmed that ultrasound-guided sciatic blocks improve the success rate of block and reduce the risk of vascular puncture when compared to neurostimulation-guided blocks.[32] Further, the ultrasound-guided subgluteal approach to the sciatic nerve resulted in an incidence rate of 16.3% (325 patients) for unintentional intraneural injection. The onset of the blockade was accelerated by intraneural injection of mepivacaine or ropivacaine, but the duration of the block was not influenced, and clinical neural injury was not observed. Further, it is intriguing to observe that the mean nerve stimulation thresholds of the intraneural and nonintraneural groups are comparable (0.43 vs. 0.45 mA).[33] This implies that it is challenging to prevent intraneural injections through nerve stimulation alone.

We admit that neurostimulation and pressure monitoring for detecting intraneural injections were not implemented in our study. These provided added safety against intraneural injections.[34] However, all TNI were performed by senior anesthesiologist with an ultrasound experience of more than 20 years and consistently practicing anterior sciatic blocks.

In the supine position, an approach to all three nerves has been described earlier and termed as a soft block.[35] However, the soft block is a multifaceted approach using three different imaging views for the femoral, obturator (medial and cranial probe direction), and sciatic (probe change, inferior to needle and rotate from axial to longitudinal), three variable needle redirections (in plane for femoral, out of plane for obturator, and in-plane longitudinal for sciatic) and one change in probe (linear to curvilinear). Contrastingly, in our study, a single curvilinear probe is necessary to identify the target areas in a single view, and with a single needle puncture, the needle is advanced toward the three target areas with an out-of-plane technique. Interestingly, no studies are addressing regional analgesia techniques for proximal tibia. Through our clinical study, we attempt to reveal the TNI approach through a single puncture which is unique to this study, and our knowledge is undescribed.

Since all blocks were performed in the immediate postoperative period, with spinal anesthesia as the primary anesthetic, the sensory and motor evaluation could not be investigated. Further, in awake patients' paraesthesia if any would be easily demonstrated, which was unlikely in this study. These would be certain limitations of the study.

Conclusion

The utilization of a single-puncture and a single-probe placement technique enables a satisfactory visualization of three fascial planes, together with a single needle redirection. Thus, the above characteristic features render this approach more appealing and worthy of consideration.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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