Evaluation of a Proximal Block Site and the Use of Nerve-Stimulator-Guided Needle Placement for Posterior Tibial Nerve Block

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BACKGROUND: Posterior tibial nerve (PTN) block has traditionally been performed in the para-medial malleolar area without nerve stimulator (NS) guidance. The PTN can also be blocked proximally (7 cm) above the medial malleolus in the subfascial plane between the flexor hallucis longus and flexor digitorum longus tendons. In this study we compared the frequency of successful PTN block at the traditional distal (D) site (2 cm above the medial malleolus) with and without NS guidance. We also compared block success and latency at the D site versus the proximal (P) block site.

METHODS: Subjects were randomized to P-NS ($n = 45$), D-NS ($n = 45$), or D without NS ($n = 45$). Levobupivacaine 0.625%, 0.15 mL/kg was used for all blocks. Pinprick sensory anesthesia was evaluated in the distribution of the medial plantar, lateral plantar, and medial calcaneal nerves. PTN block was considered successful if surgical anesthesia was achieved in all PTN distributions.

RESULTS: The frequency of successful PTN block was greater for D-NS (100%) and P-NS (93.5%), compared with D (73.3%) ($P = 0.02$). Median latency to complete block was less for D-NS (8 min, 95% CI 7–9 min) than D (20 min, 95% CI 13–26 min) ($P < 0.01$) and P-NS (15 min, 95% CI 12–18 min) ($P = 0.04$).

CONCLUSIONS: NS-guided needle placement improves the success and decreases the latency to onset of complete PTN block at the D site. The P approach to PTN block may be a useful alternative to the traditional D site approach, particularly in patients with restricted access to the D site.

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Ankle block is a well described and successful means of providing surgical anesthesia and postoperative analgesia for midfoot and forefoot surgery. Sensory efferents of the foot are located in the posterior tibial nerve (PTN), the deep peroneal nerve, the superficial peroneal nerve, the saphenous nerve, and the sural nerve. Only the PTN and deep peroneal nerve contain both sensory and motor components which allow for evaluation of the evoked motor response (EMR) when using nerve stimulator (NS)-guided needle positioning. The PTN bifurcates into the medial plantar nerve (MPN) and lateral plantar nerve (LPN), which provide cutaneous innervation to most of the plantar surface of the foot, and also innervate the musculoskeletal structures of the mid and forefoot (1,2). Thus, PTN blockade is crucial for successful ankle block. The traditional approach for PTN block is distal to the bifurcation of the PTN beneath the flexor retinaculum in the talocalcaneal canal using a blind infiltration technique (3–7). Although not previously described, the PTN can also be blocked more proximally between the tendons of the flexor digitorum and flexor hallucis longus muscles where the nerve lies anterior the medial border of the Achilles tendon (1) (Fig. 1). Theoretically, PTN block at the proximal site may overcome some of the limitations of the distal approach, including constrained local anesthetic (LA) diffusion imposed by the flexor retinaculum, difficulty in locating distal landmarks as a result of altered or nondiscernible ankle anatomy, and partial nerve blockade due to a more proximal branching of the PTN.

We hypothesized that PTN block using a proximal approach with NS guidance may overcome the aforementioned limitations inherent to the traditional distal approach, and thus, improve the latency and success of PTN block. Additionally, we hypothesized that the use of NS guidance to locate the PTN at the distal site would improve the latency and success of PTN block compared with the distal traditional infiltration technique. The present study was thus undertaken to compare the success and latency of complete PTN block using a proximal versus the traditional distal approach, and to assess the impact of NS guidance on the success and latency of complete PTN block at the distal site.

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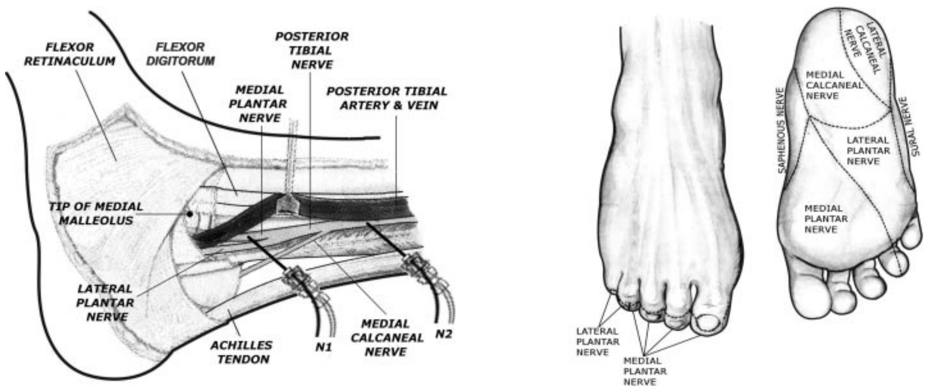

Figure 1. Left panel: Schematic presentation of posterior tibial nerve (PTN) anatomy in lower one-third of leg proximal to the talocalcaneal canal. N2 = needle insertion site for the proximal approach to PTN block. The PTN lies anterior to the medial border of Achilles tendon in the groove between the tendons of flexor digitorum and musculotendinous flexor hallucis longus. When using the nerve stimulator for PTN location, stimulation of the musculotendinous flexor hallucis longus (resulting in isolated flexion of the great toe) indicates that the needle is posterolateral to the PTN and should be redirected anteromedially. Aspiration of blood indicates that the needle tip is within the posterior tibial vessels which lie anteromedial to the PTN. N1 = needle insertion site for distal PTN location. Right panel: Cutaneous innervation of the three terminal branches of the PTN: MPN, medial plantar nerve; LPN, lateral plantar nerve; and MCN, medial calcaneal nerve. Lateral calcaneal nerve (division of sural nerve).

METHODS

IRB approval was obtained for this prospective, randomized, single-blinded study. One-hundred-thirty-five ASA I–IV patients (≥18-yr-old), scheduled to receive a PTN block as a component of ankle block for mid and/or forefoot surgery, gave written informed consent for study participation. Exclusion criteria for study eligibility were hemostatic abnormalities, chronic pain syndrome, foot deformities restricting normal foot movements, allergy to amide LA, pregnancy, infection and/or edema at the ankle, and preexisting neurologic disorders.

Consecutive study subjects who met the study criteria were randomized via a computer-generated random allocation sequence to one of the three groups using a sealed envelope method at the time of study entry. The study groups were: group P-NS, the proximal approach with NS needle guidance; group D-NS, the distal approach with NS needle guidance; and group D, the distal approach without NS needle guidance for nerve location (traditional infiltration technique). In group P-NS the site of PTN block was 7 cm proximal to the tip the of the medial malleolus slightly anterior to the medial border of the Achilles tendon in the groove between the tendons of the flexor digitorum and flexor hallucis longus muscles (Figs. 1 and 2). The distal block site for groups D-NS and D was 2 cm proximal to the tip of the medial malleolus midway between the medial border of the Achilles tendon and the medial malleolus, posterior to the posterior tibial artery pulsation when palpable (Fig. 1).

Figure 2. Needle orientation for proximal approach to the posterior tibial nerve.

Before PTN block, IV access and routine patient monitoring were established. Patients were sedated using 1–5 mg of IV midazolam and/or 25–100 μg of IV fentanyl for comfort as required during block placement. Sedation was administered incrementally ensuring a conversant and coherent state. After achieving an acceptable level of sedation, and before block placement, a baseline sensory assessment response to pinprick stimulation was performed. PTN block was performed a minimum of 30 min before the expected time of surgery by resident trainees supervised by regional anesthesia faculty. In all cases, the patient was placed in the supine position with the foot elevated by placing a blanket roll under both the knee and heel for support and block site access. For group P-NS, the needle was directed anteriorly in a slight caudad direction 60° to the sagittal plane (Fig. 2). In

Table 1. Muscle Innervations and Evoked Motor Response of the Medial Plantar and Lateral Plantar Nerves

Nerve	Muscle innervation	Evoked motor response
Medial plantar	Abductor hallucis	Plantar flexion/abduction of the great toe
	Flexor digitorum brevis	Flexion of all toes
	Flexor hallucis brevis	Flexion of great toe
	Lumbrical	Flexion of corresponding toe
Lateral plantar	Abductor digiti minimi	Abduction of fifth toe
	Adductor hallucis	Adduction of great toe
	Quadratus plantae	Contraction of tendinous arch-midfoot
	Short flexors of fifth toe	Flexion of fifth toe
	Fourth and fifth lumbricals	Flexion of fourth and fifth toes
	Interosseous	Central "stiffening" of the metatarsals

groups D-NS and D, the needle was directed anteriorly towards the medial malleolus aiming posterior-lateral to the tibial artery pulsation.

For NS-assisted blocks, a 50-mm 22-g insulated needle (Stimuplex®, B-Braun/McGaw Medical, Bethlehem, PA) was used. The needle was connected to the negative lead of a constant current NS (Stimuplex HNS-11, B-Braun/McGaw Medical). Stimulation frequency was 2 Hz pulse width was 100 ms, and the current was 1.0 mA. The end point for LA injection was a brisk EMR from the stimulation of the MPN, LPN, or combined MPN and LPN at 0.2–0.4 mA (Table 1). For group D, the block needle was advanced until bone was contacted, then withdrawn 1–2 mm before single incremental injection of the LA solution. In all cases, the LA solution used was levobupivacaine 0.625%, 0.15 mL/kg (maximum 15 mL) injected in 2–3 mL increments.

An independent investigator, blinded to the PTN block technique, performed sensory block assessments every 2 min for 10 min and subsequently every 5 min until 45 min had elapsed after completion of LA injection. Sensory block assessments were performed in the distributions of the MPN, LPN, and medial calcaneal nerve (MCN) (Fig. 1B). A three-level scale was used to determine the intensity of sensory block to pinprick stimulation: 0 = normal sensation, 1 = analgesia (pinprick felt as dull), and 2 = anesthesia (pinprick not felt at all). Complete PTN block was defined as sensory score equal to 2 in the distributions of the MPN, LPN, and MCN. Patients who did not demonstrate at least a sensory score of 1 in the distribution of the MPN and the LPN at the end of the 30-min assessment period were considered block failures and were given a supplemental block using LA infiltration at the distal block site. Additional study variables included age, height, weight, the time required for needle placement and block completion, lowest intensity NS current before LA injection, LA volume, paresthesia during needle or LA injection, and presence of complications such as hematoma or intravascular injection. Twenty-four hours after the procedure all subjects were contacted by the same investigator and questioned regarding the presence of any complication and to obtain a verbal rating score (0 = none to 10 = severe) for discomfort during the procedure.

The sample size estimated for this study ($n = 135$) was determined to detect a difference in the primary outcome, the frequency of complete block at $\alpha < 0.05$. Assumptions for this calculation were based on the previous experience at the authors' institution that the distal approach to PTN blocks using nerve location with and without P-NS assistance produced complete sensory block in approximately 95% and 80% of patients, respectively. A group sample size of 45 was expected to achieve 80% power to detect a difference of 20% in the proportion of subjects achieving complete sensory block at 25 min after injection, assuming a 45-min follow-up period using a two-sided log rank test.

The frequencies of complete PTN block and gender distribution among groups were compared using a χ^2 statistic and the Fisher's exact test. Kaplan–Meier survival curves were constructed, and the log-rank test was used to compare time to complete PTN block among the study groups. The Kruskal–Wallis H test was used to compare age, body mass index, block completion time, LA volume, and stimulating current intensity at the time of LA injection. Latency to a sensory score of 2 in the distributions of the PTN (MPN, LPN, and MCN) were compared among groups using the Kruskal–Wallis H test with Kruskal–Wallis Z test with Bonferroni correction applied for *post hoc* comparisons. A $P < 0.05$ was required to reject the null hypothesis.

RESULTS

Patient characteristics (age, body mass index, gender) as well as the side of surgery, current intensity at LA injection, needle depth at injection, the incidence of paresthesias during needle placement or LA injection, and the subject's assessment of discomfort during the procedure were comparable among the study groups (Table 2). The time required for needle placement and block completion was increased when NS guidance was used. The amount of sedative medication administered among the three groups was comparable.

The distribution of LPN, MPN, and combined EMR responses during needle placement was 13.3%, 33.3%, and 53.3% at the distal site compared with 6.7%, 26.7%, and 66.7% at the proximal site ($P = 0.37$). The time to complete nerve block as a function of elicited EMR is shown in Figure 3. Of the three subjects who did not achieve complete PTN block, two exhibited an EMR of the MPN, and one a combined LPN and MPN response ($P = 0.36$).

Table 2. Subjects and Posterior Tibial Nerve (PTN) Block Characteristics

PTN block site	P-NS	D-NS	D	*P*
Subjects (*n*)	45	45	45	
Age (yr)	50 ± 14	50 ± 14	55 ± 16	0.21
Midazolam (mg)	3.6 ± 1.4	3.9 ± 1.3	3.7 ± 1.1	0.33
Fentanyl (μg)	57 ± 29	62 ± 29	63 ± 31	0.52
Body mass index (kg/m^2)	24.5 ± 3.7	24.9 ± 4.8	24.8 ± 5.0	0.98
Gender (male/female)	4/41	6/39	10/35	0.19
Side of surgery (left/right)	19/26	23/22	18/27	0.53
Needle depth at injection (mm)	22 (19–25)	23 (20–27)	22 (21–26)	0.72
Current at desired EMR (mA)	0.3 ± 0.1	0.3 ± 0.1	–	0.36
Paresthesia (*n*)	1	1	2	0.77
Local anesthetic volume (mL)	12 ± 2	12 ± 1	12 ± 2	0.48
Needle placement and block completion time (s)	237 (160–327)	253 (201–363)	65 (58–110)	<0.005
Block discomfort score (0–10)	4 (2–5)	3 (2–4)	4 (2–5)	0.67
Complete block *n* (%)	42 (93.3)	45 (100)	34 (75.5)	<0.005

P-NS = proximal approach with nerve-stimulator-guided needle placement; D-NS = distal approach with nerve-stimulator-guided needle placement; D = distal approach without nerve stimulator; EMR= evoked motor response.

Data presented as mean ± SD or median (inter quartiles range) unless specified.

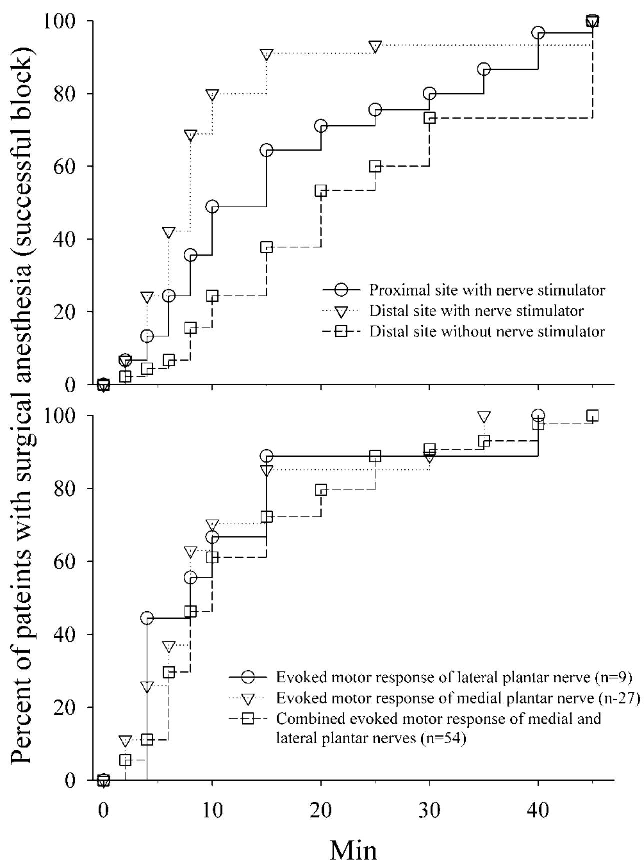

Figure 3. Upper: Percent of patients with complete posterior tibial nerve block versus time. Median time (±95% CI) to complete block for the distal site with nerve stimulator 8 (7–9) min was different from the proximal site with nerve stimulator 15 (12–18) min, and distal site without nerve stimulator 20 (13–26) min ($P < 0.005$, log-rank statistic). The proximal site with nerve stimulator was different from the distal site without nerve stimulator ($P = 0.04$, log-rank statistic). Lower: Percent of patients with complete posterior tibial nerve block versus time by evoked motor response (EMR) at needle positioning. Median times (±95% CI) to complete block for an EMR of the lateral plantar nerve was 8 (0–20) min, 8 (7–9) min for an EMR of median plantar nerve, and 10 (8–12) min for an EMR of both the lateral and medial plantar nerves.

Table 3. Latencies to Sensory Anesthesia (min) on the Plantar Aspect of the Foot by Site of Posterior Tibial Nerve (PTN) Block

PTN block site	P-NS	D-NS	D
Nerve distribution			
Medial plantar	10 (4–20)	6 (4–8)*†	15 (8–20)
Lateral plantar	9 (6–20)	6 (4–8)*†	10 (8–20)
Medial calcaneal	5 (2–10)‡	2 (2–7)*†	12.5 (4.5–20)
Complete ankle block	15 (6–25)‡	8 (5–12)*†	20 (14–30)

P-NS = proximal approach with nerve stimulator guided needle placement; D-NS = distal approach with nerve stimulator guided needle placement; D = distal approach without nerve stimulator.

Data presented as median (interquartile range).

* Different from proximal with nerve stimulator, $P = 0.05$.

† Different from distal without nerve stimulator, $P = 0.05$.

Overall 121 subjects (89.6%) reached the end point defined for complete PTN block. The frequency of complete PTN block at the proximal site using NS guidance was more than at the distal site using infiltration ($P = 0.02$). NS guidance at the distal site increased the frequency of successful PTN block compared with the traditional infiltration technique ($P < 0.005$), but not compared with the frequency at the proximal site using NS guidance ($P = 0.24$).

The percentage of patients who achieved complete PTN block as a function of time is shown in Figure 3. The median latency to complete block for group P-NS was more than that for group D-NS ($P = 0.04$), but was less than the median latency for group D ($P < 0.005$) (Table 3). The latency to a sensory score of 2 in the distributions of the MPN, LPN, and MCN among the study groups is shown in Table 3. Of the three study groups, the time to complete anesthesia was shortest in all the nerve distributions in group D-NS.

There were no immediate complications (hematoma/intravascular injection). Supplemental block using LA infiltration at the distal site was administered in the 14 cases that were considered failed blocks for the study (group P-NS = 3 cases, and group D = 11 cases), and successful anesthesia was achieved.

DISCUSSION

We report that, compared with the commonly used infiltration technique, NS-guided PTN block at the distal talocalcaneal site improves the success and reduces the latency to the onset of complete sensory block. The data from the present study also suggest that the proximal approach to PTN block is a useful alternative to the traditional distal approach, and may be the preferred method in patients who have restricted access to the distal site due to altered/distorted ankle anatomy. However, contrary to our hypothesis, the proximal approach with NS guidance for PTN block was not superior to the distal approach with respect to latency of block onset.

The PTN is the distal continuation of the tibial nerve, a division of the sciatic nerve, extending from the arcade of the soleus muscle to the tibiotalocalcaneal canal. Although several techniques of PTN block have been described, the most commonly used approach is to block the nerve at the level of the medial malleolus within 2–3 cm of its tip as it lies within the talocalcaneal canal beneath the flexor retinaculum (8,9). Block failure at this site may be due to direct LA injection either into the substance of the retinaculum or above the retinaculum, resulting in failure of LA to reach the nerve (12). Additionally, a partial block may occur when the PTN is blocked at this distal site due to proximal branching of the MPN and LPN, or MCN (1). The lower success rate of the distal infiltration technique coupled with lack of anatomical knowledge of the neural innervation of the foot have been cited as major limitations to the use of PTN (ankle) block for foot surgery (13).

The proximal site described in this study was 7 cm above the medial malleolus in line with, and slightly anterior to, the medial border of the Achilles tendon (1). At this site, the PTN would likely be blocked before dividing into the MPN and LPN, or MCN. Theoretically, therefore, the proximal approach to PTN block should be superior to the distal approach with respect to the frequency of achieving a complete block. The data from the present study, however, suggest that, when using an NS for needle placement the distal approach provides a shorter latency and the most frequent success of complete PTN block.

Important determinants of the latency to sensory anesthesia after a peripheral nerve block include the physical properties and dose (volume and concentration) of LA, the proximity of the needle to the nerve, and anatomical characteristics of the adjacent tissue layers. The LA dose and type were consistent in all the three study groups. In comparison with group D, block latency was shorter and success rate higher in groups P-NS and D-NS in which the LA was injected after needle placement with an NS. When using an NS for needle placement, the EMR may be a determinant of block success and latency. Since the MPN is the larger terminal branch of the PTN, injection of LA in the proximity of the main trunk or MPN may improve the success and latency of PTN block. We were unable to demonstrate an association between EMR and success or latency of PTN block; however, our study was under-powered to find such a difference.

The latency to complete block was shorter when the PTN was blocked at the distal site using NS-guided needle placement compared with the proximal site. We hypothesize that compared with the proximal approach, the LA in the distal approach for PTN block is deposited in a relatively restricted compartment under the flexor retinaculum. Deposition of LA in close proximity to the PTN within the restricted space may reduce LA distribution into adjacent structures that may occur at the proximal site and account for shorter latency and increased success of complete block with the distal NS approach. Differences in the nerve fiber size at the proximal and the distal site may also affect the time for drug diffusion and latency for complete nerve block.

A limitation of the findings of this study was the administration of sedative medications before sensory assessments or recording of paresthesias. Although all subjects demonstrated normal pinprick assessment before the PTN block, incrementally administered sedation may have affected sensory assessment findings.

In conclusion, we report that the use of an NS for nerve location improves the success and latency of PTN block. Contrary to our hypothesis, the distal NS approach to PTN block was superior to the proximal NS approach with respect to latency of complete sensory block. The shorter latency to complete PTN block with the distal approach using NS guidance may be related to drug deposition in the restricted compartment beneath the flexor retinaculum. The proximal NS approach to PTN block, however, may be a useful alternative in patients who have altered or distorted ankle anatomy.

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