Ultrasound Guidance Improves a Continuous Popliteal Sciatic Nerve Block When Compared With Nerve Stimulation

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Background and Objectives: Continuous sciatic nerve blockade at the popliteal level effectively alleviates postoperative pain after major foot and ankle surgery. No randomized controlled trials have previously compared the success rate of continuous sciatic nerve sensory blockade between ultrasound and nerve stimulation guidance. In the current study, we tested the hypothesis that ultrasound-guided catheter placement improves the success rate of continuous sciatic nerve sensory blockade compared with catheter placement with nerve stimulation guidance.

Methods: After research ethics committee approval and informed consent, 100 patients scheduled for elective major foot and ankle surgery were randomly allocated to popliteal catheter placement either with ultrasound or nerve stimulation guidance. The primary outcome was the success rate of sensory block the first 48 postoperative hours. Successful sensory blockade was defined as sensory loss in both the tibial and common peroneal nerve territories at 1, 6, 24, and 48 hrs postoperatively.

Results: The ultrasound group had significantly higher success rate of sensory block compared with the nerve stimulation group (94% versus 79%, $P = 0.03$). Ultrasound compared with nerve stimulation guidance also entails reduced morphine consumption (median of 18 mg [range, 0–159 mg] versus 34 mg [range, 0–152 mg], respectively, $P = 0.02$), fewer needle passes (median of 1 [range, 1–6] versus 2 [range, 1–10], respectively, $P = 0.0005$), and greater patient satisfaction (median numeric rating scale 9 [range, 5–10] versus 8 [range, 3–10)] respectively, $P = 0.0006$) during catheter placement.

Conclusion: Ultrasound guidance used for sciatic catheter placement improves the success rate of sensory block, number of needle passes, patient satisfaction during catheter placement, and morphine consumption compared with nerve stimulation guidance.

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Sciatic nerve blockade reduces postoperative pain, opioid consumption, nausea, and the length of stay and improves patient satisfaction after foot and ankle surgery.[1,2] Pain after major foot and ankle surgery is severe and prolonged and benefits from continuous sciatic nerve sensory blockade with catheter technique.[3] The success rate (SR) of postoperative posterior popliteal continuous sciatic nerve sensory blockade varies from 60% to 75% when using traditional electrical nerve stimulation technique and does not differ between stimulating and nonstimulating catheters.[4] Ultrasound guidance may improve the SR of postoperative posterior popliteal continuous sciatic nerve sensory blockade; however, this has not been clearly established. Mariano et al[5] found a catheter placement SR of 100% for ultrasound guidance and 80% for nerve stimulation guidance but did not estimate the sensory blockade. For a continuous popliteal sciatic block, ultrasound guidance has not been compared with nerve stimulation in the placement of nonstimulating catheters. In the present study, we tested the hypothesis that ultrasound guidance improves the SR of postoperative posterior popliteal continuous sciatic nerve sensory blockade compared with the electrical nerve stimulation guidance using nonstimulating catheters.

METHODS

The Central Denmark Region Committee on Biomedical Research Ethics approved the protocol of this study (identifier 20070079), and it was registered in the Clinical Trials Database (http://clinicaltrials.gov; identifier NCT00497276). After written informed consent, 100 patients scheduled for elective major foot or ankle surgery (calcaneal osteotomy, subtalar arthrodesis, total ankle replacement, or open ankle arthrodesis) were included in the study. Inclusion criteria were minimum age of 18 years and American Society of Anesthesiologists (ASA) classification I to III. Exclusion criteria were neuropathy of the sciatic or femoral nerves, impaired sensory or motor function of the lower extremities, diabetic neuropathy, Charcot-Marie-Tooth disease, local infection in the popliteal fossa, systemic infection, coagulopathy, significant peripheral vascular disease, allergy to local anesthetics, inability to comprehend the numeric rating scale (NRS), communicative disability, dementia, body mass index (BMI) greater than 35 kg/m^2, and need for bilateral surgery.

The patients were recruited consecutively and prospectively from May 2007 to September 2009 at Aarhus University Hospital, Denmark. After written informed consent and inclusion, the patients were randomly assigned on the day of surgery to 1 of 2 groups using a computer-generated sequence of random numbers and sealed envelopes—either the ultrasound (US) group or the nerve stimulation (NS) group. Peripheral intravenous access with infusion of isotonic saline was established in all patients along with application of standard monitoring (pulsed oximetry, electrocardiogram, and noninvasive blood pressure). Midazolam 1 to 2 mg intravenously and fentanyl 50 to 100 μg intravenously was used for anxiolysis as required—before randomization—and supplemental oxygen by nasal prongs.

All popliteal catheter placements were performed preoperatively by 4 staff anesthesiologists with substantial expertise in both peripheral nerve localization techniques. All popliteal catheter placements were performed with the patients in the prone position with a bolster supporting the tibia, allowing even vague deflections of the foot or toes. The site of needle insertion was identified and marked (Surgical Skin Marker VX100; Vio Healthcare, Hailsham, East Sussex, UK) as the midpoint between the tendons of biceps femoris laterally and semimembranosus and semitendinosus muscles medially 7 cm proximal to the popliteal fossa crease.[6] The insertion site was prepared with

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chlorhexidine, and an aseptic field was used. The skin insertion site was infiltrated subcutaneously with 2 mL of lidocaine 1%.

Group NS: the popliteal catheter (Contiplex catheter 20 gauge, 400 mm; Braun, Melsungen, Germany) placements were performed with an electrical nerve stimulator (Stimuplex HNS 12; Braun). The stimulation needle (18 gauge × 55 mm, 15-degree facet bevel) was inserted at the needle insertion site in the sagittal plane cephalad and 45-degree angle to the skin until appropriate distal motor response (dorsiflexion or plantarflexion of the foot or toes, or inversion), with a reduction of the current from the initial 1.5 to 0.5 mA or less, at a frequency of 2 Hz, and a stimulation duration of 100 μsec. If an appropriate motor response was not obtained, the needle was withdrawn to the skin level and reoriented 15 degrees lateral—gauged by rule of thumb—and reinserted. If the result was still negative, the insertion point was positioned 1 cm lateral to the primary point, and the procedure was repeated. After obtaining an appropriate motor response, 5 mL of saline was injected, the needle was removed, and the catheter was inserted via the sheath.

Group US: the popliteal catheter placements were performed with a Micromaxx or M-Turbo (from November 2008) ultrasound unit with a 6- to 13-MHz linear transducer (HFL38; Sonosite, Bothell, Wash) covered by a sterile sleeve.

The transducer was placed in the popliteal fossa, and the popliteal neurovascular structures were imaged in short axis. The bifurcation was traced, and the needle (same as the NS group) was advanced out of plane aiming just proximal to the sciatic bifurcation and until contact between the needle tip and the target nerve as judged from movement of the nerve and visualization of the needle tip. Five milliliters of saline was injected to verify the appropriate position of the needle tip with perineural spread of the saline. The needle was withdrawn and redirected as necessary until this end point was reached. The needle was removed, and the catheter was inserted via the sheath.

In both groups, the catheter was introduced 3 cm beyond the introducer sheath. All catheters were fixed to the skin with a snap-lock (Lockit plus; Smiths Medical ASD, Inc, Keene, NH) and covered by a transparent dressing (IV3000 1-Hand; Smith & Nephew Medical Ltd, Hull, UK) before the local anesthetic was injected. The standardized dose of 30 mL of ropivacaine 0.75% was injected via the catheter preoperatively immediately after fixation of the catheter in increments of 5 mL and with intermittent aspirations.

By the end of surgery, the surgeon executed a subcutaneous block of the saphenous nerve with 15 mL of bupivacaine 0.5% proximal to the malleolar level from the Achilles tendon to the medial edge of the tibial anterior margin in all patients.

All patients were anesthetized with propofol and remifentanil combined with a laryngeal mask. The anesthesia was induced with propofol 0.15 to 0.2 mg/kg per minute and remifentanil 0.6 to 0.8 μg/kg per minute and maintained with propofol 0.05 to 0.1 mg/kg per minute and remifentanil 0.2 to 0.4 μg/kg per minute. The dosing was titrated to acceptance of the laryngeal mask and the thigh tourniquet. The tourniquet was applied just above the popliteal level and was inflated to 350 mm Hg in all patients. Propofol infusion was stopped at deflation of the tourniquet, and remifentanil was stopped by the end of surgery. A Bair hugger (Bair Hugger Patient Warmer series 505; Arizant Healthcare, Inc, Eden Prairie, Minn) was applied perioperatively. Fentanyl 50 to 100 μg was administered intravenously as necessary if the patient had pain postoperatively.

Three hours after the initial local anesthetic bolus, a bolus of bupivacaine 0.25% 15 mL was injected via the popliteal catheter, and an infusion of bupivacaine 0.25% 5 to 10 mL/hr was initiated starting at 8 mL/hr.

Breakthrough pain was managed with an additional bolus of bupivacaine 0.25% 15 mL (maximum 4 times per 24 hrs) and the infusion velocity was increased to 10 mL/hr. If the bolus of bupivacaine did not alleviate the pain effectively after 15 mins, intravenous morphine was administered. When the NRS pain score was greater than 3 when immobile, morphine 10 mg/mL, 0.05 to 0.1 mg/kg, was administered intravenously. When the analgesic effect was inadequate (NRS still >3), the dose was repeated after 15 mins. Acetaminophen was used in all patients 1 g orally 4 times per day.

Postoperative nausea was treated with ondansetron 2 mg intravenously twice per 24 hrs.

Patient demographic data were documented (age, sex, weight, height, BMI, ASA score, and type of surgery). The primary outcome was SR of continuous sciatic nerve sensory blockade, which was defined as sensory loss of both the tibial and the common peroneal nerve at all measured time points of 1, 6, 24, and 48 hrs postoperatively. Sensory loss was defined as a score of 0 or 1 of cold sensation using ice cubes in a plastic glove applied on the dorsal side (common peroneal nerve) and the plantar side (tibial nerve) of the toes compared with the same stimulus delivered to the contralateral side. The toes were the only part of the foot accessible to control the cold sensation because of the plaster. Cold sensation was scored as follows: 0 = no cold sensation (complete sensory block), 1 = reduced cold sensation (partial sensory block), 2 = normal cold sensation (no sensory block).

The secondary outcomes were postoperative pain, pain localization (territory of worst pain), analgesia consumption, nausea, antiemetics consumption, number of needle passes, patient satisfaction, and complications.

Postoperative pain score was quantified as NRS score from 0 (“no pain”) to 10 (“worst possible pain”). The localization of postoperative pain (territory of worst pain) could be the sensory regions of the sciatic nerve (plantar or dorsal side of the foot and toes, the posterior side of the heel or anterolateral side of the ankle joint) or the saphenous nerve (anteromedial side of the ankle joint). The patients were asked to localize the maximum point of pain.

Analgesia consumption was quantified as total dose of (1) morphine (mg) the first 48 hrs postoperatively, (2) bupivacaine (mg) the first 3 to 48 hrs postoperatively, and (3) fentanyl (μg) during the post anesthesia care unit stay.

Postoperative nausea was quantified as NRS score from 0 (“no nausea”) to 10 (“worst possible nausea”). Antiemetic consumption was quantified as total dose of ondansetron (mg) the first 48 hrs postoperatively.

The number of needle passes was defined as the number of withdrawals of the needle regardless of the number of skin punctures.

Patient satisfaction was quantified as NRS score from 0 (“not satisfied”) to 10 (“completely satisfied”). Paresthesia or paralysis was evaluated by the surgeon after removal of the plaster at 6 weeks postoperatively. Paresthesia was a priori considered unrelated to regional anesthesia if all the 3 following criteria were fulfilled: (1) the paresthesia was located distal to the surgical field, (2) the nerve pathway crossed the surgical field, and (3) the paresthesia was within a well-defined terminal nerve territory. Hematoma or local infection in the popliteal fossa was evaluated by an independent observer daily the first 2 postoperative days. Sensory blockade, pain, nausea, and patient satisfaction were estimated 1, 6, 24, and 48 hrs after the end of surgery. Patient satisfaction was also evaluated immediately after catheter insertion. Territory of worst pain was evaluated 48 hrs postoperatively.

TABLE 1. Patient Demographic Data (n = 98)

	US (n = 50)	NS (n = 48)	*P*
Age, yrs	56.5 (14.7)	56.2 (13.0)	0.91
Sex, male/female	32/18 (64/36)	28/20 (58/42)	0.57
Weight, kg	83.4 (15.7)	81.5 (15.8)	0.56
Height, cm	175 (9.4)	174 (7.7)	0.33
BMI, kg/m^2	27.0 (4.0)	26.9 (4.4)	0.95
ASA (I–III)			
I	15 (30)	23 (48)	
II	32 (64)	25 (52)	0.06
III	3 (6)	0 (0)	
Surgical procedures			
Calcaneal osteotomy	7 (14)	6 (12)	
Subtalar arthrodesis	5 (10)	8 (17)	0.61
Total ankle replacement	24 (48)	25 (52)	
Ankle arthrodesis	14 (28)	9 (19)	

Values are mean (SD) except for sex, ASA, and surgical procedures that are presented as number (%).

Sampling of the data for the primary outcome and the data of the secondary outcomes based on NRS scores was performed by independent observers blinded to study group allocation. The registration of the number of needle passes and patient satisfaction after catheter placement were done by an independent observer not blinded to study group allocation. The patients and the anesthesiologist performing the catheter placement were not blinded to study group allocation.

Sample size estimate: our hypothesis was that ultrasound increases the SR of sensory blockade from 75% with nerve stimulation technique to 95% with ultrasound technique. The necessary sample size to detect this expected 20% difference was 100 patients in total for a 2-sided analysis with 5% level of statistical significance ($a = 0.05$) and 80% power ($b = 0.2$).[7]

Statistical analysis (Stata Corp, College Station, Tex): Continuous variables with normal distribution are presented as mean (SD). Continuous variables with skewed distribution and ordinal variables are presented as median (range). Categorical variables are reported as number of subjects (percentage). Normality of distribution was estimated with the Kolmogorov-Smirnov test. Continuous data with normal distribution were compared using the Student *t* test. Continuous data with nonnormal distribution as well as ordinal variables were compared using the Wilcoxon-Mann-Whitney *U* test. Comparisons of categorical variables were based on χ^2 test or Fisher exact test as appropriate.

RESULTS

Patient demographics and surgical procedures did not vary significantly between the US and NS groups (Table 1). Two

TABLE 2. Success, Pain Score, Territory of Worst Pain, Analgesia Consumption, Nausea, Antiemesis, Number of Needle Passes, and Patient Satisfaction (n = 98)

	US	NS	
	n = 50	n = 48	*P*
Continuous sciatic blockade 1, 6, 24, and 48 hrs p.o., n (%)			
Success	47 (94)	38 (79)	0.03
Failure	3 (6)	10 (21)	
Pain (NRS 0–10), median (range)			
1 hr p.o.	1 (0–8)	1 (0–9)	0.98
6 hrs p.o.	0 (0–7)	1 (0–8)	0.98
24 hrs p.o.	2.5 (0–8)	4 (0–10)	0.28
48 hrs p.o	1.5 (0–7)	2 (0–7)	0.69
Territory of worst pain 48 hrs p.o., n (%)			
Saphenous	42 (84)	27 (56)	0.003
Sciatic (tibial, peroneal, sural)	8 (16)	21 (44)	
Morphine total 0–48 hrs, median (range), mg	18 (0–159)	34 (0–152)	0.02
Bupivacaine total 3–48 hrs, mean (SD), mg	449 (76)	467 (73)	0.25
Fentanyl in PACU, median (range), μg	0 (0–300)	0 (0–800)	0.84
Nausea (NRS 0–10), median (range)			
1 hr p.o.	0 (0–10)	0 (0–10)	0.64
6 hrs p.o.	0 (0–10)	1 (0–10)	0.93
24 hrs p.o.	0 (0–8)	0 (0–10)	0.11
48 hrs p.o	0 (0–8)	0 (0–10)	0.99
Ondansetron 0–48 hrs, median (range), mg	0 (0–10)	0 (0–16)	0.73
Needle passes, median (range)	1 (1–6)	2 (1–10)	0.0005
Patient satisfaction (NRS 0–10), median (range)			
After catheter insertion	9 (5–10)	8 (3–10)	0.0006
1 hr p.o.	10 (5–10)	10 (0–10)	0.62
6 hrs p.o.	10 (4–10)	10 (0–10)	0.01
24 hrs p.o.	10 (1–10)	10 (0–10)	0.45
48 hrs p.o	10 (3–10)	10 (0–10)	0.95

p.o. indicates postoperatively; PACU, post anesthesia care unit.

patients were excluded after allocation to the NS group because of protocol violation (because both patients were included 2 times in this study [both of them had surgery twice; only the first inclusion was valid]). The target sciatic nerve was successfully located at the popliteal fossa level, and catheter placement was completed in all included patients with ultrasound or nerve stimulation technique as decided by group allocation.

The SR of continuous sciatic nerve sensory blockade was significantly higher in the US group (94%) compared with the NS group (79%, $P = 0.03$; Table 2). The incidence of attributing the worst pain to the saphenous territory at 48 hrs postoperatively was significantly higher in the US group compared with the NS group. The morphine consumption was significantly lower in the US than in the NS group. The number of needle passes was significantly lower in the US than in the NS group. Patient satisfaction after completed catheter insertion was significantly higher in the US than in the NS group.

No hematomas or local infections were observed in the popliteal fossa during the first 48 hrs postoperatively. No paralysis or regional anesthesia–related paresthesia was observed after removal of the plaster at 6 weeks postoperatively.

DISCUSSION

This study was powered to estimate the primary outcome variable, which was the SR of continuous sciatic nerve sensory blockade during the first 48 hrs postoperatively. However, the study had sufficient power to detect statistically significant better results with ultrasound compared with nerve stimulation technique for a range of secondary outcome variables: the incidence of worst pain attributed to the saphenous territory, morphine consumption, number of needle passes, and patient satisfaction after catheter insertion.

This is the first randomized controlled trial comparing the SR of continuous popliteal sciatic nerve sensory blockade between ultrasound and nerve stimulation guidance as the primary outcome. The SR of sensory blockade was 20% higher in the US group compared with the NS group.

All the patients included in this study underwent surgery for major foot and ankle surgery. Usually, it is necessary to alleviate pain from the saphenous territory (medial malleolus and anterior side of the ankle joint), even when the sciatic territory is blocked effectively, and the NRS pain score is oftentimes higher than 3. In this study, the saphenous pain was controlled by single injection of bupivacaine above the medial malleolus. If the saphenous nerve block failed, or when the effect of the saphenous block subsided—typically after 10 to 15 hrs—many patients needed opioids to alleviate the saphenous pain despite effective sciatic nerve blockade.

In the present study, the patient satisfaction was significantly higher after catheter insertion with ultrasound compared with the nerve stimulation technique. This may be explained by the fewer number of needle passes using ultrasound guidance. The better sensory blockade and the fewer number of needle passes and the higher patient satisfaction during puncture using ultrasound compared with nerve stimulation guidance for popliteal sciatic nerve block is in accordance with other studies using a single-shot technique.[2,8] It also replies in the affirmative the lesser pain during catheter placement with ultrasound compared with nerve stimulation guidance found in 1 study using continuous sciatic blockade.[5]

The incidence of nerve injury associated with peripheral nerve blockade is approximately 0.4 per 1000 blocks, and for the time being, no evidence indicates a difference between ultrasound and nerve stimulation technique.[9] We observed no regional anesthesia–related nerve injuries with neither ultrasound nor nerve stimulation technique. However, the study was not at all powered to detect any possible difference in the incidence of nerve injuries related to the 2 nerve location techniques.

It is a limitation of this study that the anesthesiologist performing the catheter placement and the patients were not blinded to study group allocation. However, the data about the number of needle passes and patient satisfaction after catheter placement were sampled by independent observers, and the data about the primary outcome and secondary outcomes based on NRS scores were sampled by independent observers blinded to study group allocation.

Our results cannot be extrapolated to other catheter insertion sites owing to anatomy-dependent variations in catheter placement and infusion characteristics.[5]

In conclusion, the use of ultrasound compared with nerve stimulation guidance for popliteal sciatic catheter placement increases the SR of sensory blockade, decreases the number of needle passes, increases the patient satisfaction during catheter placement, and decreases the morphine consumption.

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