Low-Volume Ultrasound-Guided Nerve Block Provides Inferior Postoperative Analgesia Compared to a Higher-Volume Landmark Technique

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Background and Objectives: Ultrasound guidance reduces the required local anesthetic volume for successful peripheral nerve blockade, but it is unclear whether this impacts postoperative analgesia. This prospective, randomized, observer-blinded study tested the hypothesis that a low-volume ultrasound-guided ankle block would provide similar analgesia after foot surgery compared with a conventional-volume surface landmark technique.

Methods: A total of 72 patients presenting for elective foot surgery under general anesthesia were randomized to receive a low-volume ultrasound-guided ankle block (n = 37; ropivacaine 0.5% adjacent the anterior/posterior tibial arteries and short saphenous vein; subcutaneous infiltration around the saphenous and superficial peroneal nerves) or conventional-volume surface landmark guided technique (n = 35; 30 mL of ropivacaine 0.5%). Patients received regular postoperative acetaminophen, diclofenac, and rescue tramadol. Assessment was in the recovery room and at 24 hours for pain and tramadol consumption.

Results: Mean (SD) total local anesthetic volume for the low-volume ultrasound group was 16 (2.1) mL. Block success in the recovery room was similar between groups (low-volume ultrasound 89% versus conventional-volume landmark 80%, $P = 0.34$; however, during the first 24 hours, numerically rated (0–10) "average pain" (median [10–90th percentiles] = 1 [0–4] versus 0 [0–2], $P = 0.01$), worst pain at rest (1 [0–6] versus 0 [0–2], $P = 0.03$), and the proportion of patients requiring rescue tramadol (% [95% confidence interval]: 50 [34–46] versus 20 [10–36], $P = 0.01$) were higher in the low-volume ultrasound group. Numerically rated numbness, weakness, satisfaction, and procedural time were similar between groups.

Conclusions: Low-volume ultrasound-guided ankle block is associated with a high block success rate after foot surgery; however, compared with a conventional volume (surface landmark) technique, the reduced local anesthetic volume marginally compromises postoperative analgesia during the first 24 hours.

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A major advantage of ultrasound guidance for peripheral nerve blockade compared with traditional techniques is the reduced local anesthetic volume requirement for successful block, with several studies confirming this benefit.[1–4] Although not conclusively confirmed by published studies,[5–7] theoretical advantages of decreasing local anesthetic volume include a lower systemic local anesthetic toxicity risk, reduced adjacent nerve blockade (eg, phrenic nerve),[8] and reduced direct local anesthetic neurotoxicity. Few of the many studies investigating this issue have assessed the reduced local anesthetic volume effect on block duration or postoperative analgesia. Studies assessing these outcomes in adults have been limited by short follow-up periods or small sample sizes (and, consequently, low statistical power).

The ankle block conventionally involves administering 30 to 40 mL of local anesthetic[9,10]; volumes potentially causing systemic toxicity for bilateral blocks,[11] and have been suggested as potentially causing compartment syndrome or vascular occlusion.[12] Therefore, an ankle block approach involving reduced local anesthetic volume has clinical value. Such a technique has been recently described using ultrasound guidance,[13] and relies where possible, on adjacent vascular structure visualization, thereby reducing the need to infiltrate blindly. However, local anesthetic dose reduction could potentially shorten block duration and compromise postoperative analgesia.

Therefore, a prospective randomized controlled trial was designed to determine whether a low-volume ultrasound-guided ankle block would provide similar postoperative analgesia compared with a conventional (high)-volume surface landmark technique.

METHODS

Local institutional review board approval was obtained (Northern Y Regional Ethics Committee, Hamilton, New Zealand), and the trial was registered with the Australian and New Zealand Clinical Trials Registry (ACTRN12609000074291, November 2008). We enrolled consecutive American Society of Anesthesiologists physical status I to III patients, aged 16 to 80 years scheduled for elective unilateral mid and forefoot surgery by a single surgeon (T.K.D.) in the principal investigator's practice at the Southern Cross Brightside Hospital and Auckland Surgical Centre between September 2008 and August 2010. Exclusion criteria included ankle block refusal, known amide local anesthetic drug allergy, known neuropathy of the operative extremity, nonsteroidal anti-inflammatory drug intolerance, and preoperative opioid therapy administered for more than 1 month before surgery. Written informed consent for study procedures was obtained from all patients.

Oral acetaminophen 1 g was administered 1 hour before surgery. Preemptive nonsteroidal anti-inflammatory drug analgesia was started at the time of acetaminophen premedication (Brightside Hospital; oral diclofenac slow-release 75 mg and omeprazole 20 mg) or at induction of anesthesia (Auckland Surgical Centre; intravenous parecoxib 40 mg). After intravenous sedation with up to midazolam 2 mg and alfentanil 0.5 mg, a standardized general anesthetic was administered: depending on age and weight, intravenous propofol 150 to 200 mg

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(occasionally up to 300 mg in young or anxious patients) was followed by placement of a laryngeal mask airway. At this time, the previously concealed group assignment was revealed. Randomization to the low-volume ultrasound (LVUS) or standard-volume landmark (SVL) groups was implemented by a research assistant using a computer random number generator conducted at a site away from the study procedures and delivered in pre-prepared sealed opaque envelopes.

The principal investigator, who was experienced in both approaches, performed all regional block procedures with a 22-gauge 5-cm, B-Plex needle (Plexufix, B|Braun, Bethlehem, PA) and ropivacaine 0.5%.

LVUS Group

A curvilinear 8- to 5-MHz ultrasound probe with a high-resolution machine (C11/MicroMaxx or M-Turbo; SonoSite, Bothell, WA) was used. The C11 curvilinear probe facilitates probe skin contact adjacent to bony prominences (eg, lean subjects with prominent metatarsals/extensor tendons) and concavities (eg, immediately anterior to the Achilles tendon). Because the objective was to visualize the adjacent vasculature and not the nerves themselves, the advantage provided by means of the probe shape was considered to outweigh the disadvantage consequent on its lower frequency (lower resolution).

The procedural objective was to administer local anesthetic in the presumed positions of those nerves having a consistent relationship to adjacent vascular structures.

1. Deep peroneal nerve. Local anesthetic was injected at the level of the malleoli, with an out-of-plane technique either side of the anterior tibial artery.[14]
2. Posterior tibial nerve. Local anesthetic was injected at the level of the medial malleolus, with an out-of-plane technique immediately posterior to the posterior tibial artery.
3. Sural nerve. Local anesthetic was injected just cephalad of the lateral malleolus, with an in-plane technique (anterior to posterior) around the short saphenous vein.[15]
4. Saphenous nerve. The long saphenous vein is usually visible or palpable; therefore, just cephalad of the medial malleolus, local anesthetic was injected 2 cm anterior and posterior to the vein. Ultrasound was only used for this nerve on the rare occasion that the vein could not be palpated.
5. Superficial peroneal nerve. Local anesthetic was subcutaneously infiltrated just cephalad of the lateral malleolus, between the levels of the anterior tibial ridge and the posterior border of the lateral malleolus.

For nerves 1 to 3, we used an arbitrary end point for appropriate local anesthetic volume: perivascular spread of approximately twice the width of the adjacent artery (anterior/posterior tibial arteries) or one diameter of the adjacent vein (short saphenous vein). This arbitrary volume end point was based on the known proximity of the neurovascular structures in this area.

SVL Group

The procedural objective was to administer 30 mL of local anesthetic volume according to traditionally described landmarks.

1. Deep peroneal nerve. Needle placement was either side of the anterior tibial artery pulsation at the level of the malleoli.[9,11,16] If the artery was not palpable, needle placement was between the extensor hallicus longus and extensor digitorum longus tendons.[10] In both instances, needle advancement was until bone was contacted. Approximately 6 mL of local anesthetic[9] was injected after needle withdrawal 2 to 3 mm.
2. Posterior tibial nerve. The needle was inserted just posterior of the posterior tibial artery pulsation at the level of the medial malleolus.[16] If the artery was not palpable, needle placement was at the level of the sustentaculum tali.[17] In both instances, needle advancement was until bone was contacted. Approximately 6 mL of local anesthetic[18] was injected after needle withdrawal 2 to 3 mm.
3. Sural nerve. The needle was inserted at the cephaloposterior border of the lateral malleolus. Approximately 5 mL of local anesthetic was infiltrated subcutaneously toward the Achilles tendon.[19]
4. Saphenous nerve.[18,19] Approximately 5 mL of local anesthetic was injected 2 cm anterior and posterior to the vein just cephalad of the medial malleolus. If the vein could not be palpated, local anesthetic was infiltrated between the level of the anterior tibial ridge and posterior border of the medial malleolus.
5. Superficial peroneal nerve.[18,19] Approximately 6 mL of local anesthetic was infiltrated just cephalad of the lateral malleolus subcutaneously between the levels of the anterior tibial ridge and posterior border of the lateral malleolus.

Intraoperative Management

General anesthesia was maintained with desflurane and spontaneous respiration (end-tidal minimum alveolar concentration, 0.8–1.0). No long-acting opioid was administered; however, alfentanil 0.25 mg was administered pro re nata for a respiratory rate greater than 25 breaths per minute.

Post Anesthesia Care Unit Protocol

In the post anesthesia care unit (PACU), patients reporting a numerical rating pain score (NRPS, 0–10) of more than 2 were administered intravenous morphine 2 mg every 2 minutes to obtain a NRPS of 2 or less.

Postoperative Management

Acetaminophen (1 g every 6 hrs) and diclofenac slow-release (75 mg every 12 hrs) were continued if any postoperative pain occurred. If the NRPS was more than 2 despite regular acetaminophen, and diclofenac, tramadol slow-release (100 mg every 12 hrs) was added. Discharge home occurred on the day of surgery. While in the hospital, if analgesia was inadequate (NRPS >3) despite tramadol supplementation, opioid rescue was available by telephone order (oral morphine for a NRPS <5, intravenous morphine for a NRPS >5).

Data Collection

The anesthesia assistant recorded visibility (LVUS group) or palpability (SVL group) of the anterior/posterior tibial arteries and short saphenous vein. The assistant also recorded the ropivacaine volume administered for each nerve as conveyed by the principal investigator and procedural time, defined as the time from applying antiseptic skin preparation until the needle exited the skin after the final nerve block. The patient's primary PACU nurse recorded the emergence NRPS and the need for morphine rescue. Block success in the PACU was defined as a worst NRPS of 2 or less before morphine rescue. A research assistant interrogated by telephone all subjects at precisely 24 (±1) hours after block placement and questioned for time to first pain, time to first dose of tramadol, total tramadol consumption, NRPS (at rest, on movement and "average"), foot numbness/weakness, and satisfaction (0–10, 0 = no pain, numbness/weakness, very unsatisfied, 10 = worst imaginable pain, numbness/weakness, very satisfied) during the previous

TABLE 1. Patient and Surgical Characteristics

	Low Volume (n = 37)	Standard Volume (n = 35)
Male sex	7 (19)	10 (29)
Age, y	54 (16)	55 (15)
Weight, kg	69 (10)	75 (13)
Hospital (Brightside/ Auckland Surgical Centre)	28 (76) / 9 (24)	21 (60) / 14 (40)
Surgery		
Hallux cheilectomy	7 (19)	8 (23)
Hallux valgus correction	9 (24)	5 (14)*
Metatarsal osteotomy	3 (8)	1 (3)
Other osteotomy (tarsal, calcaneal)	2 (5)	4 (11)
Metatarsophalangeal fusion	3 (8)	1 (3)
Interphalangeal fusion	4 (11)	4 (11)
Excision Morton neuroma/ganglion	4 (11)	6 (17)
Excision bony spur	2 (5)	4 (11)
Other	3 (8)	2 (6)

Values are n (%) or mean (SD).

*Apparent difference was not statistically significant.

24 postoperative hours (specifically excluding pain present in the recovery room).

Blinding

All data collection was observer- and patient-blinded except data collected by the principal investigator and his assistant at the time of block placement, that is, local anesthetic volume, visualized/palpable vessels.

Primary and Secondary Endpoints

The primary end point was "average pain" during the first 24 postoperative hours (ie, the patient's subjective assessment of their average pain during this time period). Secondary end points included analgesic (tramadol) consumption and time to first pain.

Statistical Analysis

An independent statistician (R.W.) performed all calculations. Categorical outcomes were compared using the Fisher exact test. Ordinal outcomes (procedural time, numerically rated pain, numbness, weakness, and satisfaction) were compared using the Mann-Whitney *U* test. Many patients had not experienced pain or required tramadol at the time of the 24-hour phone consult, therefore, comparison of time to first pain and first dose of tramadol was as survival data: Kaplan-Meier curves were constructed, and these were compared using the log-rank (Mantel-Cox) test. Separately from the Kaplan-Meier curves, we fit a Cox proportional hazard model to calculate an associated hazard ratio (with 95% confidence interval [CI]) for the 2 techniques: LVUS compared with SVL (baseline). *P* values less than 0.05 were considered statistically significant. Two-sided tests were used for all experimental outcomes.

Other data were summarized using appropriate descriptive statistics (mean and SD for normally distributed or symmetric variables; median and interquartile ranges or 10–90th percentiles for skewed variables; number and proportion for categorical variables). All statistical analyses were performed using R 2.12.1 (R Foundation, Vienna, Austria).

Sample size calculations were based on postoperative pain. Few studies have formally assessed postoperative pain after ankle block; consequently, previous SD data for postoperative pain were not available. One previous study did report postoperative pain with interquartile range at 4- and 8-hour time points (interquartile range, 1.5).[16] For the present study, one assessment at 24 postoperative hours was made for pain experienced during the entire previous 24-hour period—thus, we assumed a wider pain score variability (interquartile range, 2). Using this interquartile range, the formula SD = IQR/1.35 provided an SD estimate of 1.48. With this SD assumption, 75 patients would detect a shift of approximately 1 NRPS points (80% power, 5% 2-tailed type 1 significance, unpaired *t* test; Statmate 2.0, with a 15% adjustment for using the *t* test when a subsequent nonparametric test was likely). A 1-point shift in the 11-point NRP scale was considered clinically relevant given these were relatively minor procedures and, therefore, likely to be associated with relatively low pain scores.[20] We planned to enroll 80 patients to allow for dropouts.

RESULTS

Eighty patients scheduled for foot surgery were enrolled during the study period, 8 of whom were excluded because of protocol violation: 72 remaining patients were randomized to the LVUS (n = 37) and SVL groups (n = 35). Patient and surgical characteristics were comparable between groups (Table 1). One LVUS group patient was excluded after enrolment because of an unanticipated procedure extending proximally beyond the ankle block coverage. Thus, 71 patients completed the study per protocol (Tables 2 and 3).

Mean (SD) total local anesthetic volume for group LVUS was 16 (2.1) mL (Table 2). The vessels used to guide local anesthetic placement were usually visualized in the LVUS group; however, in the SVL group, the same arteries could usually not be palpated (Table 2), in part because the block was performed immediately after propofol induction. Procedural time

TABLE 2. Block Placement Details

	Low Volume (n = 37)	Standard Volume (n = 35)	*P*
Local anesthetic volume, mL			
Total	16 (2.1)	~30	
Deep peroneal	3.6 (1.3)	6.8 (1.2)	
Posterior tibial	3.5 (1.0)	6.4 (0.9)	
Sural	2.9 (0.9)	5.3 (1.7)	
Saphenous	2.9 (0.6)	5.2 (0.9)	
Superficial peroneal	3.2 (1.0)	5.8 (1.5)	
Vessels visualized/palpated			
Anterior tibial artery	35 (94)	10 (29)	<0.0001
Posterior tibial artery	35 (94)	14 (40)	<0.0001
Both anterior *and* posterior tibial	34 (92)	7 (20)	<0.0001
Short saphenous vein	33 (89)	N/A	
Procedural time (min)	5 (4.6–6.2)	3 (2.7–4)	<0.0001

Values are n (%), mean (SD), or median (IQR).

N/A indicates not applicable.

TABLE 3. Postoperative Outcomes

	Low Volume (n = 36)	Standard Volume (n = 35)	*P*
Secondary			
Tramadol required during the first 24 hrs	18 (50)	7 (20)	0.01
Pain reported during the first 24 hrs	20 (56)	17 (49)	0.64
Time to first pain (hrs)	23.5	>24*	0.44
Other			
Intraoperative alfentanil bolus ≥1	1 (3)	4 (11)	0.20
Worst pain at rest	1 (0–6)	0 (0–2)	0.03
Worst pain with movement	1 (0–6)	1 (0–5)	0.50
Numbness NRS	8 (1–10)	9 (1–10)	0.56
Weakness NRS	1 (0–6)	3 (0–8)	0.12
Satisfaction NRS	10 (8–10)	10 (8–10)	0.98

Values are n (%), median, or median (10th–90th percentiles).

*At 24 hrs, less than 50% of patients had reported pain; therefore, time to first pain could not be precisely determined.

NRS indicates numerical rating score (0–10, 0 = no numbness/weakness or very unsatisfied, 10 = very numb/weak or very satisfied).

was statistically reduced in the SVL group, but this was not clinically significant (Table 2). There was no difference between groups in block success in the recovery room (LVUS = 32/36 [89%] versus SVL = 28/35 [80%], $P = 0.34$, 95% CI of the difference between proportions = −6% to infinity, ie, a 95% probability that group LVUS had a success rate either better, or <6% worse than group SVL).

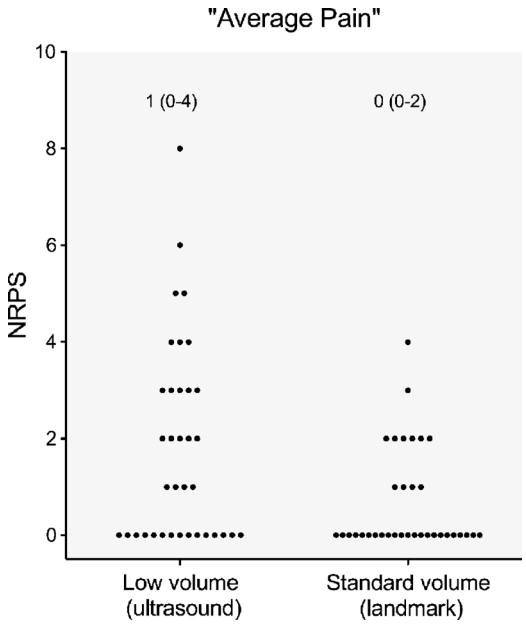

FIGURE 1. Postoperative pain scatter plot by group. ''Average pain'' refers to the patient's subjective assessment of their average pain during the previous 24 hrs. Numerical values are median (10th–90th percentiles). Groups were significantly different ($P = 0.01$). NRPS indicates numerical rating pain score.

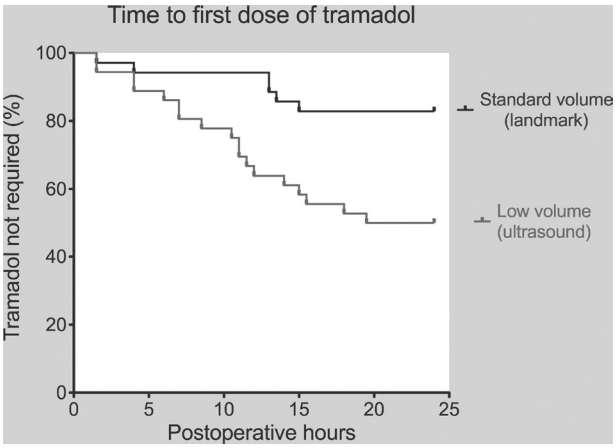

FIGURE 2. Kaplan-Meier curves for the proportion of patients requiring tramadol as a function of time. Curves were significantly different ($P = 0.009$; hazard ratio [95% CI], 3.0 [1.3–7.3]).

During the first 24 hrs, "average pain" (median [10–90th percentiles] = 1 [0–4] versus 0 [0–2], $P = 0.01$) and the proportion of patients requiring tramadol (18 [50%] versus 7 [20%], $P = 0.01$) were higher in the LVUS group (Table 3; Fig. 1). Correspondingly, time to first dose of tramadol was reduced in the LVUS group (Kaplan-Meier curves significantly different, $P = 0.009$; hazard ratio [95% CI], 3.0 [1.3–7.3]), but time to first pain was not (Kaplan-Meier curves not significantly different, $P = 0.44$) (Table 3; Fig. 2). All other measured outcomes were similar between groups (Table 3).

We also analyzed the data set including the 8 eliminated patients: the results were similar to the data set described above. No patient required morphine rescue after PACU discharge. No patient demonstrated symptoms or signs of systemic local anesthetic toxicity.

DISCUSSION

In this study, a low volume US-assisted ankle block was associated with marginally inferior analgesia and higher analgesic requirements during the first 24 hours after foot surgery compared with a traditional volume (surface landmark) technique. This was despite both techniques having similar success rates as measured by pain in the PACU.

A major advantage of ultrasound-guided regional anesthesia is the reduced local anesthetic volume requirement for successful peripheral nerve blockade. However, few studies have assessed the effect of these reduced local anesthetic volumes on block duration or postoperative analgesia. Oberndorfer et al[1] randomized young children (aged 1–8 yrs)[21] having unilateral lower limb surgery under sciatic ± femoral blocks to ultrasound (sciatic ~0.2 mL/kg, femoral ~0.15 mL/kg) or nerve stimulation (0.3 mL/kg per nerve). Block duration was prolonged in the lower-volume (ultrasound) group but likely reflected a nerve localization technique effect. Riazi et al[8] randomized 40 patients to 5 and 20 mL of interscalene ropivacaine 0.5%; their primary outcome was diaphragmatic function. The secondary outcomes of postoperative pain and morphine consumption were not significantly different between groups; however, the study had 80% power to detect a difference of 2.5 numerical pain scale points (0–10) and a difference of 14 mg of morphine equivalents

during the first 24 hours (mean morphine equivalent consumption was 23–26 mg). A similar study by Sinha et al[7] noted similar secondary outcomes. Three studies have accurately assessed the local anesthetic volume effect on block duration. Marhofer et al[22] studied a low (4 mL) and high (14.8 mL) volume axillary brachial block technique in volunteers. However, the authors stated the study had "only 17% power to compare the duration of the blocks," although block duration was shorter in the LVUS group. In two tightly controlled sequential up-down dose-finding studies for sciatic[23] and median/ulnar nerve[24] blocks, Latzke et al[23] and Ponrouch et al[24] demonstrated a clear correlation between local anesthetic volume and block duration.

Block duration is a well-recognized key to the effectiveness of postoperative regional analgesic techniques. In the present study, improved analgesia and reduced analgesic consumption was observed in patients receiving a higher local anesthetic volume compared with patients receiving a lower volume, which is in keeping with the aforementioned tightly controlled dose-finding studies. However, no difference was noted between groups in the survival curves for time to first pain. The latter negative finding may have been a consequence of the imprecise measurement of this outcome: patients were questioned at 24 postoperative hours, but only half of the subjects had reported pain at this time point, making this outcome difficult to interpret. During the study protocol design, we assumed most patients would have experienced pain by 24 hours—a block with a previously reported 8- to 12-hour duration.[11,16] At odds with the latter negative outcome was the significant difference between groups in the survival curves for time to first tramadol dose; a discordance possibly related to the difficulty patients have in recalling the exact onset of pain. Alternatively, the discordance may indicate mild pain in the higher-volume group of insufficient severity to trigger tramadol rescue.

Although there was an apparent difference in the 90th percentile for "average" pain and worst pain at rest (2- and 4-point difference respectively), only a 1-point difference in median pain was observed between groups. This apparent small between group difference in the *median value* should be interpreted in the context of the pain scores, which were low for both groups during the 24-hour observation period: a 1-point shift in median pain represents a 100% shift relative to the median value. In other words, a shift of *less* than 2 points on the 11-point numerical pain scale (a shift commonly accepted as clinically relevant at the middle of the scale) may be clinically meaningful to patients when the background level of the experienced pain is low.[20] A more significant between group shift in numerically rated pain might also be expected with more painful procedures, and if sequential pain assessments were conducted. Finally, any demonstrated treatment effect, regardless of how small, should be interpreted in the context of the downside to the intervention required to achieve that outcome benefit. In this instance, published evidence does not support the contention that higher local anesthetic volumes carry a higher risk of systemic toxicity, direct neurotoxicity, or adjacent nerve blockade.[5–7]

A limitation of the study is the inability to single out the effect of reduced local anesthetic volume from the nerve localization technique. Ideally, future studies should compare different volumes but with the same method for local anesthetic deposition. Second, the local anesthetic volume administered at each individual nerve, for each group, was not constant for each subject; therefore, the local anesthetic volume difference between groups should be viewed as representing the difference in the *total* local anesthetic volume administered. The study findings may thus not apply to low local anesthetic volumes administered on a specific nerve. Finally, we cannot rule out the possibility of patient and surgical characteristics influencing the results; for example, hallux valgus surgery was marginally more common in the LVUS group (not statistically significant).

Despite the demonstrated inferior analgesia with the low-volume local anesthetic technique, ultrasound guidance may provide significant clinical advantages for the ankle block. Recent tightly controlled studies involving the single nerves of volunteers (not, however, subject to surgery induced nociceptive stimulation of the articular fibers) have demonstrated that the use of ultrasound guidance improves sensory block onset time and block success.[14,15,25] In addition, in some patients, the surface landmark technique will be near impossible,[26] and many occasional ankle block practitioners do not have confidence with the success of the surface landmark technique.[27] Finally, the commonly described surface landmark techniques often advise eliciting paresthesia,[19] and accumulating evidence points to procedure-induced paresthesia being associated with postoperative neurological symptoms.[28,29] A possible technique drawing on the potential benefits of both treatment arms is to administer, using ultrasound guidance, a conventional volume or a low-volume at a higher concentration, for example, 15 mL of ropivacaine 0.75% to 1%.

In summary, a low-volume ultrasound-guided ankle block provided a high block success rate as assessed by the prevention of recovery room pain after foot surgery; however, compared with a conventional volume (surface landmark) technique, the reduction in total local anesthetic volume was associated with marginally inferior analgesia during the next 24 hours. These results may have clinical implications for peripheral nerve blocks performed using low volumes of local anesthetic, as is now increasingly occurring in the current environment of ultrasound-guided regional anesthesia. More tightly controlled studies involving individual nerves are suggested.

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