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ORIGINAL RESEARCH

Noninferiority of 0.25% versus 0.375% Ropivacaine in Popliteal Sciatic and Saphenous Nerve Blocks for Analgesia After Foot and Ankle Surgery: A Randomized Self-Paired Noninferiority Trial

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Purpose: Peripheral nerve blocks are an important part of postoperative analgesia for the extremities. Previously, we reported that a single shot of 0.375% ropivacaine (20 mL) via ultrasound-guided popliteal sciatic and saphenous nerve blocks provided satisfactory analgesia after foot and ankle surgery; however, toe and ankle weakness in the early postoperative period became a concern for patients. Our preliminary data indicate that 0.25% ropivacaine may be effective for postoperative analgesia. Hence, we hypothesized that the analgesic effect of 0.25% ropivacaine would be noninferior to that of 0.375% ropivacaine at the same volume and would reduce the degree of weakness.

Patients and Methods: In this randomized, double-blind, self-paired, noninferiority trial, 31 patients who were scheduled for similar, elective, bilateral foot and ankle surgeries under general anesthesia combined with popliteal sciatic and saphenous nerve blocks were enrolled. Each patient was randomly assigned to receive 0.25% ropivacaine on one side and 0.375% ropivacaine on the other side. The primary outcome was the duration of analgesia, which was defined as the time from the end of the nerve blocks until the first sensation of pain in the surgical area, as indicated by a patient-reported visual analog scale (VAS) score ≥ 1. The secondary outcomes included static VAS scores, motor and sensory block grades, patient satisfaction scores, and the incidence of adverse effects.

Results: The mean duration of analgesia was 31.7 ± 8.3 h for 0.25% ropivacaine, and 31.9 ± 8.5 h for 0.375% ropivacaine (duration difference, −0.16; 95% CI, −1.5 to 1.2; $P = 0.812$). Compared with 0.375% ropivacaine, 0.25% ropivacaine resulted in a lower incidence of motor block at 0, 2, 6 and 12 hours postoperatively ($P < 0.05$). No differences in static VAS, sensory block or patient satisfaction scores were observed between the two concentrations within 48 hours postoperatively. Furthermore, no nerve block-related adverse events were reported.

Conclusion: The results revealed that 0.25% ropivacaine is not inferior to 0.375% ropivacaine in terms of the analgesic duration of popliteal sciatic and saphenous nerve blocks for bilateral foot and ankle surgery. Moreover, 0.25% ropivacaine reduced the incidence of motor block. Therefore, we recommend 0.25% ropivacaine for postoperative analgesia for foot and ankle surgery.

Keywords: ropivacaine, analgesia, foot and ankle surgery, nerve block, popliteal sciatic nerve, saphenous nerve

Introduction

Foot and ankle surgery often results in severe and sustained pain for 24–48 h postoperatively; this pain can be difficult to control with intravenous or oral medications, and many modalities are needed for postoperative analgesia.[1,2] Peripheral nerve blocks (PNBs) are medical procedures that involves the injection of local anesthetics (LAs) into a specific peripheral nerve or a group of nerves, with the goal of blocking the transmission of pain signals to the brain. PNBs have proven to be safe in the control of postoperative pain after limb surgery, as they lead to decreased narcotic use and associated adverse effects, longer analgesia, and greater patient satisfaction, and more referrals.[3–6] Ropivacaine is a long-acting amide LA commonly used for

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PNBs. Previous studies have reported that ropivacaine concentrations of 0.5% to 1% for sciatic and saphenous nerve blocks provide effective analgesia within 24 hours after foot and ankle surgeries.[5,7,8] Owing to the increasing demand for patient comfort and advances in surgical methods, popliteal sciatic and saphenous nerve blocks with lower concentrations of LAs combined with general anesthesia are often implemented for elective foot and ankle surgeries.[9,10] However, the duration of analgesia with ropivacaine at concentrations less than 0.5% has not been fully evaluated.

In addition to satisfactory analgesia, many orthopedic surgeries and foot and ankle surgeries require early recovery of motor function to rule out surgery-induced nerve damage or to achieve early functional recovery and training.[11,12] Typically, PNBs with LAs require a threshold volume to reach the target nerve, with the concentration of the LAs being the primary determinant of the efficacy of analgesia and motor block.[13,14] As a result, anesthesiologists are interested in the optimal concentrations of LAs to balance analgesia and motor function. Compared with other LAs, ropivacaine has a faster recovery from motor block despite similar sensory properties for regional anesthesia, the management of postoperative analgesia and labor pain.[15,16] Previously, we reported that popliteal sciatic and saphenous blocks with 0.375% ropivacaine prior to general anesthesia provided good postoperative analgesia after foot and ankle surgery;[17] however, toe and ankle weakness in the early postoperative period became a concern for patients. Reducing the ropivacaine concentration to less than 0.375% with a single shot for postoperative analgesia after foot and ankle surgery has not been studied, and whether it reduces motor block or has an impact on the analgesic effect remains unclear.

Bilateral surgery can be used to address problems in both the feet and ankles simultaneously, so this approach is very popular among patients. However, the risk of systemic and direct neurotoxicity increases as the amount of LAs increases during bilateral surgery.[18,19] Thus, the American Society of Regional Anesthesia and Pain Medicine recommends the use of the lowest effective dose of LA (dose = product of volume × concentration) to prevent systemic toxicity.[20] Our preliminary data indicate that 0.25% ropivacaine may be effective for postoperative analgesia when administered around the popliteal sciatic and saphenous nerves. Therefore, we hypothesized that the analgesic effect of 0.25% ropivacaine would be noninferior to that of 0.375% ropivacaine in ultrasound-guided popliteal sciatic and saphenous nerve blocks, and would provide better early postoperative functional movement for foot and ankle surgery.

Materials and Methods

Study Design and Ethics

This study was a randomized, double-blinded, paired, noninferiority clinical trial. The trial followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines. The study protocol was presented in Supplemental information 1. Ethical approval was obtained from the Ethics Committee of Beijing Tongren Hospital in February 2021 (TRECKY2021-054), and the study was conducted in accordance with the Declaration of Helsinki. This trial was registered in the Chinese Clinical Trial Registry before patient enrollment (Registration number: ChiCTR2100053929; Date of registration: December 2, 2021; Principal Investigator: Lili Wu). Written informed consent was obtained from all patients prior to randomization.

Participants

The study included patients aged 18–74 years who were scheduled for bilateral similar foot and ankle surgery with general anesthesia combined with popliteal sciatic and saphenous nerve blocks. The inclusion criteria were as follows: American Society of Anesthesiologists (ASA) physical status I–III, a body mass index (BMI) of 18–30 kg/m^2, and the ability to understand the protocol and provide informed consent. The exclusion criteria were as follows: patients who did not have ASA physical status I–III, contraindications to PNB (coagulopathy, infection at the puncture site, allergy to general or LAs), anticipated difficult airways, central or peripheral neurological diseases, pregnancy or breastfeeding, chronic opioid use, abnormal liver or kidney function, poorly controlled diabetes (fasting glucose >11 mmol/L), enrollment in other trials, malignant tumors, Charcot osteoarthropathy, and daily use of steroids. Patient recruitment and surgery performance were conducted between December 15, 2021, and February 25, 2022 in Beijing Tongren Hospital, Capital Medical University.

Randomization and Blinding

Patients scheduled for bilateral identical foot and ankle surgeries were assigned a study number (1–33) in order of their enrollment. A computer-generated randomization sequence was prepared by an independent statistician who was not involved in the trial. This sequence contained 33 numbers randomly generated by the computer within 100. These 33 numbers corresponded to the patients' study numbers in turn. Then, the 33 numbers were sorted from small to large. The patients with the first 16 numbers received plan A, and the patients with the last 17 numbers received plan B. In protocol A, patients received 0.25% ropivacaine on the right side and 0.375% ropivacaine on the left side. In protocol B, patients received 0.25% ropivacaine on the left side and 0.375% ropivacaine on the right side.

The allocation information was kept in sealed, opaque, sequentially numbered envelopes. The envelopes were delivered to a nurse, who was responsible for preparing the trial medication according to the allocation inside the envelopes and was not otherwise involved in the trial. Syringes containing an equivalent volume of indistinguishable local anesthetic were prepared and labelled as either the "right syringe" or the "left syringe" according to the contents. All patients, investigators, anesthesiologists, surgeons, outcome assessors, and data analysts were blinded to the treatment allocation.

Procedure and Intervention

Patients abstained from food and water for 8 hours before surgery. After arriving at the preoperative preparation room, the patient's venous access was opened, and routine monitoring of blood pressure (BP), heart rate (HR), and pulse oxygen saturation (SpO_2) was conducted.

Oxygen was delivered to the patient at 4 L/min via a face mask. Before nerve block, each patient received 0.1 μg/kg sufentanil and 0.02 mg/kg midazolam intravenously for sedation and analgesia, respectively. Additionally, 10 mg of dexamethasone was administered intravenously to prolong the duration of analgesia as we reported recently.[17] All nerve blocks were performed via ultrasound guidance by experienced anesthesiologists with more than 300 PNB procedures (Dr. Wu LL and Dr. Lei GY). We used an ultrasound system with a 4–15 MHz linear probe (Wisonic Navi Sevies, Shenzhen, China) and a 21-gauge, 100-mm insulated nerve blockade needle.

Popliteal sciatic nerve block was performed with the patient in the supine position by resting the foot on an elevated footrest. The transducer was positioned at the level where the tibial nerve and common peroneal nerve start diverging but are still within the common sciatic nerve sheath. The needle was inserted in the plane from the lateral-to-medial direction. The needle tip was finally positioned between the tibial and common peroneal nerves within the paraneural sheath. Ropivacaine was administered in two injections at 6:00 and 12:00 around the bifurcation, with 10 mL per injection, for a total volume of 20 mL.

Saphenous nerve block was performed in the supine position, with the thigh abducted and externally rotated to allow easily access to the medial thigh. The transducer was placed anteromedially, approximately at the junction between the middle and distal thirds of the thigh. The needle was inserted in-plane in a lateral-to-medial orientation and advanced. The saphenous nerve was identified as a hyperechoic, oval or round structure anterolateral to the femoral artery, and 10 mL ropivacaine was injected (Figure 1A and B). We performed aspiration prior to injection to avoid intravascular injection. After administration of the nerve blocks, an independent observer (Dr. Li H or Dr. Hu CH) who was blinded to the treatment, assessed the effectiveness of the block via a pinprick test. This assessment was conducted every 5 minutes for three assessments. Block success was defined as no sensation of cold or pain in the sciatic or saphenous nerve dermatomes 30 min after the final ropivacaine injection.

The patient received general anesthesia when the nerve blocks were determined to be effective. The anesthetic agents used were midazolam 0.02mg/kg, sufentanil 0.2 μg/kg, propofol 1.5–2 mg/kg, and rocuronium 0.6 mg/kg. After induction, a laryngeal mask airway (LMA) was inserted, and intermittent positive pressure ventilation (IPPV) was initiated. The tidal volume was set at 6–8 mL/kg to maintain end-tidal carbon dioxide ($EtCO_2$) levels between 35–40 mmHg. The tourniquet was placed in the middle of the thigh, applied before the start of the procedure and stopped after the procedure. During the operation, the depth of general anesthesia was monitored with the bispectral Index (BIS), and total intravenous anesthesia was performed with a continuous infusion of remifentanil 0.1–0.2 μg/kg/min and propofol 5–8 mg/kg/h to maintain a BIS value between 40–60. The fluctuations in mean arterial pressure (MAP) and heart rate (HR) were maintained within 20% of the preoperative values of the patients. All surgical procedures were

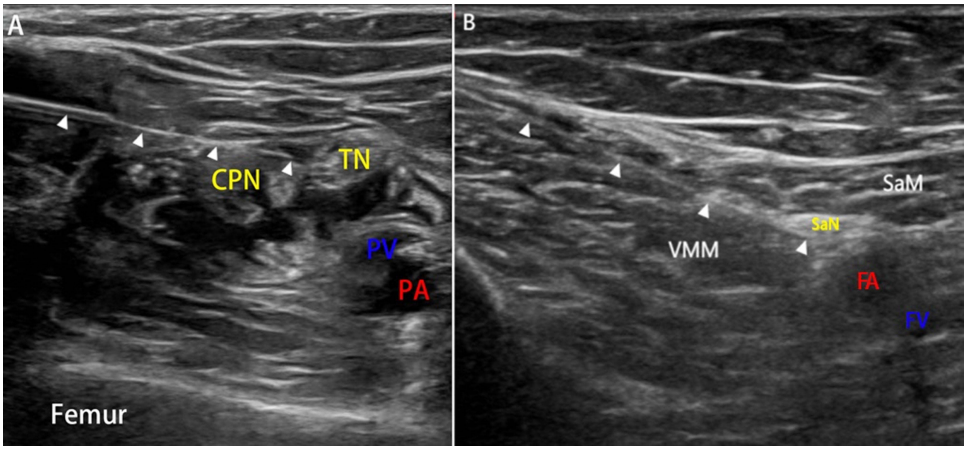

Figure 1 (**A**) Transverse ultrasound view of the popliteal sciatic nerve block during injection with the needlepoint at 12:00 around the bifurcation. (**B**) Ultrasonographic visualization of the injection for the saphenous nerve block. The block needle is highlighted using arrow heads.
Abbreviations: TN, tibial nerve; CPN, common peroneal nerve; PA, popliteal artery; PV, popliteal vein; SaN, saphenous nerve; SaM, sartorius muscle; VMM, vastus medialis muscle; FA, femoral artery; FV, femoral vein.

conducted by a fixed team of surgeons. Drug infusion was stopped at the end of surgery. Once the patient recovered consciousness, the LMA was removed, and the patient was transferred to the post-anesthesia care unit (PACU) for at least 30 min of observation (Dr. Yue Wang) until they met the discharge criteria.

Postoperative pain management included patient-controlled analgesia (PCA) with sufentanil at 1.5 μg/kg and 24 mg of ondansetron prepared in a 100-mL analgesia device. The device has a continuous background dose of 2 mL per hour, a single additional dose of 2 mL, and a lock-in time of 15 minutes. Patients were allowed to self-administer additional analgesics as needed and were followed by a special team (Dr. Wan MX, Dr. Wu HY or Dr. Yin Y).

Outcomes and Definitions

The primary outcome was the duration of analgesia, which was defined as the time from the end of the nerve blocks until the first sensation of pain at the surgical site as measured by a patient-reported visual analog scale (VAS) score ≥ 1 (on a scale ranging from 0–10). The secondary outcomes included static VAS scores for pain in the PACU and at 2, 6, 12, 24, 36 and 48 h post-operatively; motor block; sensory block; patient satisfaction scores (on a scale ranging from 0–10); and adverse events such as persistent numbness, paranesthesia, motor deficits, vascular injury, local anesthetic toxicity and nerve injury. Motor block was assessed for ankle and toe movements and was graded on a 3-point scale: 0 = no block; 1 = paresis (slight or partial paralysis); and 2 = complete paralysis. The sensory block was graded on a 3-point scale using a cold test: 0 = no block; 1 = analgesia (patient can feel touch, no cold), and 2 = anesthesia (patient cannot feel touch) as described in a previous study.[14]

Sample Size

This study was a randomized, double-blinded, paired, noninferiority trial. The primary outcome (duration of analgesia) was used to determine the appropriate sample size. We hypothesized that the analgesic duration of 0.25% ropivacaine would be noninferior to that of 0.375% ropivacaine. In a preliminary study with seven patients, the mean duration difference was 0.16 hours, with a standard deviation (SD) of 3.78. PASS 15.0 software (NCSS, LLC; Kaysville, UT, USA) was used for sample size calculation, and a noninferiority margin of 2 hours was considered clinically relevant,[21] with a one-sided alpha of 0.025, a beta of 0.2 and a power of 80%. The minimum sample size was calculated to be 27 for each group. Under the assumption of a potential dropout rate of 20%, we planned to recruit 33 patients.

Statistical Analysis

Statistical analysis was performed via IBM SPSS Statistics for Windows, version 24.0 (IBM Corp, Armonk, NY, USA). The Shapiro–Wilk test was used to test whether the data were normally distributed. Normally distributed variables are expressed as

the means ± SDs and were analyzed with paired Student's *t* test. Nonnormally distributed variables are expressed as medians [IQRs] and were analyzed with the paired Wilcoxon signed-rank test. Categorical variables are presented as n (%). A noninferiority study design was used to assess the primary outcome. Kaplan–Meier curves were used to analyze time-to-event (the event was defined as a patient reported VAS score ≥ 1) data, and the Log rank test was used to compare the survival distributions between the two concentrations. Sensory and motor block scores were compared via the Mantel–Haenszel linear–by–linear χ^2 test. We also used a Bonferroni–Holm correction to test a threshold for the statistical significance of multiple outcomes.[22] All tests were two-sided, and $P < 0.05$ indicated statistical significance.

Results

Patient Characteristics

In total, 33 patients scheduled for bilateral foot and ankle surgeries were recruited between 15 December 2021 and 25 February 2022. One patient each from Protocol A and Protocol B declined to participate, leaving 31 patients who received the allocated intervention. All 31 patients completed the trial and were analyzed for the primary outcome, as presented in the CONSORT flow diagram (Figure 2). The demographic data, patient characteristics, and clinical parameters are listed in Table 1. All nerve blocks were successful and uneventful.

Primary and Secondary Outcomes

The mean duration of analgesia was 31.7 ± 8.3 h in the 0.25% ropivacaine group and 31.9 ± 8.5 h in the 0.375% ropivacaine group (duration difference, −0.16; 95% CI, −1.5 to 1.2; $P = 0.812$), as shown in Table 2. The lower bound of the 95% confidence interval (−1.5) was greater than the noninferiority margin (−2). The Kaplan–Meier curves representing the complete pain relief time revealed that there was no difference between 0.25% ropivacaine and 0.375% ropivacaine ($P = 0.900$) (Figure 3).

There were no significant differences in static VAS scores between the two groups in the PACU or at 2, 6, 12, 24, 36, and 48 h postoperatively. Similarly, the patient satisfaction scores at 12, 24, and 48 h after surgery were not significantly different between the two groups. Moreover, the durations of surgery and tourniquet application were similar between the two groups. Notably, there were no ropivacaine-related adverse events or nerve block complications in either group (Table 2).

Patients with 0.25% ropivacaine had significantly less motor block at PACU, at 2, 6 and 12 h; no other statistically significant differences in block density were observed at 24 h or later (Table 3). There was no significant difference in the sensory block between the two groups at any assessment time point (Table 4). All patients recovered from complete motor block and sensory block at 72 h postoperatively. No nerve block-related complications were reported postoperatively.

Discussion

In this randomized, self-paired study, we found that the duration of analgesia with 0.25% ropivacaine was noninferior to that with 0.375% ropivacaine in ultrasound-guided popliteal sciatic and saphenous nerve blocks for foot and ankle surgeries. Additionally, motor block with 0.25% ropivacaine was milder within 24 hours postoperatively than motor block with 0.375% ropivacaine was.

Undesired weakness of the toes and ankles is a common occurrence after popliteal sciatic nerve block. Decreasing the concentration of LAs is often used to minimize motor block, however, it remains unknown whether the analgesic effect is affected and the results are contradictory. A previous study examined the concentration of LAs and reported no difference in the analgesic duration of the interscalene block between 10 mL of 0.75% ropivacaine and 20 mL of 0.375% ropivacaine at a fixed dose.[23] However, 20 mL of 0.5% ropivacaine yielded longer postoperative analgesia than did 20 mL of 0.375% ropivacaine after a costoclavicular brachial plexus block.[14] A recent systematic review and meta-analysis indicated that the duration of sensory blockade with 0.75% ropivacaine was similar to that with 0.5% ropivacaine, and that 0.5%–1% ropivacaine may provide a similar sensory block duration but longer motor block duration than 0.375% ropivacaine.[24] In addition, although low-concentration ropivacaine for continuous sciatic nerve block may provide analgesia for up to several days, catheterization of continuous blocks may not be necessary because of rapid discharge from the hospital after foot and

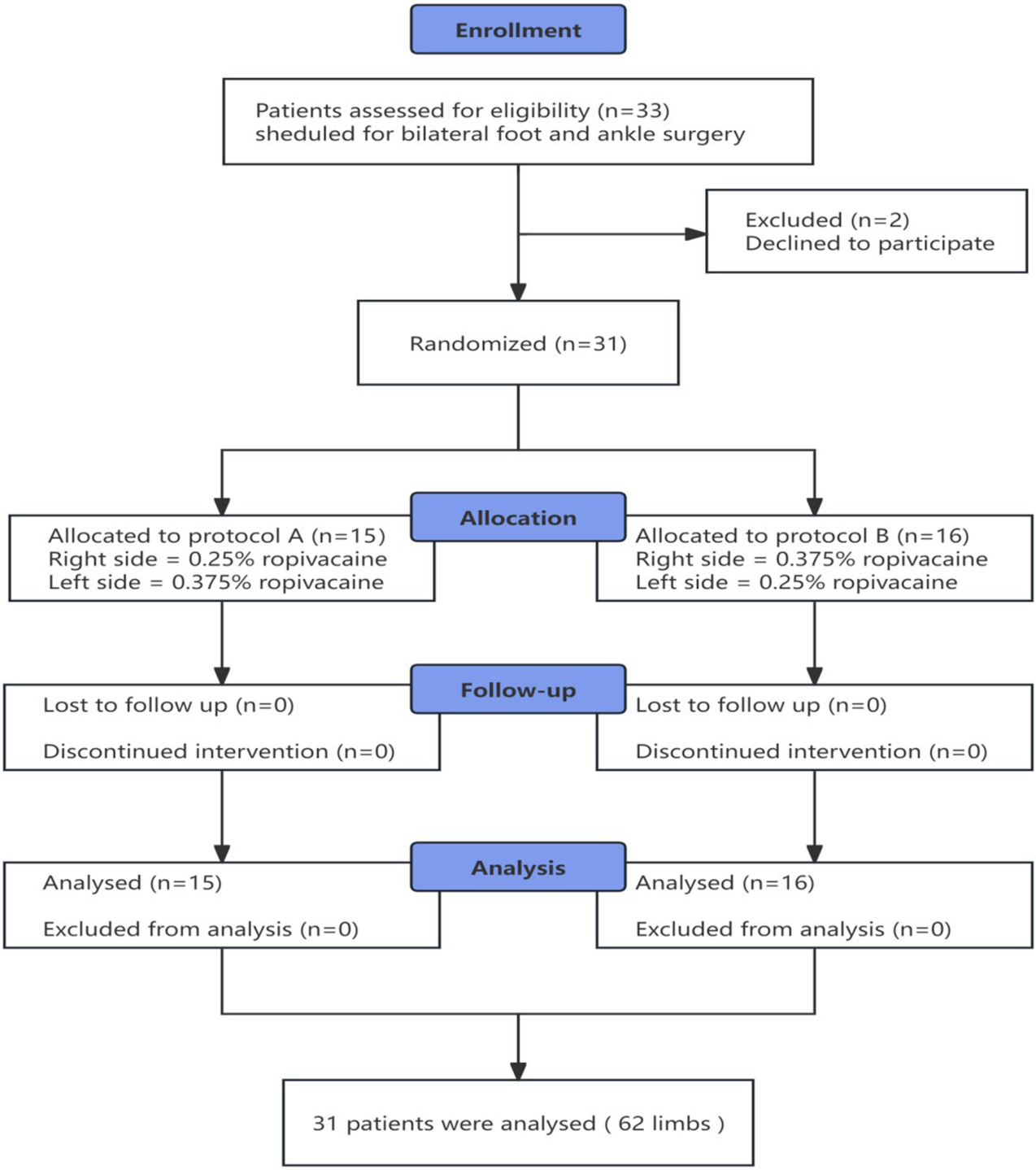

Figure 2 CONSORT flowchart diagram.

ankle surgery. In this study, two different concentrations of ropivacaine with the same volume of nerve blocks were used in patients who underwent bilateral foot and ankle surgery, with a concentration of 0.375% on one side and 0.25% on the other side. We found that the analgesic duration of 0.25% ropivacaine was approximately 32 hours, and was similar to that of 0.375% ropivacaine. Therefore, we believe that a concentration of 0.25% ropivacaine is sufficient for postoperative analgesic purposes alone and can reduce the total amount of LAs used in bilateral surgery.

Table 1 Demographics and Baseline Values

Variable	
Age (yr)	47.6 ± 16.8
Female	30 (96.8%)
Height (m)	1.6 ± 0.1
Weight (kg)	61.9 ± 8.7
BMI (kg/m2)	23.6 ± 3.1
ASA Physical Status, n (%)	
I	13 (41.9%)
II	18 (58.1%)
Hypertension	6 (19.4%)
Diabetes mellitus	5 (16.1%)
Coronary artery disease	2 (6.5%)
Type of surgery, n (%)	
Arthrodesis	21 (67.7%)
Osteotomy	8 (25.8%)
Complex ligament reconstruction	2 (6.5%)
Time to first analgesic request (h)	33.6 ± 8.3
Sufentanil consumption	
ISE 0–24 hours tota (μg)	11.3 ± 1.6
ISE 0–48 hours tota (ug)	44.3 ± 25.7

Note: Data are presented as the means ± SDs or n (%).
Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; ISE, intravenous sufentanil equivalent; SD, standard deviation.

Table 2 Primary and Secondary Outcomes and Clinical Parameters

	0.25% Ropivacaine (n=31)	**0.375% Ropivacaine (n=31)**	**Mean Difference (95% CI)**	**P value**
Duration of analgesia (h)	31.7±8.3	31.9±8.5	−0.16 (−1.5 to 1.2)	0.812
Duration of surgery (min)	64.5±15.3	69.2±17.5	−4.68 (−10.6 to 1.3)	0.119
Duration of tourniquet application (min)	61 [55,73]	64 [59,76]	−0.71 (−9.4 to 8.0)	0.706
Static VAS in PACU	0 [0,0]	0 [0,0]	0 (0 to 0)	1.000
Static VAS at 2 h	0 [0,0]	0 [0,0]	0 (0 to 0)	1.000
Static VAS at 6 h	0 [0,0]	0 [0,0]	0 (0 to 0)	1.000
Static VAS at 12 h	0 [0,0]	0 [0,0]	−0.1 (−0.4 to 0.1)	0.317

(*Continued*)

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Table 2 (Continued).

	0.25% Ropivacaine (n=31)	0.375% Ropivacaine (n=31)	Mean Difference (95% CI)	P value
Static VAS at 24 h	0 [0,1]	0 [0,1]	0.1 (−0.2 to 0.4)	0.518
Static VAS at 36 h	2 [1,6]	2 [0,6]	0 (−0.6 to 0.6)	0.746
Static VAS at 48 h	3 [1,5]	2 [1,5.]	0.19 (−0.4 to 0.8)	0.630
Patient satisfaction at 12 h	10 [8,10]	10 [10,10]	−0.2 (−0.6 to 0.2)	0.238
Patient satisfaction at 24 h	10 [9,10]	10 [9,10]	0 (−0.2 to 0.2)	1.000
Patient satisfaction at 48 h	9 [8,10]	9 [8,10]	−0.2 (−0.4 to 0.1)	0.197

Notes: Data are expressed as the means ± SDs or medians [IQRs] or mean differences (95% CIs), as appropriate.

The concentration, volume, total dose of LAs, and anatomical structures surrounding the target nerve may influence the analgesic duration of PNBs.[23,25] Typically, the volume of LAs is considered paramount in determining analgesic duration, as a greater volume of LAs is more likely to completely surround the target nerve. The ED_{95} minimal effective anesthetic volume (MEAV) was 16 mL for ultrasound-guided popliteal sciatic nerve block with 0.5% ropivacaine, and 1.9 mL for saphenous nerve block with 2% mepivacaine.[26,27] Our previous study revealed that 20 mL for sciatic nerve block and 10 mL for the saphenous nerve block provided analgesia for over 24 hours after foot and ankle surgery.[17]

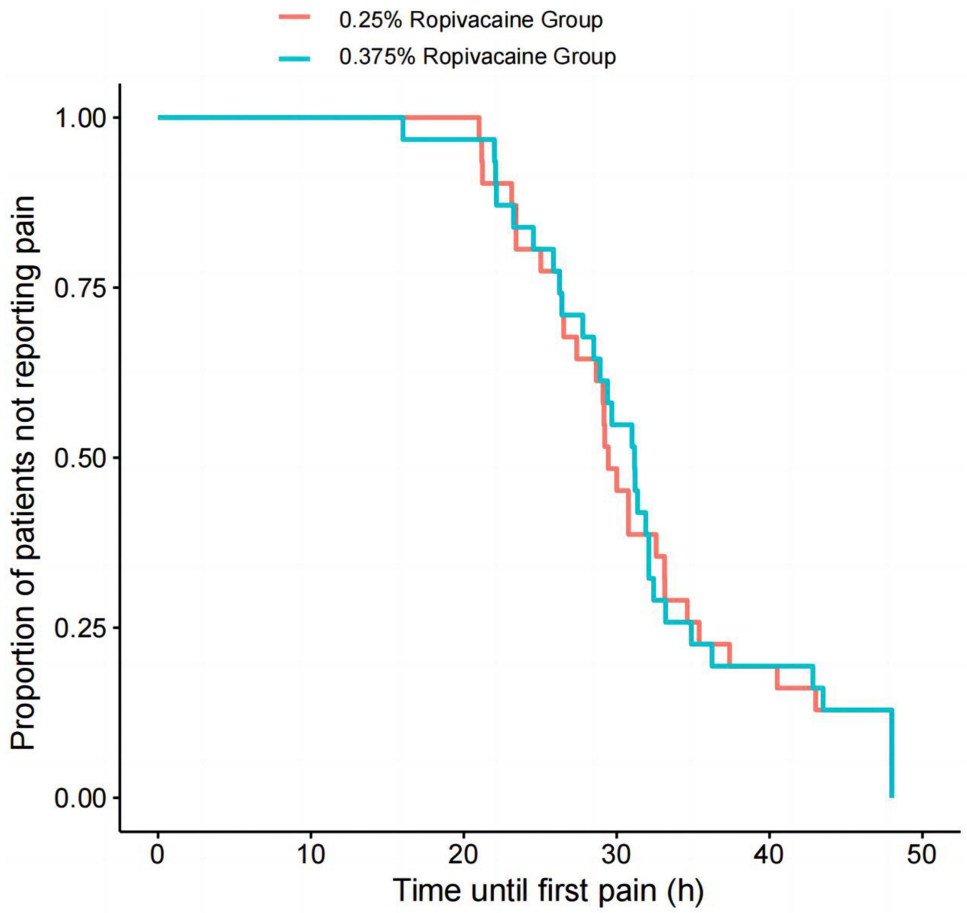

Figure 3 Kaplan–Meier survival curve representing the complete pain relief time in the two groups. (P = 0.900).

Table 3 Motor Block Within 48 hours Postoperatively

	0.25% Ropivacaine (n=31)			0.375% Ropivacaine (n=31)			P (holm P)
	Block Score (n, %)			Block Score (n, %)			
Time	0	1	2	0	1	2	
At PACU	3 (9.7)	17 (54.8)	11 (35.5)	0 (0)	9 (29.0)	22 (71.0)	0.010
2 hours	3 (9.7)	16 (51.6)	12 (38.7)	1 (3.2)	7 (22.6)	23 (74.2)	0.019
6 hours	3 (9.7)	18 (58.1)	10 (32.3)	1 (3.2)	8 (25.8)	22 (71.0)	0.009
12 hours	6 (19.4)	18 (58.1)	7 (22.6)	3 (9.7)	8 (25.8)	20 (64.5)	0.004 (0.007)
24 hours	17 (54.8)	11 (35.5)	3 (9.7)	12 (38.7)	12 (38.7)	7 (22.6)	0.286
36 hours	21 (67.7)	9 (29.0)	1(3.23%)	18 (58.1)	12 (38.7)	1 (3.2)	0.719
48 hours	24 (77.4)	6 (19.4)	1 (3.2)	22 (71.0)	8 (25.8)	1 (3.2)	0.830

Notes: Data are presented as n (%). Motor block score: 0 = no block; 1 = paresis (slight or partial paralysis); and 2 = complete paralysis.

Table 4 Sensory Block Within 48 hours Postoperatively

	0.25% Ropivacaine (n=31)			0.375% Ropivacaine (n=31)			P value
	Block Score (n, %)			Block Score (n, %)			
Time	0	1	2	0	1	2	
At PACU	0 (0)	7 (22.6)	24 (77.4)	0 (0)	5 (16.1)	26 (83.9)	0.520
2 hours	0 (0)	6 (19.4)	25 (80.7)	0 (0)	5 (16.1)	26 (83.9)	0.740
6 hours	0 (0)	8 (25.8)	23 (74.2)	0 (0)	6 (19.4)	25 (80.7)	0.544
12 hours	2 (6.5)	17 (54.8)	12 (38.7)	0 (0)	17 (54.8)	14 (45.2)	0.341
24 hours	9 (29.0)	17 (54.8)	5 (16.1)	10 (32.3)	15 (48.4)	6 (19.34)	0.874
36 hours	20 (64.5)	10 (32.3)	1 (3.2)	19 (61.3)	11 (35.5)	1 (3.2)	0.964
48 hours	27 (87.1)	4 (12.9)	0 (0)	26 (83.9)	5 (16.1)	0 (0)	0.718

Notes: Data are presented as n (%). Sensory block score: 0 = no block; 1 = analgesia (patient can feel touch, no cold), and 2 = anesthesia (patient cannot feel touch).

Therefore, we applied the same volume of LA in this study to rule out the effect of volume on analgesic efficacy. We deduce that the most important factor for the analgesic duration in our study is the anatomical characteristics of the sciatic nerve at the popliteal fossa, where there are paraneural sheaths covering the tibial nerve (TN) and common peroneal nerve (CPN) above and below their divergence. These anatomical features provide excellent conditions for lower concentrations of the LA to infiltrate the TN and CPN, which are slimmer and more likely to be blocked than the sciatic nerve trunk above the divergence.[28] Therefore, 20 mL of 0.25% ropivacaine with subparaneural injection can effectively block both the TN and CPN simultaneously, resulting in long-acting analgesia and sensory block. Our results support the findings of Christiansen et al, who reported that ropivacaine concentrations ranging from 0.04% to 0.5% had similar sensory block durations on the common peroneal nerve in healthy volunteers.[29] In addition, the analgesic duration in this study was significantly longer than that reported in previous studies (approximately 24 hours).[5,8] We believe that this may be related to our use of a two-point injection method, as it has been reported in the literature that two-point administration may achieve a longer analgesic effect by encircling the longer sciatic nerve.[30] Given that the effectiveness of PNBs is dependent on the skill of the operator, further multicenter studies could be performed to confirm our results.

In our study, severe motor block was significantly lower in the 0.25% ropivacaine group than in the 0.375% ropivacaine group within 24 hours postoperatively. This finding is particularly important for facilitating early discharge and rehabilitation after surgery because prolonged dense motor blockade is another limitation of subparaneural popliteal sciatic nerve block that concerns the surgeon, and patients also find it unpleasant. The prolonged postoperative motor blockade may be related to the slow washout (elimination) of the LAs from the relatively avascular subparaneural compartment. Previous studies have shown that both high concentrations and large volumes of local anesthetics can affect motor block, and LA dilution results in reduced motor block duration.[29,31] Typically, higher concentrations of ropivacaine, such as 0.5% to 1%, are used in regional anesthesia, primarily because of their rapid onset and effectiveness as intraoperative anesthesia. In our study, general anesthesia was used to ensure patient comfort and to mitigate the effects of thigh tourniquets. The benefits of high-concentration LAs were not detectable, whereas the disadvantages of motor blocks were evident in this situation. Thus, we suggest that a lower concentration of local anesthetics, such as 0.25% ropivacaine, may optimize postoperative analgesia, minimize motor block, and increase patient comfort.

Limitations

This study has several limitations. First, we assessed only postoperative static pain, not dynamic pain, because most patients were unable to move their feet and ankles freely within 24 hours because of the motor block. This concern is mitigated by the low static pain scores reported in both groups. Second, it was not possible to evaluate the differences in opioid consumption at different concentrations of ropivacaine since this was a self-controlled experiment. Typically, there are subjective differences in patients' perceptions and scoring of pain. By comparing the patient's bilateral feet and ankles, we minimized individual variability in subjective pain experiences, thereby reducing bias in assessing analgesic efficacy. Thirdly, the duration of analgesia in this study was longer than that in previous studies, which may be related to our block skills, and multicenter studies are needed to confirm these results. Finally, most of our patients were diagnosed with first metatarsophalangeal joint (MPJ) arthrodesis and underwent arthrodesis or osteotomy. As previously reported, the number of female patients with this type of disease who need surgical treatment is much higher than that of male patients.[32,33] As a result, the majority of our study subjects were women. Further research is needed to determine whether our conclusions can be confirmed in men or other foot and ankle surgeries.

Conclusion

Our results demonstrated that the analgesic duration of 0.25% ropivacaine was noninferior to that of 0.375% ropivacaine for popliteal sciatic and saphenous nerve blocks following bilateral foot and ankle surgery. Moreover, a lower concentration resulted in less severe motor block, thereby promoting early postoperative mobilization. These findings support the use of 0.25% ropivacaine as a suitable choice for achieving effective analgesia with reduced motor block and reducing the total amount of LAs for the purpose of postoperative analgesia after foot and ankle surgery. It may also facilitate early rehabilitation and discharge from the hospital during ambulatory surgery.

Data Sharing Statement

The raw data supporting the conclusions of this article will be available by the authors without undue reservation. After the article is published, readers can contact the corresponding author, Guyan Wang, to obtain data by email.

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Disclosure

The authors report no conflicts of interest in this work.

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