

Popliteal Sciatic Perineural Local Anesthetic Infusion

A Comparison of Three Dosing Regimens for Postoperative Analgesia

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Background: This randomized, double-blind study investigated the efficacy of continuous and patient-controlled ropivacaine infusion *via* a popliteal sciatic perineural catheter in ambulatory patients undergoing moderately painful orthopedic surgery of the foot or ankle.

Methods: Preoperatively, patients (n = 30) received a posterior popliteal sciatic perineural catheter and nerve block. Postoperatively, patients were discharged home with a portable infusion pump delivering 0.2% ropivacaine (500 ml) in one of three dosing regimens: the basal group (12-ml/h basal rate, 0.05-ml patient-controlled bolus dose), the basal-bolus group (8-ml/h basal rate, 4-ml bolus dose), or the bolus group (0.3-ml/h basal rate, 9.9-ml bolus dose).

Results: The bolus group experienced an increase in baseline pain, breakthrough pain incidence and intensity, and sleep disturbances compared with the other two groups ($P < 0.05$ for all comparisons). Compared with the basal-bolus group, the basal group experienced an increase in these outcome measures only after local anesthetic reservoir exhaustion, which occurred earlier than in the other two groups ($P < 0.05$ for all comparisons). Satisfaction scores did not differ among the three groups.

Conclusions: This study demonstrates that when providing analgesia with 0.2% ropivacaine *via* a popliteal sciatic perineural catheter after moderately painful surgery of the foot or ankle, a continuous infusion is required to optimize infusion benefits. Furthermore, adding patient-controlled bolus doses allows for a lower continuous basal rate and decreased local anesthetic consumption and thereby increases the duration of infusion benefits when in an ambulatory environment with a limited local anesthetic reservoir.

A CONTINUOUS popliteal sciatic nerve block with a perineural local anesthetic infusion has been shown to provide multiple benefits after moderately painful orthopedic procedures of the foot, including decreased pain, opioid use, opioid-related adverse effects, and sleep disturbances.^{1,2} Although there are previously published studies involving various aspects of this technique, none address the issue of infusion optimization.¹⁻⁵ This lack of

data has resulted in practitioners administering different local anesthetic delivery regimens.¹⁻⁵ Investigations of interscalene,^{6,7} infraclavicular,⁸ axillary,⁹ fascia iliaca,¹⁰ extended femoral,^{11,12} and subgluteal¹³ catheters have demonstrated that the optimal infusion method of local anesthetic delivery varies with anatomical location. For example, it has been shown that for a bupivacaine infusion *via* an extended femoral catheter after major knee surgery, a basal infusion (exclusively or added to bolus doses) only increases local anesthetic consumption and does not add to infusion benefits.¹¹ Consequently, a bolus-only regimen has been recommended.¹¹ However, for interscalene perineural bupivacaine infusion, a basal infusion is required to maximize infusion benefits.⁷ As a result, data from studies involving other catheter locations cannot necessarily be applied to popliteal sciatic placement. In addition, ambulatory perineural infusion requires patients to carry the local anesthetic reservoir. In this case, minimizing the local anesthetic consumption rate allows for maximum infusion duration. Therefore, this investigation was undertaken to evaluate three different local anesthetic dosing regimens for popliteal sciatic perineural infusion.

Furthermore, there is growing recognition that inaccurate catheter placement occurs in a substantial number of cases,^{6,14,15} as high as 40% in some reports.¹⁶ In an attempt to improve placement success rates, catheters that deliver electrical current to their tips were developed.¹⁷ Requests for clinical investigations using these new "stimulating catheters" followed.¹⁶ Although such catheters have been described previously in other anatomical locations,^{8,17-20} there are, to our knowledge, no published studies that document with predefined, objective criteria the surgical block or catheter placement success rate of these devices in the popliteal fossa.

The primary objective of this randomized, double-blind study was to determine whether local anesthetic infused *via* a popliteal sciatic perineural catheter delivered as (1) a basal infusion, (2) patient-controlled bolus doses, or (3) a combination of these two provides optimal analgesia while minimizing oral analgesic requirements. Secondary outcomes investigated included initial surgical block success rate, sleep disturbances, infusion duration, and patient satisfaction.

Materials and Methods

Enrollment

After obtaining approval from the University of Florida Institutional Review Board (Gainesville, Florida), we pro-

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spectively enrolled adult patients scheduled to undergo moderately painful, ambulatory, unilateral, orthopedic surgery of the lower extremity at or distal to the ankle who desired popliteal sciatic perineural catheter placement. Patients were required (1) to be able to understand the possible local anesthetic-related complications, study protocol, and care of the catheter and infusion pump system and (2) to have a caretaker who would remain with them during the local anesthetic infusion. Exclusion criteria included any contraindication to popliteal sciatic nerve block or catheter, history of opioid dependence, current chronic analgesic therapy, allergy to study medications, known hepatic or renal insufficiency/disease, American Society of Anesthesiologists physical score greater than II, peripheral neuropathy, or an anticipated extensive skin incision in the saphenous nerve distribution.

After giving written, informed consent, patients had a peripheral intravenous (intravenous) catheter inserted and were placed in the prone position. Standard noninvasive monitors were applied, and oxygen was administered *via* a facemask. Midazolam and fentanyl (intravenous) were titrated for patient comfort while it was ensured that patients remained responsive to verbal cues. The area that would be subsequently covered by the catheter dressing was prepared with chlorhexidine gluconate and isopropyl alcohol (ChlorPrep One-Step; Medi-Flex Hospital Products, Inc., Overland Park, KS) and then shaved with a surgical safety razor, if necessary.

Catheter Insertion

All perineural catheters were placed using a slightly modified technique of a method described previously.¹⁸ After sterile preparation and draping, a local anesthetic skin wheal was raised 1 cm directly caudad to the apex of the popliteal fossa (bounded by the semimembranosus muscle medially and the biceps femoris muscle laterally) but not more than 10 cm cephalad to the popliteal fossa skin crease.^{1,21-23} An 8.9-cm, 17-gauge insulated needle (StimuCath; Arrow International, Reading, PA) was inserted through the skin wheal, with the long axis of the needle at a 45° angle to the skin/gurney and the bevel directed cephalad. The needle was connected to a nerve stimulator (Stimuplex-DIG; B. Braun Medical, Bethlehem, PA) initially set at 1.2 mA, 2 Hz, with an impulse duration of 0.1 m/s. When the needle tip was through the skin and superficial fascia, the stylet was removed to allow for identification of a penetrated vessel. If the sciatic nerve was not identified after 5–8 cm of insertion, depending on patient habitus, the needle was withdrawn and redirected laterally, then medially, until discrete, stimulated foot/toe plantar flexion occurred with a current amplitude between 0.30 and 0.50 mA.

The 19-gauge catheter was then placed through the length of the needle and the nerve stimulator connecting

wire transferred from the needle to the catheter, which has a conducting wire through its length to deliver current to its tip. The stimulating current was increased to 0.80 mA, and the catheter was advanced 5 cm beyond the needle tip. If plantar flexion decreased as the stimulating catheter was advanced, the catheter was withdrawn into the needle, the needle was redirected or rotated, and the catheter was readvanced. If there was resistance during catheter withdrawal, the needle was retracted until the catheter resistance resolved. If resistance impeded catheter advancement after 10 attempts, the catheter was removed from the needle and 20 ml preservative-free normal saline was injected after a negative aspiration. If the resistance had resolved, the catheter was advanced 5 cm past the needle tip (without muscle motion as a guide). If the catheter could not be placed after this maneuver, the patient was withdrawn from the study.

When a catheter had been successfully advanced 5 cm past the needle tip, the needle itself was withdrawn over the catheter, the catheter stylet was removed, and the catheter was tunneled subcutaneously 5–7 cm laterally using the included needle stylet and 17-gauge insulated needle.⁸ The injection port was attached to the end of the catheter, the nerve stimulator was attached to the injection port, and the minimum current resulting in muscle contraction was noted. The catheter was secured with sterile liquid adhesive, an occlusive dressing, and an anchoring device to affix the catheter hub to the patient (StatLock; Venetec International, San Diego, CA).

After negative aspiration, 50 ml anesthetic solution was injected *via* the catheter with gentle aspiration between divided doses. The injectate contained 1.5% mepivacaine, 125 µg epinephrine, and 100 µg preservative-free clonidine. After 15–30 min, block onset was evaluated and scored in the affirmative if motor control was nearly abolished during either plantar or dorsa flexion. Specific nerve distributions and degree of sensory blockade were not formally evaluated.

If a skin incision was expected in the saphenous nerve distribution, this nerve was blocked using a previously described technique and/or the surgeon infiltrated the region with 0.5% subcutaneous bupivacaine.¹ This nerve block was not formally evaluated in regard to the current investigation.

No additional opioids or benzodiazepines were administered after catheter placement. Intraoperatively, 0–50 µg · kg⁻¹ · min⁻¹ propofol was titrated for sedation. A successful sciatic nerve block was defined as a patient requiring less than 50 µg · kg⁻¹ · min⁻¹ propofol for the surgical procedure (as opposed to block onset, defined above). If this dose was inadequate, higher doses of propofol and nitrous oxide inhaled *via* a laryngeal mask airway were used to administer a general anesthetic.

Randomization

After successful catheter/block placement (defined by block onset for either plantar or dorsa flexion), patients were randomly assigned in a double-blinded fashion to receive one of three possible postoperative catheter infusion regimens of local anesthetic using a computer-generated table: a basal infusion of 12 ml/h and a patient-controlled bolus dose of 0.05 ml available every 1 h (basal group); a basal infusion of 8 ml/h and a patient-controlled bolus dose of 4 ml available every 1 h (basal-bolus group); or a basal infusion of 0.3 ml/h and a patient-controlled bolus dose of 9.9 ml available every 1 h (bolus group; 9.9 is the pump maximum). The basal group had a 0.05-ml bolus available so that the pump would respond to a bolus request and retain group blinding. The bolus group received a 0.3-ml/h basal infusion to keep the catheter patent. Past experience has demonstrated a high rate of catheter occlusions if the catheter is left completely unused for a period of time.

Patient Education

Postoperatively, patients were discharged home with a portable, electronic infusion pump (CADD-Legacy PCA; Deltec [Smiths Medical], St. Paul, MN) attached to the 500-ml reservoir of 0.2% ropivacaine (AstraZeneca Pharmaceuticals, Wilmington, DE). The patient and caretaker were given standard postoperative outpatient instructions as well as verbal and written instructions on the use of the pump and catheter. Telephone and pager numbers for physicians available at all times were given to each patient. Patients were instructed to keep their operative limb well protected during the infusion period and to not use the limb for weight bearing. The following supplies were given to patients: crutches, a medication log, a prescription for an oral analgesic (5 mg oxycodone combined with 500 mg acetaminophen), a pair of nonsterile gloves, and a self-addressed and stamped padded envelope for pump return. As part of their postoperative education, patients self-administered one bolus from their infusion pump when the infusion was initiated before discharge from the recovery room.

In the event of breakthrough pain, patients were instructed to first use the bolus function of the infusion pump. If the pain had not resolved after 20 min, patients were instructed to use oral analgesics and to record this use in the medication log.

Patient Follow-up

Patients were telephoned beginning the night of surgery and each evening thereafter through the night after catheter removal. Data were collected during these contacts. The specific questions regarding surgical pain were as follows: "Please answer the following questions regarding your surgical pain since the last time we spoke using a scale of 0–10, 0 being no pain at all and 10 being the worst pain you can imagine. What was the *worst*

pain you have felt? While you were resting, what was the *average* pain you have felt?" Patients were also questioned about symptoms of local anesthetic toxicity, gross sensory and motor function, and the appearance of the catheter site. If complete anesthesia of their surgical extremity was experienced at any time on or after the morning of postoperative day (POD) 1, patients were instructed to pause their infusion until they regained feeling in their extremity and then to restart the infusion.

On the evening of POD 3 or when the anesthetic reservoir was empty, patients' caretakers removed the catheters using the pair of nonsterile gloves, with the physician in telephone contact throughout. The presence of a metallic catheter tip confirmed complete removal. Patients disposed of the catheter and any residual infusate, and the pump was returned to the surgical center in the supplied padded envelope *via* the postal service. On arrival at the surgical center, the infusion pump memory containing all pump "events" with a date/time stamp (*e.g.*, bolus activation) was downloaded to a desktop computer.

Statistical Analysis

Sample size calculations were centered around our primary hypothesis that a basal infusion of local anesthetic *via* a popliteal sciatic perineural catheter combined with patient-controlled bolus doses decreases postoperative pain compared with exclusively bolus doses and decreases oral analgesic use compared with a simple basal infusion. To this end, we chose the outcome variables "average" pain at rest on POD 1 for the basal-bolus and bolus groups and number of oral analgesic tablets consumed on POD 1 for the basal and basal-bolus groups to estimate a probable sample size. We considered a 50% reduction in pain score or oral analgesic requirements to be clinically relevant. Based on our previous experience, we expected patients with a basal infusion and bolus doses to have a median "average" pain score of 1.5 on a scale of 0 to 10 (0 = no pain, 10 = worst imaginable) and to require 1.5 oral analgesic tablets on POD 1.¹ Assuming a SD in all groups of 1.1 for both variables, a two-sided type I error protection of 0.05, and a power of 0.80, approximately 10 patients in each group were required to reveal a clinically significant difference among study groups using an analysis-of-variance design that allows sample size calculation for three or more groups (SigmaStat 2.03; SPSS, Inc., Chicago, IL).

Normality of distribution was determined using the Kolmogorov-Smirnov test with Lilliefors correction (Sigma Stat 2.03). Continuous, parametric data are reported as mean \pm SD. Nonparametric data are graphically presented as median with 25th–75th percentile bars and 10th–90th percentile whiskers or textually noted using a median (5th–95th confidence intervals). For normally distributed data, multiple comparisons

Table 1. Population Data, Block Details, and Surgical Information for the Three Study Groups

	Basal Group (n = 10)	Basal-Bolus Group (n = 10)	Bolus Group (n = 10)
Age, yr	52 ± 14	46 ± 16	46 ± 16
Sex, F/M	4/6	5/5	5/5
Height, cm	169 ± 13	173 ± 11	173 ± 10
Weight, kg	78 ± 26	81 ± 21	98 ± 24
Intravenous fentanyl, µg*	150 (117–183)	200 (127–203)	200 (128–205)
Intravenous midazolam, mg*	3.0 (2.3–3.5)	4.0 (2.9–4.2)	4.0 (2.7–4.0)
Minimum current via catheter, mA	0.49 ± 0.27	0.34 ± 0.25	0.41 ± 0.18
Surgery duration, min	63 ± 36	58 ± 23	55 ± 23
Tourniquet duration, min	57 ± 30	54 ± 22	43 ± 23

Values are reported mean ± SD or median (5th–95th confidence intervals) for parametric and nonparametric data, respectively. There were no statistically significant differences among the study groups.

* Sedation only for preoperative block placement.

were made using nonrepeated or repeated-measures analysis of variance with Tukey *post hoc* pairwise testing, when appropriate. For nonparametric data, nonrepeated or repeated-measures analysis of variance for ranks with Tukey *post hoc* pairwise testing was used when appropriate. Categorical data were analyzed using the chi-square test with Yates continuity correction. $P < 0.05$ was considered significant. Analysis was performed according to the intention-to-treat principle.²⁴

Results

Enrollment and Catheter Placement

Thirty-two patients enrolled. In one case (3%), plantar flexion could not be elicited with a current below 0.50 mA, and this subject was removed from the study before randomization. In another subject, the catheter was placed successfully, but lack of motor block onset by 30 min forced patient withdrawal from the study before randomization (this patient emerged with a dense surgical block and experienced profound postoperative perineural analgesia). Of the remaining 30 subjects, all experienced surgical block onset as defined by near abolition of plantar or dorsa flexion (one patient required an injection of normal saline *via* the needle to allow for successful catheter placement). During their procedure, 28 patients (94%) required less than 50 µg · kg⁻¹ · min⁻¹ propofol, 1 patient (3%) required general anesthesia secondary to an inadequate surgical block, and 1 patient (3%) underwent surgery without sedatives but required general anesthesia for thigh tourniquet pain during skin closure (the tourniquet was placed at thigh level so that an equinus release could be performed). Therefore, of 32 attempts, 29 patients (91%) experienced a successful sciatic nerve block as defined by this study. The 30 subjects who experienced surgical block onset were randomized to the basal group (ropivacaine basal rate = 12 ml/h; bolus dose = 0.05 ml; lockout = 1 h; n = 10), the basal-bolus group (basal rate = 8 ml/h; bolus dose = 4 ml; lockout = 1 h; n = 10), or the bolus group (basal rate = 0.3 ml/h; bolus dose = 9.9 ml;

lockout = 1 h; n = 10). There were no statistically significant differences among the study groups in demographics, block placement, or surgical procedures (tables 1 and 2).

Of the 30 patients randomized, all had sensory changes in their lower extremity in the evening of POD 1, suggesting that their perineural catheter was functional. The “average” pain scores of the bolus group were significantly higher than those of the other two groups during local anesthetic infusion (fig. 1). The bolus group also required more oral analgesics than the other two groups during ropivacaine infusion (fig. 2). In addition, patients in the bolus group reported more difficulty sleeping because of pain and a greater number of nightly awakenings because of pain compared with the other two groups during infusion (figs. 3A and B). Evidence of this can be found in the number of bolus doses delivered at night, which was significantly higher in the bolus group compared with the basal-bolus group (fig. 3C). Compared with the basal-bolus group, the basal group experienced an increase in these outcome measures only after local anesthetic reservoir exhaustion, which occurred earlier than in the other two groups ($P < 0.05$ for all comparisons).

All but one patient in the basal group exhausted their local anesthetic reservoir in less than 43 h, whereas this occurred after a median of 55 h in the basal-bolus

Table 2. Surgical Procedures for the Three Study Groups

	Basal Group (n = 10)	Basal-Bolus Group (n = 10)	Bolus Group (n = 10)
Ankle ORIF	1	0	2
Calcaneal excision/resection	1	0	1
Claw toes correction	1	1	0
Hallux rigidus correction	1	3	2
Hallux valgus correction	2	1	2
Metatarsal osteotomy	3*	3	2
Subtalar fusion	1	2	1

There were no statistically significant differences among the study groups.

* An equinus release was included for one subject.

ORIF = open reduction, internal fixation.

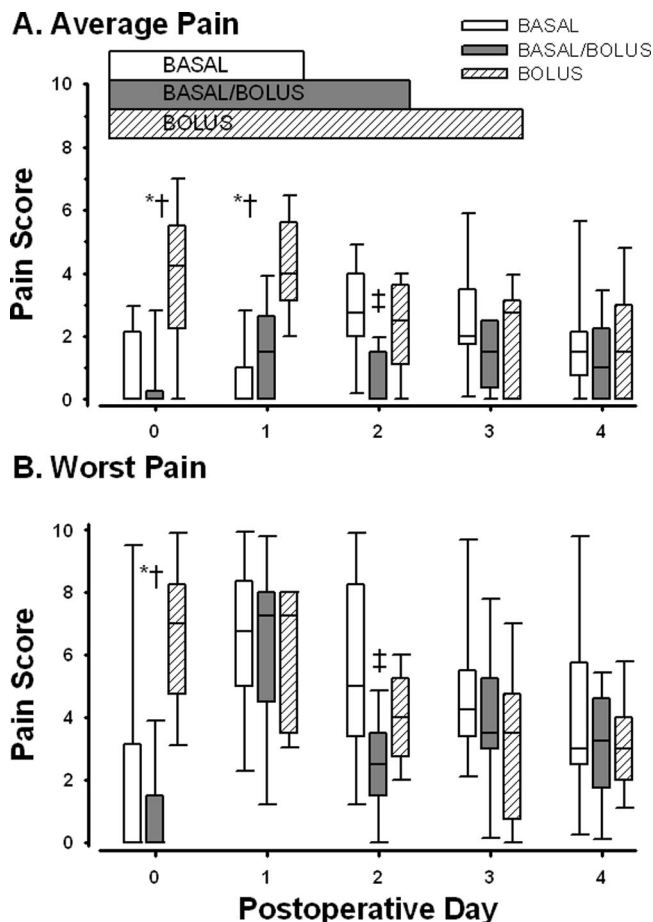


Fig. 1. Effects of popliteal sciatic perineural ropivacaine infusion dosing regimen on average (A) and worst (B) pain after moderately painful surgery of the lower extremity (scale, 0–10). The catheters were discontinued as indicated by the *horizontal boxes*. Data are expressed as median (*horizontal bar*) with 25th–75th (*box*) and 10th–90th (*whiskers*) percentiles for patients randomly assigned to the basal group (basal rate = 12 ml/h; bolus dose = 0.05 ml; lockout = 1 h; n = 10), the basal-bolus group (basal rate = 8 ml/h; bolus dose = 4 ml; lockout = 1 h; n = 10), or the bolus group (basal rate = 0.3 ml/h; bolus dose = 9.9 ml; lockout = 1 h; n = 10). For tightly clustered data (e.g., A, postoperative day 2, basal-bolus group), the median approximated the 10th and 25th percentile values. In this case, the median is 0.0, and only the 75th and 90th percentiles are clearly noted. $P < 0.05$ for group comparisons for a given postoperative day: * basal-bolus versus bolus; ‡ basal-bolus versus basal; † bolus versus basal.

group, and all of the patients in the bolus group had anesthetic remaining at the time of catheter removal after a median of 76 h (table 3). Three to five patients in each group reported minimal, occasional leakage of fluid from their catheter site. Two patients from the basal group, four from the basal-bolus group, and none from the bolus group paused their infusions at least once due to a complete lack of sensation in their surgical extremity after POD 0. Satisfaction scores did not differ among the three groups.

One patient from the basal-bolus group had his catheter inadvertently dislodged on POD 2, with 78 ml local anesthetic remaining. He had not experienced fluid leak-

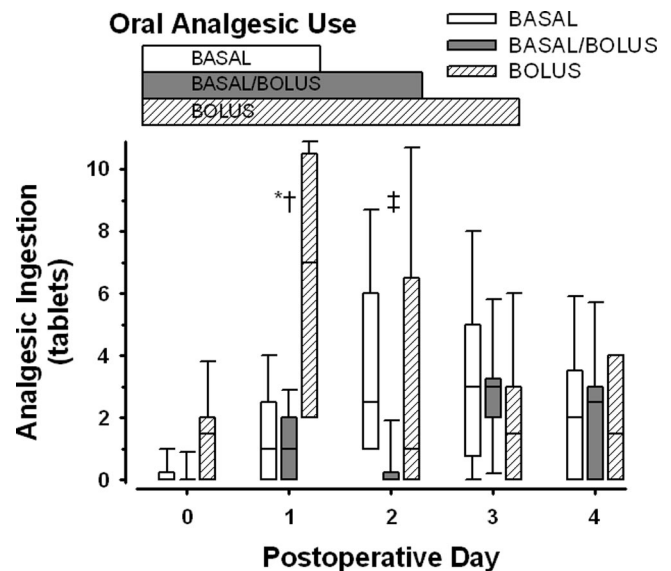


Fig. 2. Effects of popliteal sciatic perineural ropivacaine infusion dosing regimen on oral analgesic use after moderately painful surgery of the lower extremity (5 mg oxycodone, 500-mg acetaminophen tablets). The catheters were discontinued as indicated by the *horizontal boxes*. Data are expressed as median (*horizontal bar*) with 25th–75th (*box*) and 10th–90th (*whiskers*) percentiles for patients randomly assigned to the basal group (basal rate = 12 ml/h; bolus dose = 0.05 ml; lockout = 1 h; n = 10), the basal-bolus group (basal rate = 8 ml/h; bolus dose = 4 ml; lockout = 1 h; n = 10), or the bolus group (basal rate = 0.3 ml/h; bolus dose = 9.9 ml; lockout = 1 h; n = 10). For tightly clustered data (e.g., postoperative day 2, basal-bolus group), the median approximated the 10th and 25th percentile values. In this case, the median is 0.0, and only the 75th and 90th percentiles are clearly noted. $P < 0.05$ for group comparisons for a given postoperative day: * basal-bolus versus bolus; ‡ basal-bolus versus basal; † bolus versus basal.

age from the catheter site. The remaining catheters were all removed by patients' caretakers without difficulty. Six patients had a nonscheduled contact with the on-call physician during the course of their infusion, although only patient reassurance was required in all cases (two from each group). There were no pump malfunctions or alarms, and all infusion pumps were returned to the surgical center *via* the postal service.

Discussion

This investigation demonstrates that after moderately painful surgery of the foot or ankle, providing exclusively patient-controlled bolus doses of ropivacaine *via* a popliteal sciatic perineural catheter results in less satisfactory analgesia, increased opioid requirements, and increased sleep disturbances compared with a regimen including a basal infusion. Furthermore, adding patient-controlled bolus doses allows for a lower continuous basal rate and decreased local anesthetic consumption, thereby increasing the duration of infusion benefits when in an ambulatory environment with a limited local anesthetic reservoir. The stimulating catheter used in

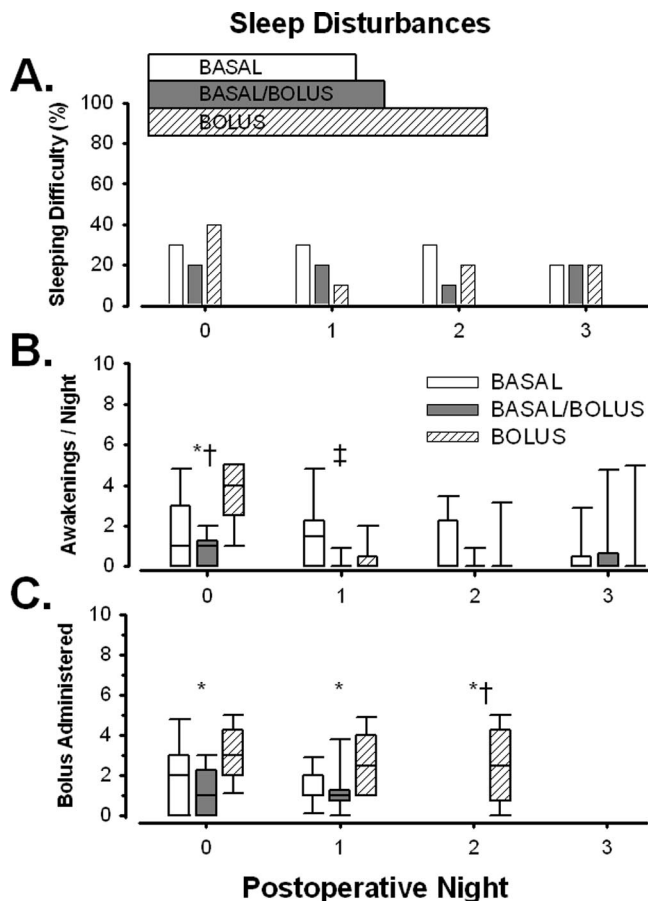


Fig. 3. Effects of popliteal sciatic perineural ropivacaine infusion dosing regimen on sleep disturbances after moderately painful surgery of the lower extremity. Endpoints included difficulty sleeping because of pain (A), number of awakenings because of pain (B), and number of bolus doses self-administered between 11 PM and 7 AM (C). The catheters were discontinued as indicated by the horizontal boxes. (A) Data expressed as fraction of patients reporting difficulty sleeping because of pain. (B and C) Data are expressed as median (horizontal bar) with 25th–75th (box) and 10th–90th (whiskers) percentiles for patients randomly assigned to the basal group (basal rate = 12 ml/h; bolus dose = 0.05 ml; lockout = 1 h; n = 10), the basal-bolus group (basal rate = 8 ml/h; bolus dose = 4 ml; lockout = 1 h; n = 10); or the bolus group (basal rate = 0.3 ml/h; bolus dose = 9.9 ml; lockout = 1 h; n = 10). For tightly clustered data (e.g., B, postoperative day 2, basal group), the median approximated the 10th and 25th percentile values. In this case, the median is 0.0, and only the 75th and 90th percentiles are clearly noted. $P < 0.05$ for group comparisons for a given postoperative day: * basal-bolus versus bolus; ‡ basal-bolus versus basal; † bolus versus basal.

this investigation provided surgical anesthesia in 91% and postoperative analgesia in 97% of patients.

Anatomical Location

The results of this investigation provide additional evidence that the optimal method of local anesthetic administration varies with anatomical location.^{6–13} For example, it has been demonstrated that for fascia iliaca perineural ropivacaine infusion after major knee surgery, a basal infusion (exclusively or added to bolus doses)

only increases local anesthetic consumption and does not add to infusion benefits.¹⁰ Therefore, a bolus-only regimen has been recommended.¹⁰ However, the current study suggests that for popliteal sciatic perineural ropivacaine infusion, it is the basal infusion that is required to maximize infusion benefits, with the addition of bolus doses limited to decreasing local anesthetic consumption.

Local Anesthetic Choice

In addition to anatomical location, the specific local anesthetic used postoperatively may impact the optimal infusion regimen. For example, previous studies involving bupivacaine perineural infusion *via* “extended” femoral catheters (anterior lumbar plexus) found no differences in benefits among basal-only, bolus-only, or basal-bolus dosing regimens after total knee and hip arthroplasty. Therefore, bolus-only dosing was recommended when using bupivacaine because it minimized local anesthetic consumption.^{11,12} Whether this difference in results between the current study, involving ropivacaine, and the previous studies, involving bupivacaine, is due to the shorter duration of ropivacaine compared with bupivacaine or an inherent difference between the lumbar plexus and sciatic nerve remains unresolved. Of note, bolus-only patients in the current study, involving ropivacaine, experienced more awakenings because of pain compared with the two groups with a basal infusion. Studies using bupivacaine that found no benefit to basal infusions and therefore recommended bolus-only dosing did not examine sleep quality, although there were no statistically significant differences in overall satisfaction scores among the various groups.^{11,12}

The portable infusion pump described in this report that allowed objective evaluation of nightly awakenings is unusual in that it records infusion/bolus details in its internal memory, which may be subsequently downloaded to a desktop computer for analysis. There were no infusion pump malfunctions or alarms during more than 1,700 h of cumulative pump use, in contrast to previous reports involving other portable electronic infusion pumps.^{1,25,26} This contributed to a decrease in unscheduled patient contacts with the on-call physician compared with previous experiences.^{1,25,26}

Safety of Ambulatory Infusion

Although at-home perineural local anesthetic infusion offers significant improvements in pain control after many ambulatory procedures, there are several potential inherent risks involving perineural catheters, including infection,²⁷ nerve injury,^{28,29} catheter migration,³⁰ local anesthetic toxicity,³¹ and catheter retention.^{8,32} All patients in this study had their catheter removed without difficulty by their caretakers, but the procedure seemed to be more anxiety provoking than in previous patients,¹

Table 3. Infusion Profile by Study Group

	Basal Group (n = 10)	Basal-Bolus Group (n = 10)	Bolus Group (n = 10)
Bolus doses attempted	12 (5–37)	13 (8–22)	42 (13–111)
Bolus doses delivered	9 (6–15)‡	10 (6–14)‡	28 (24–38)*†
Infusion duration, h§	43 ± 5†‡	55 ± 20*‡	76 ± 5*†
Bolus doses delivered/24 h	4.4 (3.0–8.8)‡	3.7 (2.3–5.7)‡	8.5 (7.5–12.6)*†
Unused local anesthetic, ml	0 (0–0)‡	0 (0–27)‡	217 (110–277)*†
Satisfaction, 0–10	9.0 ± 1.2	9.4 ± 1.3	7.9 ± 2.5

Values are reported mean ± SD or median (5th–95th confidence intervals) for parametric and nonparametric data, respectively.

$P < 0.05$ for group compared with * Basal, † Basal-Bolus, ‡ Bolus. § Infusion was stopped in the evening of postoperative day 3 regardless of local anesthetic volume remaining in reservoir.

primarily because of the increased length of the catheter to be removed with the addition of the tunneling procedure. For example, with the catheter tunneled 7 cm subcutaneously, 5 cm from skin to the sciatic nerve, and 5 cm along the nerve itself, a total of 17 cm had to be removed by patient caretakers. Whether tunneling improves the retention rate for posterior popliteal sciatic catheters remains to be determined.

Study Limitations

The relatively small number of patients included in this investigation does not permit us to draw definite conclusions about its relative safety. Because not all patients desire or are capable of accepting the extra responsibility that comes with the catheter and pump system, appropriate patient selection is crucial for safe ambulatory local anesthetic infusion. An additional limitation is the infusion rate accuracy of the pump used, which infused at 90% of the set rate over 100 h during multiple laboratory tests previously reported.³³ This pump also continuously displays the reservoir volume, and although not instructed about how to do this, some patients may have determined their basal rate and bolus dose with this information, compromising the double-blind nature of the study. In addition, only three different dosing regimens were investigated for this study, and different combinations of basal rates, bolus doses, and lockout periods may provide differing results. Finally, these results apply only to surgical procedures producing moderate-to-severe postoperative pain. It is possible—even probable—that adequate analgesia for procedures inducing mild postoperative pain would be adequately treated with a bolus-only dosing regimen.³⁴

In conclusion, this study demonstrates that when providing analgesia with 0.2% ropivacaine *via* a popliteal sciatic perineural catheter after moderately painful surgery of the foot or ankle, a continuous infusion is required to optimize infusion benefits. Furthermore, adding patient-controlled bolus doses allows for a lower continuous basal rate and decreased local anesthetic consumption, thereby increasing the duration of infusion benefits when in an ambulatory environment with a limited local anesthetic reservoir.

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References

- Ilfeld BM, Morey TE, Wang RD, Enneking FK: Continuous popliteal sciatic nerve block for postoperative pain control at home: A randomized, double-blinded, placebo-controlled study. *ANESTHESIOLOGY* 2002; 97:959–65
- White PF, Issioui T, Skrivaneck GD, Early JS, Wakefield C: The use of a continuous popliteal sciatic nerve block after surgery involving the foot and ankle: Does it improve the quality of recovery? *Anesth Analg* 2003; 97:1303–9
- Singelyn FJ, Aye F, Gouverneur JM: Continuous popliteal sciatic nerve block: An original technique to provide postoperative analgesia after foot surgery. *Anesth Analg* 1997; 84:383–6
- di Benedetto P, Casati A, Bertini L, Fanelli G, Chelly JE: Postoperative analgesia with continuous sciatic nerve block after foot surgery: A prospective, randomized comparison between the popliteal and subgluteal approaches. *Anesth Analg* 2002; 94:996–1000
- Klein SM, Greengrass RA, Gleason DH, Nunley JA, Steele SM: Major ambulatory surgery with continuous regional anesthesia and a disposable infusion pump. *ANESTHESIOLOGY* 1999; 91:563–5
- Ilfeld BM, Morey TE, Wright TW, Chidgey LK, Enneking FK: Continuous interscalene brachial plexus block for postoperative pain control at home: A randomized, double-blinded, placebo-controlled study. *Anesth Analg* 2003; 96:1089–95
- Singelyn FJ, Seguy S, Gouverneur JM: Interscalene brachial plexus analgesia after open shoulder surgery: Continuous versus patient-controlled infusion. *Anesth Analg* 1999; 89:1216–20
- Ilfeld BM, Morey TE, Enneking FK: Infraclavicular perineural local anesthetic infusion: A comparison of three dosing regimens for postoperative analgesia. *ANESTHESIOLOGY* 2004; 100:395–402
- Iskandar H, Rakotondriamihary S, Dixmieras F, Binje B, Maurette P: [Analgesia using continuous axillary block after surgery of severe hand injuries: Self-administration versus continuous injection]. *Ann Fr Anesth Reanim* 1998; 17:1099–103
- Eledjam JJ, Cuvillon P, Capdevila X, Macaire P, Serri S, Gaertner E, Jochum D: Postoperative analgesia by femoral nerve block with ropivacaine 0.2% after major knee surgery: Continuous versus patient-controlled techniques. *Reg Anesth Pain Med* 2002; 27:604–11
- Singelyn FJ, Gouverneur JM: Extended “three-in-one” block after total knee arthroplasty: Continuous versus patient-controlled techniques. *Anesth Analg* 2000; 91:176–80
- Singelyn FJ, Vanderelst PE, Gouverneur JM: Extended femoral nerve sheath block after total hip arthroplasty: Continuous versus patient-controlled techniques. *Anesth Analg* 2001; 92:455–9
- di Benedetto P, Casati A, Bertini L: Continuous subgluteal sciatic nerve block after orthopedic foot and ankle surgery: Comparison of two infusion techniques. *Reg Anesth Pain Med* 2002; 27:168–72
- Coleman MM, Chan VW: Continuous interscalene brachial plexus block. *Can J Anaesth* 1999; 46:209–14
- Ganapathy S, Wasserman RA, Watson JT, Bennett J, Armstrong KP, Stockall CA, Chess DG, MacDonald C: Modified continuous femoral three-in-one block for postoperative pain after total knee arthroplasty. *Anesth Analg* 1999; 89:1197–202
- Salinas FV: Location, location, location: Continuous peripheral nerve blocks and stimulating catheters. *Reg Anesth Pain Med* 2003; 28:79–82
- Boezaart AP, de Beer JF, du Toit C, van Rooyen K: A new technique of continuous interscalene nerve block. *Can J Anaesth* 1999; 46:275–81
- Ilfeld BM, Enneking FK: Perineural catheter placement for a continuous nerve block: A single operator technique. *Reg Anesth Pain Med* 2003; 28:154–5
- Pham-Dang C, Kick O, Collet T, Gouin F, Pinaud M: Continuous peripheral nerve blocks with stimulating catheters. *Reg Anesth Pain Med* 2003; 28:83–8

20. Ilfeld BM, Morey TE, Wright TW, Chidgey LK, Enneking FK: Interscalene perineural ropivacaine infusion: A comparison of two dosing regimens for postoperative analgesia. *Reg Anesth Pain Med* 2004; 29:9-16
21. Vloka JD, Hadzic A, April E, Thys DM: The division of the sciatic nerve in the popliteal fossa: Anatomical implications for popliteal nerve blockade. *Anesth Analg* 2001; 92:215-7
22. Vloka JD, Hadzic A, Lesser JB, Kitain E, Geatz H, April EW, Thys DM: A common epineural sheath for the nerves in the popliteal fossa and its possible implications for sciatic nerve block. *Anesth Analg* 1997; 84:387-90
23. Hadzic A, Vloka JD, Singson R, Santos AC, Thys DM: A comparison of intertendinous and classical approaches to popliteal nerve block using magnetic resonance imaging simulation. *Anesth Analg* 2002; 94:1321-4
24. Todd MM: Clinical research manuscripts in anesthesiology. *ANESTHESIOLOGY* 2001; 95:1051-3
25. Ilfeld BM, Morey TE, Enneking FK: Continuous infraclavicular brachial plexus block for postoperative pain control at home: A randomized, double-blinded, placebo-controlled study. *ANESTHESIOLOGY* 2002; 96:1297-304
26. Capdevila X, Macaire P, Aknin P, Dadure C, Bernard N, Lopez S: Patient-controlled perineural analgesia after ambulatory orthopedic surgery: A comparison of electronic versus elastomeric pumps. *Anesth. Analg* 2003; 96:414-7
27. Adam F, Jaziri S, Chauvin M: Psoas abscess complicating femoral nerve block catheter. *ANESTHESIOLOGY* 2003; 99:230-1
28. Ribeiro FC, Georgousis H, Bertram R, Scheiber G: Plexus irritation caused by interscalene brachial plexus catheter for shoulder surgery. *Anesth Analg* 1996; 82:870-2
29. Borgeat A, Ekatothramis G, Kalberer F, Benz C: Acute and nonacute complications associated with interscalene block and shoulder surgery: A prospective study. *ANESTHESIOLOGY* 2001; 95:875-80
30. Hogan Q, Dotson R, Erickson S, Kettler R, Hogan K: Local anesthetic myotoxicity: A case and review. *ANESTHESIOLOGY* 1994; 80:942-7
31. Tuominen MK, Pere P, Rosenberg PH: Unintentional arterial catheterization and bupivacaine toxicity associated with continuous interscalene brachial plexus block. *ANESTHESIOLOGY* 1991; 75:356-8
32. Motamed C, Bouaziz H, Mercier FJ, Benhamou D: Knotting of a femoral catheter. *Reg Anesth* 1997; 22:486-7
33. Ilfeld BM, Morey TE, Enneking FK: Delivery rate accuracy of portable, bolus-capable infusion pumps used for patient-controlled continuous regional analgesia. *Reg Anesth Pain Med* 2003; 28:17-23
34. Rawal N, Allvin R, Axelsson K, Hallen J, Ekback G, Ohlsson T, Amilon A: Patient-controlled regional analgesia at home: Controlled comparison between bupivacaine and ropivacaine brachial plexus analgesia. *ANESTHESIOLOGY* 2002; 96:1290-6