

Infraclavicular Perineural Local Anesthetic Infusion

A Comparison of Three Dosing Regimens for Postoperative Analgesia

Brian M. Ilfeld, M.D.,* Timothy E. Morey, M.D.,† F. Kayser Enneking, M.D.‡

Background: In this randomized, double-blind study, the authors investigated the efficacy of continuous and patient-controlled ropivacaine infusions *via* an infraclavicular perineural catheter in ambulatory patients undergoing moderately painful orthopedic surgery at or distal to the elbow.

Methods: Preoperatively, patients (n = 30) received an infraclavicular perineural catheter and nerve block. Postoperatively, patients were discharged home with both oral analgesics and a portable infusion pump delivering 0.2% ropivacaine (500-ml reservoir) in one of three dosing regimens: the basal group (12 ml/h basal, 0.05-ml patient-controlled bolus dose), the basal-bolus group (8 ml/h basal, 4 ml bolus), or the bolus group (0.3 ml/h basal, 9.9 ml bolus). Investigators and patients were blinded to random group assignment.

Results: The basal group (n = 10) required more oral analgesics than the basal-bolus group ($P = 0.002$) and had a shorter median infusion duration than the other two groups ($P < 0.001$ for both). The bolus group had the longest median infusion duration ($P < 0.001$ for both) but experienced an increase in breakthrough pain incidence ($P = 0.004$) and intensity ($P = 0.04$ *vs.* basal-bolus group) as well as sleep disturbances ($P < 0.001$ for both) compared with the other groups. Overall satisfaction was greatest in the basal-bolus group (9.7 ± 0.5 *vs.* 7.9 ± 1.7 and 8.1 ± 1.5 ; $P < 0.05$ for both).

Conclusions: After moderately painful orthopedic surgery at or distal to the elbow, 0.2% ropivacaine delivered as a continuous infusion combined with patient-controlled bolus doses *via* an infraclavicular perineural catheter optimizes analgesia while minimizing oral analgesic use compared with basal- or bolus-only dosing regimens.

A CONTINUOUS infraclavicular brachial plexus nerve block with a local anesthetic infusion *via* a perineural catheter has been shown to decrease pain, opioid use, opioid-related side effects, and sleep disturbances after moderately painful orthopedic procedures of the hand or forearm.¹ Although there has been increased interest in the infraclavicular block recently, the majority of investigations have involved a single-injection technique, and no data are available regarding postoperative infu-

sion optimization.²⁻⁹ Previous investigations of interscalene,¹⁰ axillary,¹¹ fascia iliaca,¹² extended femoral,^{13,14} and subgluteal¹⁵ catheters have shown that the optimal infusion method of local anesthetic administration varies with anatomic location. Therefore, data from studies involving other catheter locations cannot necessarily be applied to infraclavicular placement. In addition, ambulatory perineural infusion necessitates that patients 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 infraclavicular perineural infusion using portable infusion pumps that record infusion/bolus details in their internal memories. This data may be subsequently retrieved for detailed analysis of previously unavailable information.

Furthermore, there is growing recognition that inaccurate catheter placement occurs in a substantial number of cases¹⁶⁻¹⁸—as high as 40% in some reports.¹⁹ In an attempt to improve placement success rates, catheters that deliver current to their tips were developed.²⁰ Calls for “stimulating-catheter” use in clinical investigations followed.¹⁹ Although such catheters have been described previously,²⁰⁻²² there are no studies that document the surgical block success rate of these devices with predefined, objective criteria.

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

Materials and Methods

Enrollment

After approval by the University of Florida Institutional Review Board (Gainesville, Florida), we prospectively enrolled adult patients scheduled to undergo moderately painful ambulatory, unilateral, orthopedic surgery of the upper extremity at or distal to the elbow who desired infraclavicular perineural catheter placement. Patients were required to be able to understand the possible local anesthetic-related complications, study protocol, and care of the catheter and infusion pump system; and to

* Assistant Professor of Anesthesiology, † Associate Professor of Anesthesiology, Department of Anesthesiology, ‡ Professor of Anesthesiology and Orthopaedics and Rehabilitation, Departments of Anesthesiology and Orthopaedics and Rehabilitation.

Received from the Departments of Anesthesiology and Orthopaedics and Rehabilitation, University of Florida, Gainesville, Florida. Submitted for publication August 5, 2003. Accepted for publication October 6, 2003. Supported by the Department of Anesthesiology, University of Florida, Gainesville, Florida. Manufacturers donated the portable infusion pumps (Deltec Corporation, St. Paul, MN), catheters (Arrow International, Reading, PA), and ropivacaine (AstraZeneca Pharmaceuticals, Wilmington, DE) used for this investigation. An abstract of the pilot study for this investigation was presented at the Annual Meeting of the American Society of Anesthesiologists, San Francisco, California, October 15, 2003. Dr. Ilfeld performs consulting work for Arrow International, Reading, Pennsylvania.

Address reprint requests to Dr. Ilfeld: Department of Anesthesiology, P. O. Box 100254, 1600 Archer Road, Gainesville, Florida 32610-0254. Address electronic mail to: bilfeld@ufl.edu. Individual article reprints may be purchased through the Journal Web site, www.anesthesiology.org.

have a caretaker who would remain with them during the local anesthetic infusion. Exclusion criteria included any contraindication to infraclavicular nerve block, previously diagnosed chronic obstructive pulmonary disease, history of opioid dependence, current chronic analgesic therapy, allergy to study medications, known hepatic or renal insufficiency/disease, and peripheral neuropathy.

After patients provided written, informed consent, they were placed in the supine position with their head turned slightly away from the operative extremity. Standard noninvasive monitors were applied, and oxygen was administered *via* a facemask. Intravenous midazolam and fentanyl were titrated for patient comfort, while it was ensured that patients remained responsive to verbal cues. All catheters were placed by one of the authors (B. M. I.) using a slightly modified technique of one described previously.²¹ 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

After sterile preparation and draping, a local anesthetic skin wheal was raised 2 cm medial and 2 cm caudad to the center of the coracoid process.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 perpendicular to the gurney in all planes and with the bevel directed toward the scalene muscles. This was connected to a nerve stimulator (Stimuplex-DIG; B. Braun Medical, Bethlehem, PA) initially set at 1.2 mA, 2 Hz, and an impulse duration of 0.1 m/s. After the needle tip was through the skin and superficial fascia, the stylet was removed to allow for identification of a penetrated vessel. If the brachial plexus was not identified after 5–8 cm of insertion, depending on patient habitus, the needle was withdrawn and redirected either cephalad or caudad in the paramedian sagittal plane until discrete, stimulated motion occurred in any digit with a current between 0.30 and 0.50 mA. Movement in the median nerve distribution was preferred over the ulnar or radial nerve distributions. Directing the needle tip out of the paramedian sagittal plane was strictly prohibited—neither medially toward the lung nor laterally toward the terminal nerves of the brachial plexus. Flexion or extension at the elbow or wrist that resulted in motion of the fingers, without intrinsic hand/digit motion, was rejected as a sign of incorrect needle tip position.

The 19-gauge catheter was then placed through the length of the needle, and the nerve stimulator was transferred from the needle to the catheter, which has a conducting wire through its length, delivering current to

its tip. The stimulating current was increased to 0.80 mA, and the catheter was advanced 3–5 cm beyond the needle tip. If finger motion 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. At this point in the procedure, the needle hub could be moved away from the scalene muscles, directing the needle tip cephalad and medially and moving the long axis of the needle out of the paramedian sagittal plane to lessen its acute angle with the brachial plexus. However, the needle was never advanced in this trajectory, and uninterrupted finger motion suggested the needle tip remained near the brachial plexus.

After a catheter had been successfully advanced 3–5 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 toward the midline using the included needle stylet and 17-gauge insulated needle.²⁰ 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 (StatLock; Venetec International, San Diego, CA) to affix the catheter hub to the patient.

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, terminal nerve blockade was evaluated and considered successful if motor control had been nearly abolished (axillary = deltoid, musculocutaneous = biceps, radial = triceps, ulnar = thumb to fifth-digit adduction, median = second-digit flexion). Infraclavicular block success was defined as a successful block of the musculocutaneous, median, ulnar, and radial nerves. Specific nerve distributions and degree of sensory blockade were not formally evaluated. No additional opioids or benzodiazepines were administered after catheter placement. Intraoperatively, 0–50 $\mu\text{g} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ propofol was titrated for sedation. 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, 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; pump maximum was 9.9). 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. Experience has shown a high rate of catheter occlusions if the catheter is left completely unused for a period of time.

Patient Education

Postoperatively, patients were discharged to their homes with a portable, electronic infusion pump (CADD-Legacy; Deltec, 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. Specific attention was given to signs and symptoms of local anesthetic toxicity, catheter site infection, and catheter migration. 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 in a sling during the infusion period, unless instructed otherwise by their surgeon or physical therapist. The following supplies were given to patients: 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 their medication log.

Patient Follow-up

Patients were telephoned beginning on 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 the surgical extremity was experienced at any time on or after the

morning of postoperative day (POD) 1, patients were instructed to pause infusion until they regained feeling in the 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* an infraclavicular 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 variable "average" pain at rest on POD 1 for groups 2 (basal-bolus) and 3 (bolus) and the number of oral analgesic tablets consumed on POD 1 for groups 1 (basal) and 2 to estimate a probable sample size. We considered a 50% reduction in pain score or oral analgesic tablets 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 0–10 (0 = no pain, 10 = worst pain imaginable) and to need 1.5 oral analgesic tablets on POD 1.¹ Assuming an 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 needed to reveal a clinically significant difference among study groups (StatMate 1.01; GraphPad Software, San Diego, CA).

Normality of distribution was determined using the Kolmogorov-Smirnov test with Lilliefors correction (Sigma Stat 2.03; SPSS, Inc., Chicago, IL). Continuous, parametric data are reported as mean \pm SD. Nonparametric data are graphically presented as median with 25th–75th percentile bars and tenth–ninetieth percentile whiskers or are textually noted using median (5th–95th confidence intervals). For normally distributed data, multiple comparisons were made using nonrepeated or repeated-measures analysis of variance with Tukey *post hoc* pairwise testing, when appropriate. For nonparametric data, the Mann-Whitney rank sum test or nonrepeated or repeated-measures analysis of variance for ranks was used, when appropriate. Categorical data were analyzed using the chi-square test with the Yates continuity correction. $P < 0.05$ was considered signifi-

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	57 ± 16	54 ± 11	49 ± 17
Sex, F/M	8/2	6/4	8/2
Height, cm	166 ± 6	169 ± 11	162 ± 5
Weight, kg	81 ± 13	86 ± 18	76 ± 22
Intravenous fentanyl, µg*	150 (112–188)	200 (145–200)	200 (130–220)
Intravenous midazolam, mg*	3.8 (3.2–4.4)	3.5 (2.3–3.9)	3.3 (2.2–4.4)
Minimum current via catheter, mA	0.50 ± 0.17	0.58 ± 0.17	0.65 ± 0.18
Surgery duration, min	71 ± 32	66 ± 19	68 ± 22
Tourniquet duration, min	71 ± 35	64 ± 18	68 ± 22

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

* Sedation only for preoperative block placement.

cant. Analysis was performed according to the intention-to-treat principle.²⁴

Results

Enrollment and Catheter Placement

Thirty-five patients were enrolled. In five cases (14%), finger motion could not be elicited with a current below 0.50 mA, and these subjects were removed from the study before randomization, although four patients did have a catheter placed with a minimal needle current of 0.50–0.80 mA. Of these four catheters, two produced surgical-quality initial blocks as defined by this study, but only one provided postoperative analgesia. Therefore, of 35 attempts, 32 (91%) produced a successful infraclavicular block as defined by this study. Of these 35 placement attempts, 4 (11%) resulted in axillary artery penetration by the needle, suggested by the force of blood return. In three of these patients, catheters were subsequently placed successfully.

Of the 30 subjects who had a catheter placed with a needle current below 0.50 mA per protocol, all experienced a successful infraclavicular block as defined by this study (motor block of the musculocutaneous, median, ulnar, and radial nerves). Eighteen patients (60%) had a motor block of the axillary nerve. These 30 subjects 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 these 30 patients, 28 underwent surgery with less than 50 µg · kg⁻¹ · min⁻¹ propofol for sedation, 1 received a general anesthetic 30 min after incision (per patient request secondary to low back discomfort), and 1 patient underwent general anesthesia after surgical block failure. In this last case, the patient had a complete motor block of the musculocutaneous, median, ulnar,

and radial nerves and was comfortable during surgery until the surgeon reached bone during an open-reduction, internal fixation of the distal humerus.

Of the 30 patients randomized, all had sensory changes in the upper extremity on 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. 1A). The basal group had an increase in breakthrough pain incidence (table 3) and intensity (fig. 1B) compared with the basal-bolus group. The basal group required more oral analgesics than the basal-bolus group (fig. 2). Patients in the bolus group reported more difficulty sleeping 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 than in the other two groups (fig. 3C).

All but one patient in the basal group exhausted their local anesthetic reservoir in less than 42 h, while this occurred after a median of 60 h in the basal-bolus group, and all patients in the bolus group had anesthetic remaining at the time of catheter removal after a median of 75 h (table 3). Four patients—at least one from each

Table 2. Surgical Procedures for the Three Study Groups

	Basal Group (n = 10)	Basal-Bolus Group (n = 10)	Bolus Group (n = 10)
Metacarpal arthroplasty	2	1	2
Radial or ulnar ORIF–fusion–resection	5	4	3
Thumb suspensionplasty–fusion	2	2	1
Scaphoid ORIF or styloidectomy	0	1	1
Wrist suspensionplasty	1	0	1
Distal humeral ORIF or capsulectomy	0	2	2

There were no statistically significant differences among the study groups. ORIF = open reduction, internal fixation.

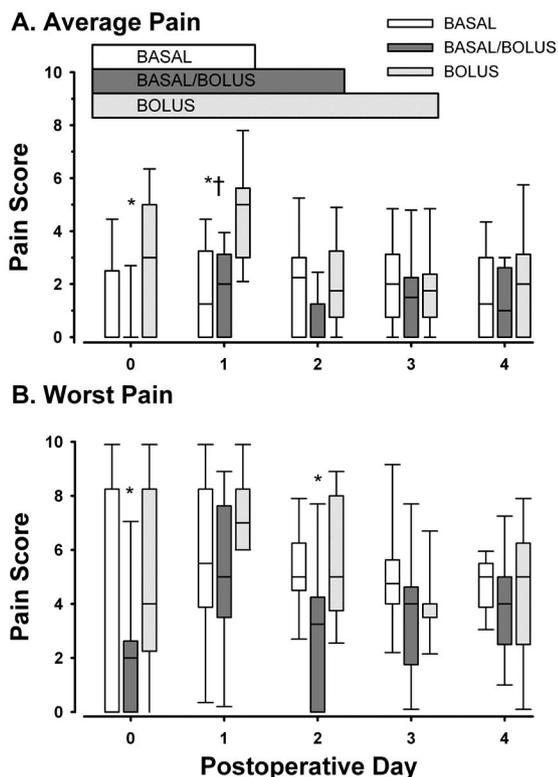


Fig. 1. Effects of infraclavicular perineural ropivacaine infusion dosing regimen on average (A) and worst (B) pain after moderately painful surgery of the upper extremity (scale: 0–10). The catheters were discontinued, as indicated by the *horizontal boxes*. Data are expressed as median (*horizontal bars*) with 25th–75th (*boxes*) and 10th–90th (*whiskers*) percentiles for patients randomly assigned to the basal group (basal rate, 12 ml/h; bolus dose, 0.05 ml; lock-out, 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 0, 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 group *versus* bolus group; † bolus group *versus* basal group.

group—reported minimal, occasional leakage of fluid from their catheter site. Three patients from the basal group, three from the basal–bolus group, and none from the bolus group paused their infusions because of a complete lack of sensation in their surgical extremity after POD 0. Patients in the basal–bolus group reported

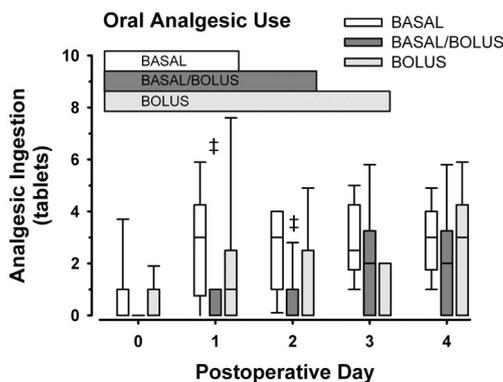


Fig. 2. Effects of infraclavicular perineural ropivacaine infusion dosing regimen on oral analgesic use after moderately painful surgery of the upper extremity (5 mg oxycodone, 500-mg acetaminophen tablets). The catheters were discontinued as indicated by the *horizontal boxes*. Data are expressed as median (*horizontal bars*) with 25th–75th (*boxes*) 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, 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 group *versus* basal group.

significantly higher satisfaction with their postoperative analgesia compared with the other two groups (table 3).

Adverse Events

One patient from the basal group had her catheter inadvertently dislodged on POD 2 after her reservoir had been exhausted but before intentional removal with physician instruction. She had not experienced fluid leakage from the catheter site, although her catheter had only been threaded 3 cm beyond the needle tip secondary to resistance after this distance. Patients’ caretakers were able to safely remove the remaining perineural catheters at home, with the exception of one patient. This patient had an unremarkable catheter placement and postoperative infusion, but during removal by her caretaker at home, she reported acute pain with even the slightest traction. Fluoroscopy did not reveal a knot,²⁵ and the catheter was extracted surgically under general anesthesia *via* a 4-cm incision. Under direct

Table 3. Infusion Profile by Study Group

	Basal Group (n = 10)	Basal–Bolus Group (n = 10)	Bolus Group (n = 10)
Bolus doses attempted, No.	23 (9–50)	11 (4–13)*	47 (0–180)†
Bolus doses administered, No.	11 ± 9*	7 ± 4*	28 ± 13†‡
Infusion duration, h§	45 ± 13*†	63 ± 7*‡	75 ± 1†‡
Bolus doses administered/24 h, No.	6.5 ± 5.4	2.6 ± 1.7*	9.0 ± 4.2†
Unused local anesthetic, ml	0 (0–51)*	0 (0–4)*	210 (123–325)†‡
Satisfaction (0–10)	7.9 ± 1.7†	9.7 ± 0.5*‡	8.1 ± 1.5†

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

P < 0.05 for group compared with * bolus group, † basal–bolus group, ‡ basal group. § Infusion was stopped on the evening of postoperative day 3 regardless of local anesthetic volume remaining in the reservoir.

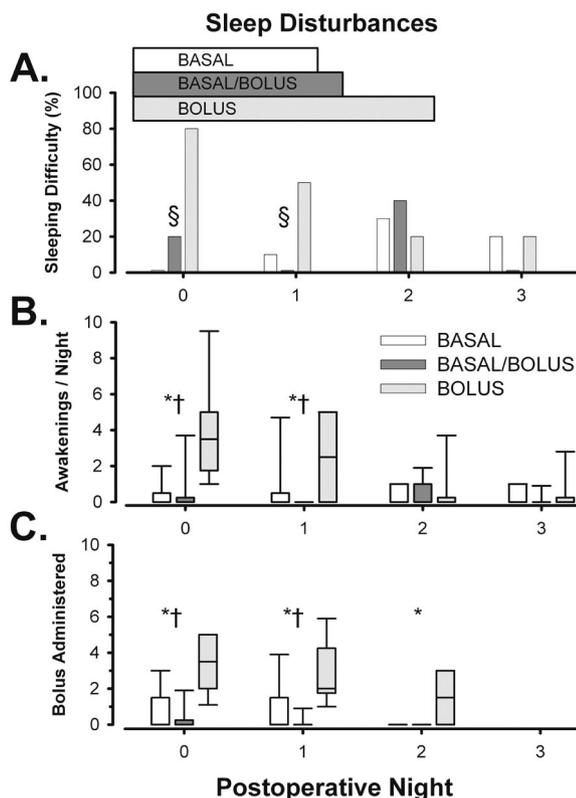


Fig. 3. Effects of infraclavicular perineural ropivacaine infusion dosing regimen on sleep disturbances after moderately painful surgery of the upper extremity. Endpoints included difficulty sleeping because of pain (A), number of awakenings because of pain (B), and number of bolus doses self-administered between 11 PM and 7 AM (C). The catheters were discontinued as indicated by the horizontal boxes. (A) Data are expressed as fraction of patients reporting difficulty sleeping because of pain. (B and C) Data are expressed as median (horizontal bars) with 25th–75th (boxes) 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., C, postoperative day 0, 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 group versus bolus group; † bolus group versus basal group; § comparing all groups for a given day using chi-square analysis.

observation, it appeared that the metallic tip had caught on either the median nerve or the surrounding fascia. The pathology report confirmed the misshapen catheter tip, but no tissue remained on the tip for analysis. This patient subsequently experienced occasional mild subscapular discomfort that resolved completely within 3 weeks. This event was reported to the US Food and Drug Administration's MedWatch Adverse Events reporting program as well as the catheter manufacturer.

Three patients—one from each group—had an unscheduled contact with the on-call physician during the course of their infusion: two involving surgical issues and one because of an insensate extremity before pausing her infusion. 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 ambulatory surgery of the upper extremity at or distal to the elbow, providing exclusively patient-controlled bolus doses of ropivacaine *via* an infraclavicular perineural catheter results in a longer duration of catheter use but less potent analgesia, increased sleep disturbances, and lower satisfaction compared with a regimen including both a basal infusion and bolus capability. Furthermore, providing a continuous basal infusion alone results in higher oral analgesic use, a shorter duration of infusion, and lower satisfaction than a basal-bolus regimen. The stimulating catheter used in this investigation provided surgical anesthesia and postoperative analgesia in 91% and 89% of patients, respectively.

Infusion Regimen

That the basal group required more oral opioids than the basal-bolus group to achieve equivalent analgesia shows that simply increasing the basal local anesthetic rate cannot replace bolus doses. As has been previously verified, the use of oral^{1,17,26} or intravenous²⁷ opioids results in undesirable side effects such as nausea, vomiting, pruritus, and sedation. This suggests that even in hospitalized patients who are not required to carry the anesthetic reservoir, patient-controlled bolus doses improve the postoperative experience. Evidence for this may be found in the increased satisfaction patients in the basal-bolus group reported compared with the basal group. In addition, ambulatory patients who exhaust the limited local anesthetic reservoir relatively quickly risk a subsequent decrease in analgesia. In this study, the median “average” pain score of basal patients was 1.3 on POD 1 with infusion *versus* 2.3 on POD 2 after reservoir exhaustion, whereas these same scores decreased during this period, from 2.0 to 0.0 and from 5.0 to 1.8 for the basal-bolus and bolus groups, respectively.

Previous investigations involving bupivacaine perineural infusion *via* “extended” femoral catheters (anterior lumbar plexus) found no differences in pain scores or supplemental analgesic use among basal-only, bolus-only, or basal-bolus dosing regimens after total knee and hip arthroplasty.^{13,14} Therefore, bolus-only dosing was recommended because it minimized local anesthetic consumption, as was found in the current study. However, the other findings were not reflected in the current study of ropivacaine, with the bolus group experiencing greater “average” pain, a higher incidence and intensity of breakthrough pain, and lower satisfaction than the basal-bolus group. Whether this difference is due to the shorter duration of ropivacaine compared with bupiva-

caine²⁸ or an inherent difference between the brachial plexus and lumbar plexus remains unresolved. Of note, bolus-only patients in the current study experienced more difficulty sleeping and a higher number of awakenings because of pain compared with the two groups with a basal infusion. Evidence of this can be found in the number of bolus doses delivered at night, which was significantly higher in the bolus group than in the other two groups. The previously mentioned studies involving bupivacaine that recommended basal-only dosing did not examine sleep quality, although there were no statistically significant differences in overall satisfaction scores among the various groups.^{13,14}

The portable infusion pump described in this report, which allowed objective evaluation of nightly awakenings, is unusual in that it records infusion/bolus details in its internal memory that 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.^{1,26,29} This contributed to a significant decrease in unscheduled patient contacts with the on-call physician compared with previous experiences.^{1,26,30}

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,³¹ nerve injury,^{32,33} catheter migration,³⁴ local anesthetic toxicity,³⁵ and catheter retention.²⁵ All but one patient 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,^{1,17,26} primarily because of the increased traction required for removal.

Study Limitations

The relatively small number of patients included in this investigation does not permit us to draw definite conclusions about its relative safety. Of note, the overall risk of catheter retention necessitating surgical extraction is unknown. Of more than 10,000 Arrow Stimucath catheters placed in one series at the University of Iowa (Iowa City, Iowa), there was one incidence of a retained catheter (Andre Boezaart, M.D., personal communication, May 2003). 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 reported previously.³⁶ This pump also continuously displays the reservoir volume, and although not instructed on how to do this,

some patients may have determined their basal rate and bolus dose with this information, compromising the double-blinded nature of the study. Finally, these results apply only to surgical procedures producing moderate-to-severe postoperative pain. It is possible—even probable—that adequate analgesia for procedures of the upper extremity inducing mild postoperative pain would be adequately treated with a bolus-only dosing regimen.³⁷

In summary, after moderately painful orthopedic surgery at or distal to the elbow, 0.2% ropivacaine delivered as a continuous infusion combined with patient-controlled bolus doses *via* an infraclavicular perineural catheter optimizes analgesia while minimizing oral analgesic use compared with basal- or bolus-only dosing regimens.

The authors thank Paul C. Dell, M.D. (Professor of Orthopaedics and Rehabilitation, University of Florida College of Medicine, Gainesville, FL), for his assistance in conducting this study. In addition, the authors thank the perioperative nursing staff of the Florida Surgical Center of Shands Hospital at the University of Florida for valuable assistance.

References

1. Iffeld 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
2. Gaertner E, Estebe JP, Zamfir A, Cuby C, Macaire P: Infraclavicular plexus block: Multiple injection versus single injection. *Reg Anesth Pain Med* 2002; 27:590-4
3. Ootaki C, Hayashi H, Amano M: Ultrasound-guided infraclavicular brachial plexus block: An alternative technique to anatomical landmark-guided approaches. *Reg Anesth Pain Med* 2000; 25:600-4
4. Kapral S, Jandrasits O, Schabernig C, Likar R, Reddy B, Mayer N, Weinstabl C: Lateral infraclavicular plexus block vs. axillary block for hand and forearm surgery. *Acta Anaesthesiol Scand* 1999; 43:1047-52
5. Borgate A, Ekatothramis G, Dumont C: An evaluation of the infraclavicular block *via* a modified approach of the Raj technique. *Anesth Analg* 2001; 93:436-41
6. Jandard C, Gentili ME, Girard F, Ecoffey C, Heck M, Laxenaire MC, Bouaziz H: Infraclavicular block with lateral approach and nerve stimulation: Extent of anesthesia and adverse effects. *Reg Anesth Pain Med* 2002; 27:37-42
7. Salazar CH, Espinosa W: Infraclavicular brachial plexus block: Variation in approach and results in 360 cases. *Reg Anesth Pain Med* 1999; 24:411-6
8. Koscielniak-Nielsen ZJ, Nielsen PR, Mortensen CR: A comparison of coracoid and axillary approaches to the brachial plexus. *Acta Anaesthesiol Scand* 2000; 44:274-9
9. Desroches J: The infraclavicular brachial plexus block by the coracoid approach is clinically effective: An observational study of 150 patients. *Can J Anaesth* 2003; 50:253-7
10. 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
11. Iskandar H, Rakotondriamihary S, Dixmerias F, Binje B, Murette 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
12. 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
13. 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
14. Singelyn FJ, Gouverneur JM: Extended "three-in-one" block after total knee arthroplasty: Continuous versus patient-controlled techniques. *Anesth Analg* 2000; 91:176-80
15. di Benedetto P, Casati A, Bertini L: Continuous subgluteus sciatic nerve block after orthopedic foot and ankle surgery: Comparison of two infusion techniques. *Reg Anesth Pain Med* 2002; 27:168-72
16. Coleman MM, Chan VW: Continuous interscalene brachial plexus block. *Can J Anaesth* 1999; 46:209-14
17. Iffeld 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
18. 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
 19. Salinas FV: Location, location, location: Continuous peripheral nerve blocks and stimulating catheters. *Reg Anesth Pain Med* 2003; 28:79-82
 20. Boezaart AP, de Beer JF, du TC, van Rooyen K: A new technique of continuous interscalene nerve block. *Can J Anaesth* 1999; 46:275-81
 21. Ilfeld BM, Enneking FK: Perineural catheter placement for a continuous nerve block: A single operator technique. *Reg Anesth Pain Med* 2003; 28:154-5
 22. 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
 23. Wilson JL, Brown DL, Wong GY, Ehman RL, Cahill DR: Infraclavicular brachial plexus block: Parasagittal anatomy important to the coracoid technique. *Anesth Analg* 1998; 87:870-3
 24. Todd MM: Clinical research manuscripts in anesthesiology. *ANESTHESIOLOGY* 2001; 95:1051-3
 25. Motamed C, Bouaziz H, Mercier FJ, Benhamou D: Knotting of a femoral catheter. *Reg Anesth* 1997; 22:486-7
 26. 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
 27. Matheny JM, Hanks GA, Rung GW, Blanda JB, Kalenak A: A comparison of patient-controlled analgesia and continuous lumbar plexus block after anterior cruciate ligament reconstruction. *Arthroscopy* 1993; 9:87-90
 28. Borgeat A, Kalberer F, Jacob H, Ruetsch YA, Gerber C: Patient-controlled interscalene analgesia with ropivacaine 0.2% versus bupivacaine 0.15% after major open shoulder surgery: The effects on hand motor function. *Anesth Analg* 2001; 92:218-23
 29. 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
 30. Ilfeld BM, Morey TE, Enneking FK: Continuous infraclavicular perineural infusion with clonidine and ropivacaine compared with ropivacaine alone: A randomized, double-blinded, controlled study. *Anesth Analg* 2003; 97:706-12
 31. Adam F, Jaziri S, Chauvin M: Psoas abscess complicating femoral nerve block catheter. *ANESTHESIOLOGY* 2003; 99:230-1
 32. 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
 33. Borgeat A, Ekatodramis G, Kalberer F, Benz C: Acute and nonacute complications associated with interscalene block and shoulder surgery: A prospective study. *ANESTHESIOLOGY* 2001; 95:875-80
 34. Hogan Q, Dotson R, Erickson S, Kettler R, Hogan K: Local anesthetic myotoxicity: A case and review. *ANESTHESIOLOGY* 1994; 80:942-7
 35. Tuominen MK, Pere P, Rosenberg PH: Unintentional arterial catheterization and bupivacaine toxicity associated with continuous interscalene brachial plexus block. *ANESTHESIOLOGY* 1991; 75:356-8
 36. 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
 37. Rawal N, Allvin R, Axelsson K, Hallen J, Ekback G, Ohlsson T, Amilon A: Patient-controlled regional analgesia (PCRA) at home: Controlled comparison between bupivacaine and ropivacaine brachial plexus analgesia. *ANESTHESIOLOGY* 2002; 96:1290-6