Is Circumferential Injection Advantageous for Ultrasound-Guided Popliteal Sciatic Nerve Block? A Proof-of-Concept Study

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Background: Ultrasound (US) guidance, in some instances, can increase the success rate and reduce the onset and procedure times for peripheral nerve blockade compared with traditional nerve localization techniques. The presumptive mechanism for these benefits is the ability to accurately inject local anesthetic circumferentially around the target nerve. We aimed to determine whether ensuring circumferential spread of local anesthetic is advantageous for US-guided popliteal sciatic nerve block.

Methods: Sixty-four adult patients undergoing US-guided popliteal sciatic block for elective foot and ankle surgery were randomly assigned to 1 of 2 groups, circumferential or single-location injection. Using a short-axis nerve view and out-of-plane needle approach, the needle tip was advanced to the posterior external surface of the sciatic nerve. A 30-mL local anesthetic admixture (1:1 lidocaine 2%/bupivacaine 0.5% with 1:200,000 epinephrine) was injected either entirely at this location (single location) or incrementally at multiple locations to ensure circumferential spread around the sciatic nerve (circumferential). Sensory and motor functions were assessed by a blinded observer at predetermined intervals. The primary outcome was sensory block defined as loss of sensation to pinprick in the distribution of both tibial and common peroneal nerves at 30 mins after injection.

Results: Sensory block was achieved in 94% of patients in the circumferential injection group compared with 69% in the single-location injection group (P = 0.010). There were no differences detected in block performance time, pain during block performance, or block-related complications between groups.

Conclusions: Ultrasound-guided circumferential injection of local anesthetic around the sciatic nerve at the popliteal fossa can improve the rate of sensory block without an increase in block procedure time or block-related complications compared with a single-location injection technique.

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METHODS

This randomized controlled study was approved by the University Health Network Research Ethics Board. Following written informed consent, adult American Society of Anesthesiologists status I-III patients undergoing preoperative popliteal block for analgesia after an elective major foot or ankle surgery were randomly assigned to 2 groups based on computer-generated sequence. Assignments were concealed in a sealed opaque envelope. Exclusion criteria included age younger than 18 or older than 80 years, language barrier, contraindication(s) to regional anesthesia, weight greater than 100 kg, or having preexisting neurologic deficit in the distribution to be anesthetized, local infection, or coagulopathy.

On the day of surgery, peripheral intravenous access was established, and an infusion of normal saline initiated at a maintenance rate for all patients. Routine electrocardiogram, noninvasive blood pressure, and pulse oximetry monitoring were applied, and baseline readings obtained. Patients were positioned prone, and midazolam 1 to 2 mg intravenously was used for axiolysis as needed. All blocks were performed by a staff regional anesthesiologist or supervised regional anesthesia fellow. The skin site was sterilized with chlorhexidine 2% in isopropyl alcohol 70% solution and infiltrated with 1 to 2 mL lidocaine 1%. A standard
30-mL local anesthetic admixture containing 15 mL lidocaine 2% and 15 mL bupivacaine 0.5% with 1,200,000 epinephrine was used for all patients. The sciatic nerve was imaged in short axis using a Philips HD 11 unit with a linear 3- to 12-MHz probe (Philips Ultrasound, Bothell, Wash) or SonoSite Micromaxx with a linear 6- to 13-MHz probe (SonoSite Inc, Bothell, Wash). The US screen was facing away from the patient to assist in patient blinding. Beginning in the popliteal fossa, the sciatic nerve was traced proximally, and nerve blockade was performed immediately proximal to the bifurcation of the sciatic nerve into the tibial and common peroneal nerves. A 22-gauge, 50- or 80-mm insulated needle (Stimuplex; B.Braun Medical, Bethlehem, Pa) was inserted out of plane with the US beam. The needle was advanced until the needle tip was positioned at the posterior external surface of the sciatic nerve in the anterior-posterior plane and at the midpoint of the sciatic nerve in the medial-lateral plane (Fig. 1). Correct positioning was typically accompanied by a “fascial click” as the needle tip was felt to penetrate the anterior aponeurosis of the biceps femoris muscle. A small amount (1–2 mL) of the 30-mL local anesthetic injectable solution was used for needle-tip hydrolocation at the discretion of the operating anesthesiologist.

**Circumferential Injection Group**

The needle-tip position was adjusted as necessary to ensure circumferential spread of local anesthetic around the sciatic nerve. “Circumferential” was defined as local anesthetic injectate visualized in at least 3 of the 4 quadrants surrounding the sciatic nerve imaged in short axis (Fig. 1 [inset], Fig. 2, and Video, Supplemental Digital Content 1, http://links.lww.com/AAP/A27). The number of needle passes, rate of injection, and incremental delivery of the local anesthetic injectate were left entirely to the discretion of the operator so long as circumferential spread was the ultimate goal.

**Single-Location Injection Group**

All local anesthetic solution was injected with the needle tip positioned at the posterior external surface of the sciatic nerve in the anterior-posterior plane and closest to the midpoint of the sciatic nerve in the medial-lateral plane. No adjustments in needle-tip position relative to the sciatic nerve were permitted during injection. The resultant distribution of local anesthetic spread relative to the sciatic nerve as visualized by the provider anesthesiologist following the completed injection was subsequently recorded as circumferential (see definition in the previous section) or “noncircumferential” (Fig. 3, Video, Supplemental Digital Content 2, http://links.lww.com/AAP/A28).

**Block Evaluation**

Block evaluation was performed every 5 mins after injection of local anesthetic for 30 mins by an independent observer who was blinded to the group assignment. Sensory block was tested in the tibial (plantar surface of the foot) and common peroneal (dorsal surface of the foot) territories and evaluated using a 3-point score: 2 = normal sensation, 1 = loss of sensation to pinprick, or 0 = loss of sensation to light touch compared with the normal contralateral limb. Sensory block was defined as loss of sensation to pinprick in both tibial and common peroneal territories (sensory score = 1) or loss of sensation to light touch (sensory score = 0). Motor block was tested in the tibial (foot plantar flexion) and common peroneal (foot dorsiflexion) components and evaluated using a 3-point score: 2 = normal strength, 1 = reduced power, or 0 = no power compared with the normal contralateral limb. Motor block was defined as reduced strength (motor score = 1) or no movement (motor score = 0) in the distribution of both tibial and common peroneal nerves. Also recorded were the block performance time (defined as the duration from placement of the US probe on the skin to needle removal), pain (verbal response scale, out of 10) during performance of the block, and any block-related complications.

After block evaluation and completion of block room data collection, all patients proceeded to the operating room under
Follow-up was conducted by a research assistant blinded to the procedures to inquire about pain severity and potential block-related complications, specifically localized pain, bruising, and prolonged numbness and/or weakness on the first postoperative day and at 1 week postoperatively. On the first postoperative day, each patient was asked to report the time at first onset of pain in the operative site, the time at first requirement for oral analgesic medication, the severity of pain at rest and during movement, and satisfaction with postoperative analgesia.

**Statistical Analysis**

The primary outcome measure was sensory block defined as diminished sensation to pinprick (sensory score ≤1) in each of the tibial and common peroneal nerve distributions 30 mins after completion of local anesthetic injection. Based on our previous experience, we assumed that US-guided circumferential injection would increase the rate of sensory block from 60% to 90% compared with a single-location injection. A 2-sided power calculation with \( \alpha = 0.05 \) and \( \beta = 0.2 \) required a sample size of 64 patients (32 per group). Data were analyzed using SPSS 11.0 for Windows (SPSS Inc, Chicago, Ill). Data are presented as mean (SD) unless otherwise specified. Tests of significance included the \( t \) test and Mann-Whitney \( U \) test of ranks for parametric and nonparametric testing of continuous variables respectively. The \( \chi^2 \) test was used to analyze categorical data. Statistical significance was established at \( P < 0.05 \).

**RESULTS**

Ninety-nine patients were recruited to participate in this study (Fig. 4). On the day of surgery, 35 patients were excluded...
from this study for nonmedical reasons. Sixty-four patients were therefore included in the primary outcome analysis. Patient characteristics according to group are listed in Table 1.

Sensory block was achieved in 94% of patients in the circumferential injection group compared with 69% in the single-location injection group ($P = 0.010$). Patients in the circumferential injection group achieved sensory block (Fig. 5A) earlier than patients in the single-location injection group (Fig. SB), but the time to achieve motor block was similar between groups (Figs. 6A, B). Block performance time was similar between groups (circumferential 7.6 [SD, 2.4] mins; single location 7.0 [SD, 3.0] mins; $P = 0.411$). There was no difference in pain (verbal response scale) reported by patients during block performance (circumferential 2.3 [SD, 2.0]; single location 2.1 [SD, 1.7]; $P = 0.736$). No patients reported paresthesias during the block procedure. No cases of unintentional intraneural injection (defined as any increase in nerve diameter visualized on US) were reported by the provider anesthesiologists.

Among the 32 patients in the single-location injection group, resultant circumferential spread of injectate was visualized in 14 patients (44%) (Fig. 4). Subgroup analysis revealed no difference in the block success rate among patients in the single-location injection group with resultant circumferential spread of injectate (79%) compared with those with noncircumferential spread (61%; $P = 0.290$), although this subgroup analysis is most likely underpowered. Among the 32 patients in the circumferential injection group, resultant circumferential spread of injectate was visualized in all but 1 patient, for whom local anesthetic spread was limited to only 2 of the 4 quadrants, presumably due to multiple fascial septa.

Block-related complications are listed in Table 2. One patient in the circumferential injection group reported persistent paresthesias in the operative extremity at 7 days, which resolved spontaneously by 2 months postoperatively. One patient in the single-location injection group also reported persistent paresthesias in the operative extremity at 7 days, and these symptoms had not resolved by 2 months postoperatively. It is not clear whether these patients’ symptoms were caused by the nerve block or the surgical procedure itself.

**DISCUSSION**

Our results suggest that ensuring circumferential spread of local anesthetic using real-time sonographic visualization can improve the rate of sensory block following US-guided popliteal sciatic nerve block compared with a single-location injection technique. We were unable to capture any differences in the rate of motor block likely because of our relatively short (but clinically relevant) evaluation period of only 30 mins. We did

**TABLE 1. Patient Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Circumferential Injection Group</th>
<th>Single-Location Injection Group</th>
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<tbody>
<tr>
<td>(n = 32)</td>
<td></td>
<td>(n = 32)</td>
</tr>
<tr>
<td>Sex, no. male/no. female</td>
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<td>18/14</td>
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<tr>
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<tr>
<td>Type of surgery, n</td>
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</tr>
<tr>
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<td>4</td>
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<tr>
<td>Osteotomy</td>
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<td>3</td>
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<tr>
<td>Total ankle arthroplasty</td>
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<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

ASA indicates American Society of Anesthesiologists physical status.
not evaluate the extent of sensory or motor block postoperatively because of the possibility of residual neuraxial anesthesia and/or the presence of an immobiling splint or cast. Given the trend of our motor block data, it is possible that a difference in the motor block rate between groups would be demonstrable with a longer assessment period. Perhaps not surprisingly, our success rate in the single-location injection group (61%) is identical to that which we previously reported using nerve stimulator guidance alone, wherein local anesthetic is injected at only 1 location.8 Similarly, our success rate in the circumferential injection group is consistent with our previously reported experience using US guidance to ensure circumferential spread around the popliteal sciatic nerve.9 Even though we found that circumferential spread of injectate incidentally follows nearly half of the cases of single-location injection US-guided popliteal block, our data indicate that intentional circumferential injection of local anesthetic improves block success without prolonging the procedure time compared with a single-location injection.

Our study is associated with several limitations. Although group allocation was not disclosed to the study patients at any time, they were not systematically blinded; as such, multiple needle passes or the lack thereof may have allowed patients to infer their group allocation. Blinding would have necessarily entailed exposing all patients to multiple needle passes with associated discomfort, delay, and increased potential for complications. To limit operator bias under the present study conditions, adjunctive peripheral nerve stimulation for nerve localization was not used. If a nerve stimulator had also been used to guide needle advancement, it is possible that the minimal stimulating threshold current could have influenced the operator to alter the direction of needle advancement or final needle-tip position. We also did not assess or trace the distribution of local anesthetic injectate proximally or distally along the short axis of the sciatic nerve or along the longitudinal axis of the nerve, nor did we assess the relative spread of local anesthetic distal to the bifurcation of the sciatic nerve around the tibial and common peroneal nerves individually. As such, it is possible that we underestimated the true rate of resultant circumferential spread for the patients in our single-location injection group. Furthermore, the ultimate clinically relevant goal, that is, efficacious postoperative analgesia, was not measured because of the heterogeneity of surgical procedures and different intraoperative anesthetic and postoperative analgesic requirements. As such, all secondary outcome measures presented herein must be interpreted with caution. Our results may not be generalizable to other volumes of local anesthetic, other approaches to sciatic nerve block, other nerves in the human body, or other definitions of circumferential spread and/or US guidance performed in conjunction with other nerve localization techniques, such as nerve stimulation.12-14

In summary, US-guided circumferential injection of local anesthetic around the sciatic nerve at the popliteal fossa can improve the rate of sensory block compared with a single-location injection technique. Further study is recommended to determine if circumferential spread of local anesthetic can account for improvements in other block-related characteristics associated with US guidance compared with traditional nerve localization techniques for peripheral nerve blockade.

REFERENCES


Ultrasound-Guided (Needle-in-Plane) Perineural Catheter Insertion
The Effect of Catheter-Insertion Distance on Postoperative Analgesia

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Background: When using ultrasound guidance to place a perineural catheter for a continuous peripheral nerve block, keeping the needle in plane and nerve in short axis results in a perpendicular needle-to-nerve orientation. Many have opined that when placing a perineural catheter via the needle, the acute angle may result in the catheter bypassing the target nerve when advanced beyond the needle tip. Theoretically, greater catheter tip-to-nerve distances result in less local anesthetic-to-nerve contact during the subsequent peripheral infusion, leading to inferior analgesia. Although a potential solution may appear obvious—advancing the catheter tip only to the tip of the needle, leaving the catheter tip at the target nerve—this technique has not been prospectively evaluated. We therefore hypothesized that during needle-in-plane ultrasound-guided perineural catheter placement, inserting the catheter a minimum distance (0–1 cm) past the needle tip is associated with improved postoperative analgesia compared with inserting the catheter a more traditional 5 to 6 cm past the needle tip.

Methods: Preoperatively, subjects received a popliteal-sciatic perineural catheter for foot or ankle surgery using ultrasound guidance exclusively. Subjects were randomly assigned to have a single-orifice, flexible catheter inserted either 0 to 1 cm (n = 50) or 5 to 6 cm (n = 50) past the needle tip. All subjects received a single-injection mepivacaine (40 mL of 1.5% with epinephrine) nerve block via the needle, followed by catheter insertion and a ropivacaine 0.2% infusion (basal 5 mL/hr, bolus 4 mL, 30-min lockout), through at least the day after surgery. The primary end point was the average surgical pain as measured with a 0 to 10-point numeric rating scale the day after surgery. Secondary end points included time for catheter insertion, incidence of catheter dislodgement, maximum ("worst") pain scores, opioid requirements, fluid leakage at the catheter site, and the subjective degree of an insensitive extremity.

Results: Average pain scores the day after surgery for subjects of the 0- to 1-cm group were a median of 2.5 (interquartile range, 0.0–5.0), compared with 2.0 (interquartile range, 0.0–4.0) for subjects of the 5- to 6-cm group (P = 0.42). Similarly, among the secondary end points, no statistically significant differences were found between the 2 treatment groups. There was a trend of more catheter dislodgements in the minimum-insertion group (5 vs 1; P = 0.20).

Conclusions: This study did not provide evidence to support the hypothesis that, for popliteal-sciatic perineural catheters placed using ultrasound guidance and a needle-in-plane technique, inserting the catheter a minimum distance (0–1 cm) past the needle tip improves (or worsens) postoperative analgesia compared with inserting the catheter a more traditional distance (5–6 cm). Caution is warranted in extrapolating these results to other catheter designs, ultrasound approaches, or anatomic insertion sites.

(Reg Anesth Pain Med 2011;36: 261–265)

The previous decade has produced an abundance of research involving continuous peripheral nerve blocks or "perineural local anesthetic infusion." However, the overwhelming majority of these reports involve the use of electrical stimulation to guide nerve localization and subsequent catheter insertion, to the near exclusion of ultrasound guidance. A recent comparison of these 2 techniques suggests that whereas ultrasound guidance may result in a higher catheter-insertion success rate in certain circumstances, the use of electrical current to guide a stimulating catheter results in improved analgesia—for successfully placed catheters—during the subsequent perineural local anesthetic infusion. One theory proposed to explain the inferior postoperative analgesia observed in the ultrasound group involves the needle-nerve orientation during ultrasound-guided perineural catheter insertion.

When using ultrasound guidance, it is most common to visualize the target nerve in cross section or short axis, which allows for easier differentiation of the nerve from surrounding tissue. The needle is then often inserted within the ultrasound plane (needle in plane), permitting real-time needle-tip visualization and identification of its location relative to the target nerve. Subsequent local anesthetic injection and perineural spread may be visualized and evaluated, with needle repositioning and local anesthetic reinjection, as necessary. However, unlike nearly all reports of electrical stimulation-guided perineural catheter insertion with the long axis of the needle advanced parallel to the longitudinal axis of the target nerve, needle-in-plane ultrasound guidance results in a perpendicular nerve-to-needle orientation. When placing a perineural catheter via the needle, it is conceivable
that the acute angle may result in the catheter bypassing the target nerve when advanced beyond the needle tip.\textsuperscript{4} Theoretically (although currently unexamined and unproven), greater catheter tip–nerve distances result in less local anesthetic-to-nerve contact during the subsequent perineural infusion,\textsuperscript{5} leading to inferior analgesia.\textsuperscript{2}

Although a potential solution may appear obvious—advancing the catheter tip only to the tip of the needle, leaving the catheter tip at the target nerve—this technique was not used in the overwhelming majority of continuous peripheral nerve blocks reports of the past few decades. The reason for advancing the catheter beyond the needle tip was rarely addressed, but was probably an attempt to decrease catheter-tip dislodgement during or after insertion. The analgesic effects, if any, of leaving the catheter tip at the needle tip (and thus target nerve) remain unknown. As ultrasound-guided regional anesthesia becomes more common, ultrasound-guided perineural catheter insertion will doubtlessly follow. It is important that postoperative analgesia not suffer because of a change in insertion technique (electrical stimulation to ultrasound guidance).\textsuperscript{2} Thus, it is critical to determine strategies to optimize ultrasound-guided perineural catheter insertion.

We therefore tested the hypothesis that, during needle-in-plane, nerve-in-shoot-out, ultrasound-guided perineural catheter placement, inserting the catheter a minimum distance (0–1 cm) past the needle tip is associated with improved postoperative analgesia compared with inserting the catheter a more traditional 5 to 6 cm past the needle tip.

**MATERIALS AND METHODS**

The institutional review board (University of California, San Diego School of Medicine, San Diego, Calif) approved the protocol and oversaw the study through data analysis. The trial was prospectively registered at clinicaltrials.gov (NCT00997867). All subjects provided written, informed consent before any study procedures. Patients offered enrollment included adults (≥18 years) scheduled for at least moderately painful orthopedic surgery of the foot and/or ankle who desired, and were approved for, a continuous popliteal–sciatic nerve block for postoperative analgesia. Exclusion criteria included known neuropathy of any etiology in the surgical extremity, pregnancy, incarceration, current chronic opioid use (daily opioid consumption for more than the previous 4 weeks of >10 mg oxycodone equivalent), history of opioid abuse, and inability to communicate with the investigators and hospital staff.

**Randomization**

Subjects were randomized to 1 of 2 treatment groups using a computer-generated randomization table based in a secure, password-protected, encrypted central server (www.PAINFRE.com, Clinical and Translational Science Institute, Gainesville, Fla). The treatment groups defined the distance that the catheter tip would be inserted past the needle tip: 0 to 1 cm or 5 to 6 cm. All subjects had a peripheral intravenous catheter inserted, standard noninvasive monitors applied, supplemental oxygen administered via a face mask, and placed in the prone position. Intravenously administered midazolam and fentanyl were titrated for patient comfort, while ensuring that patients remained responsive to verbal cues. Any hair that would be subsequently covered by the catheter dressing was removed with a surgical clipper. The popliteal fossa area was cleansed with chlorhexidine gluconate and isopropyl alcohol (Chloraprep One-Step, Medi-Flex Hospital Products, Overland Park, Kan), and a clear, sterile, fenestrated drape applied.

All subjects had their target nerve located using ultrasound guidance. With a high-frequency linear array transducer (HF138; SonoSite M-Turbo, Bothell, Wash) in a sterile sleeve, the sciatic nerve was identified in a transverse cross-sectional view at the apex of the popliteal fossa. Once the optimal image of the sciatic nerve cephalad to the bifurcation was obtained, a local anesthetic skin wheal was raised lateral to the ultrasound transducer. An 8.9-cm, 17-gauge, Tuohy-tip needle (FlexTip; Teleflex Medical, Reading, Pa) was inserted through the skin wheal in-plane beneath the ultrasound transducer and directed medially toward the sciatic nerve. Local anesthetic solution (40 mL, mepivacaine 1.5% with epinephrine 2.5 µg/mL) was injected in divided doses circumferentially around the target nerve via the needle. The needle tip was returned to a position immediately anterolateral to the sciatic nerve to standardize the insertion protocol among all study subjects.

**Catheter Insertion**

A 19-gauge catheter (FlexTip; Arrow International) was then placed through the length of the needle and advanced either 0 to 1 cm or 5 to 6 cm beyond the needle tip, determined by their randomization group described previously. The needle was then withdrawn over the stationary catheter at least 2 cm. The needle was held stationary, and 2 to 3 cm of catheter was inserted to create “slack” between the nerve and skin exit point. Finally, the needle was withdrawn over the remaining catheter. The injection port was attached to the catheter, and the catheter secured with sterile liquid adhesive, an occlusive dressing, and an anchoring device. Any difficulty with catheter insertion was recorded, as well as the time for placement (first needle insertion until final needle withdrawal).

Fifteen minutes after injection, block onset was evaluated and scored in the affirmative if patients exhibited decreased plantar-flexion and dorsiflexion at the ankle and experienced decreased sensory perception to light touch on the dorsal and plantar surfaces of the foot compared with the contralateral limb. Subjects with a successful surgical block were retained in the study. Also noted was placement of a femoral or saphenous nerve block.

Postoperatively, each perineural catheter was attached to an electronic, portable infusion pump (Pain Pump 2 [Stryker Instruments, Kalamazoo, Mich]) or ambIT Preset (Summit Medical, Salt Lake City, Utah) set to deliver 0.2% ropivacaine (basal rate of 6 mL/hr, patient-controlled bolus of 4 mL, 30-min lockout interval). For postoperative surgical pain, subjects were instructed to self-administer a local anesthetic bolus dose, wait 15 mins, and only then use oral opioids (oxycodone 5-mg tablets), if desired.

**Outcome Measurements**

The primary end point was the average pain in the 3 hrs before a data-collection phone call the morning after surgery as measured on a 0–10-point numeric rating scale (NRS) (0 = no pain, 10 = worst imaginable pain). Secondary end points included time for catheter insertion (Tuohy needle insertion until final withdrawal), incidence of catheter dislodgement during the perineural infusion, maximum ("worst") pain scores during the same 3-hr period before the data-collection phone call, opioid requirements, fluid leakage at the catheter site, and the subjective degree of an insensate extremity (0 = no numbness, 10 = completely insensitive to touch).

**Statistical Analysis**

The sample size estimate was centered around the primary hypothesis that when inserting a perineural catheter for a continuous popliteal–sciatic nerve block using an ultrasound-guided,
TABLE 1. Population Data and Procedural Information

<table>
<thead>
<tr>
<th></th>
<th>Group 0–1 cm (n = 50)</th>
<th>Group 5–6 cm (n = 50)</th>
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<tbody>
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<td>Age, y</td>
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<td>47 (17)</td>
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<tr>
<td>Height, cm</td>
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<td>Weight, kg</td>
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<td>BMI, kg/m²</td>
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<td>28 (6)</td>
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</table>

Values are reported as mean (SD) or number of subjects, as indicated.

In the needle-in-plane technique, inserting the catheter 0 to 1 cm past the needle tip was associated with decreased postoperative pain compared with inserting the catheter 5 to 6 cm past the needle tip. We considered a difference of 1.5 on the NRS to be clinically relevant. Based on an SD of each group of 2.5,2 and assuming a 2-sided type I error protection of 0.05 and a power of 0.80, approximately 45 patients in each group were required (StatMate 2.0; GraphPad Software, San Diego, Calif). To account for a possible increased SD, we enrolled 50 subjects in each treatment group.

Normality of distribution was determined using the Kolmogorov-Smirnov test (GraphPad InStat; GraphPad Software). For normally distributed data, comparisons of independent samples were performed using a t test. Additional analyses included the Fisher exact test for categorical variables and the Mann-Whitney U for comparisons of nonparametric continuous variables. A 2-sided P < 0.05 was considered statistically significant for the primary end point. Continuous data are summarized with mean (SD) and 2-sample t test P values. In cases where Kolmogorov-Smirnov tests indicate violation of the normality assumption, we present median (interquartile) and Mann-Whitney U test P values. For purposes of analysis, each of these subjects was retained in their respective treatment group per the intention-to-treat principle.7

RESULTS

Of 100 subjects enrolled, 50 were randomized to each treatment group. Demographic, anthropometric, and surgical characteristics were similar between groups (Tables 1 and 2). All subjects had a successful catheter placement, and all exhibited nerve block onset as defined by the study protocol. No catheter appeared dislodged during Tuohy needle withdrawal over the perineal catheter (judging from the length of catheter noted at the skin).

TABLE 2. Primary Surgical Procedures

<table>
<thead>
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<th>Group 0–1 cm (n = 50)</th>
<th>Group 5–6 cm (n = 50)</th>
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<td>Achilles tendon repair</td>
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<tr>
<td>Foot osteotomy or ORIF</td>
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<td>Ankle ligament/tendon repair</td>
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<td>3</td>
</tr>
<tr>
<td>Ankle arthroscopy, synovectomy, and/or debridement</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Values are reported as number of subjects. ORIF indicates open reduction–internal fixation.

Average pain scores the day after surgery for subjects of the 0–1 cm group were a median of 2.5 (interquartile range, 0.0–5.0), compared with 2.0 (interquartile range, 0.0–4.0) for subjects of the 5–6 cm group (P = 0.42). Worst pain scores during the same period for subjects of the 0–1 cm group was a median of 6.0 (interquartile range, 3.0–9.0), compared with 7.0 (interquartile range, 3.0–8.0) for subjects of the 5–6 cm group (P = 0.37). Similarly, among the secondary end points, no statistically significant differences were found between the 2 treatment groups (Table 3).

DISCUSSION

This study did not find evidence to support the hypothesis that, for popliteal-sciatic perineural catheters placed using ultrasound guidance and a needle-in-plane technique, inserting the catheter a minimum distance (0–1 cm) past the needle tip improves postoperative analgesia compared with inserting the catheter a more traditional distance (5–6 cm). Although there were no definitive drawbacks to using a minimum-insertion distance, there was a trend of more catheter dislodgements in the 0–1 cm group (5 vs 1; P = 0.20). It remains unknown whether this trend was simply due to a chance finding in a secondary end point, or a true difference exists but did not reach the level of statistical significance as the investigation was not powered to detect small differences in secondary end points.

Historical Context

No clinical trial evolves within a vacuum, and the reasoning behind the current trial deserves comment. As with most investigators before 5 years ago,5 our group used nerve stimulation to localize a target nerve, followed by blind insertion of a nonstimulating perineural catheter to provide a continuous popliteal-sciatic nerve block.9 We then gravitated to stimulating catheters as they became widely available,10 with the suspicion that they provided a more reliable catheter insertion and higher-quality postoperative analgesia.11 After adopting ultrasound guidance for nerve localization, we did not perceive our success rate to change noticeably,12 and so our first controlled study involving ultrasound compared the insertion times for stimulating catheters placed using electrical current and nonstimulating catheters placed using ultrasound guidance.13 However, secondary end points included average and worst pain scores, both of which suggested a non–statistically significant trend toward inferior analgesia with ultrasound-guided placement. Given that the study was powered only for the primary
end point of placement time, no definitive conclusions could be drawn.

We therefore redid the trial with a primary end point of average pain the day after surgery and doubled the sample size.2 This second study found a statistically and clinically significant difference between the two treatment groups, with subjects who had an ultrasound-guided catheter insertion reporting a median average pain score of 5.0 (interquartile range, 3.0–6.0) compared with 3.0 (1.0–4.8) for those who received a stimulating catheter (on a 0–10-point NRS of pain, P = 0.003). We suspected that our insertion technique—derived from a decade of published research—of passing the catheter tip 5 cm past the needle tip led to a less accurate catheter tip placement for the ultrasound group, on average, than when we had used a more parallel needle-to-nerve trajectory using electrical stimulation for nerve identification. It was for this reason that we designed and executed the current study. However, the negative results of the current study do not lend credence to this theory.

**Catheter Design**

The catheters used for this study are relatively flexible and have a single orifice at the tip. We, as well as other investigators, have suspected (without objective evidence) that a more rigid catheter often overshoots the target nerve using a needle-in-plane, nerve-in-short-axis ultrasound technique. Thus, we have preferred flexible catheters when using ultrasound guidance to place a perineural catheter.12 The results of the current study may not necessarily be applied to other catheter designs. Similarly, if a multiport catheter is not inserted past the needle tip, leaving the catheter tip at the location of the target nerve, local anesthetic exiting from the proximal orifice(s) may not provide similar analgesia as single-orifice catheters of the current study.15 And previous investigations suggest that whereas a bolus dose administered under relatively high pressure will equally exit orifices, a relatively low-pressure basal infusion will exit primarily the proximal orifice.15

**Infusion Pumps**

After enrollment of the first 80 subjects, Stryker Instruments recalled the portable infusion pumps we had been using. We therefore completed the study using Summit Medical's ambIT infusion pump. These electronic, programmable pumps infuse at nearly identical degrees of precision.16,17 The same proportion of subjects from each treatment group received each of these devices.

**Comparative-Effectiveness Research**

This investigation was a comparative-effectiveness study that provides relevant information to practitioners on optimizing patient care by directly comparing 2 current treatments.18 Historically, comparative-effectiveness research has been neglected and is therefore being newly promoted by the National Institutes of Health19 and the Institute of Medicine.20 A possible criticism of the present study design is that local anesthetic was injected through the needle first followed by catheter insertion, resulting in a catheter tip that was not immediately adjacent to the target nerve.11 Although there are ways to estimate catheter tip location using ultrasound,21 to date there are no studies providing the positive and negative predictive value of any technique.1 Regardless, even if it was possible to accurately estimate catheter tip location, this would be a surrogate end point—it is irrelevant to patients where the tip appears to be relative to the target nerve. The end point of interest to practitioners is the degree of analgesia provided by the perineural infusion. It is for this reason that we used postoperative analgesia as the primary end point of this study. Our goal was not to compare catheter tip location specifically, but rather to provide practitioners with relevant clinical information directly comparing 2 currently used perineural catheter-insertion distances. Clinicians require prospectively collected data from a randomized study to help determine their relative risks and benefits.

**Study Limitations**

Although the comparative-effectiveness research design we used offers many advantages—especially for clinicians—one limitation is a relative lack of information regarding mechanisms for the observed outcome(s). For example, although our results suggest that catheter-insertion distance correlates poorly with postoperative pain scores, it remains unknown if subjects of 1 treatment group self-administered more bolus doses, resulting in the similar pain scores. Given an increased dose presumably results in increased motor block—an end point not measured in our investigation—the relative number of self-administered bolus doses may be clinically relevant. Thus, further investigation is warranted.

In addition, this study was unmasked, although it is doubtful that subjects or the research coordinator making data-collection phone calls had a bias toward 1 technique. The results of the present study apply specifically to the needle-in-plane, nerve-in-short-axis, ultrasound-guided catheter-insertion technique and should not be extrapolated to all ultrasound-guided approaches.1 Lastly, the results of this study may not be applicable for insertion sites other than the popliteal-scatic location because perineural anatomy directly affects infusion characteristics.22,23

In summary, this randomized, controlled study found no evidence that catheter-insertion distance is associated with an improvement or detriment in postoperative analgesia for popliteal-scatic perineural catheters placed using ultrasound guidance and a needle-in-plane, nerve-in-short-axis technique. Caution is warranted if extrapolating these results to other catheter designs, ultrasound approaches, or anatomic insertion sites.

**ACKNOWLEDGMENTS**

The authors thank Eliza Ferguson, BS, research coordinator, Department of Anesthesiology, University of California, San Diego, for her invaluable assistance, and the entire operating and recovery room staff at the University of California, San Diego–Hillcrest (San Diego, Calif) and Thornton hospitals (La Jolla, Calif).

**REFERENCES**

Background and Objectives: Current guidelines from the American Society of Regional Anesthesia state that an international normalized ratio (INR) of 1.4 is the upper limit of warfarin anticoagulation for safe removal of an epidural catheter. However, these guidelines are based primarily on expert consensus, and there is controversy regarding this recommendation as being "too conservative."  

Methods: Prospective (3211) and retrospective (1154) patients undergoing total joint replacement followed by daily warfarin thromboprophylaxis were enrolled in this observational study. All nonsteroidal anti-inflammatory drugs and anticoagulants were held before surgery, and all patients had normal coagulation test results before surgery. Patients were followed twice a day by the acute pain service, no other anticoagulants except nonsteroidal anti-inflammatory drugs were administered, and epidural analgesia was discontinued per institutional protocol. Only patients with INR greater than 1.4 at the time of removal of epidural catheter were included. Neurologic checks were performed for 24 hrs after removal.  

Results: A total of 4365 patients were included, and 79% underwent knee replacement and 18% hip replacement. Mean age was 68 yrs, and mean weight was 81 kg. Mean (SD) duration of epidural analgesia was 2.1 (0.6) days. Mean (SD) INR at the time of epidural removal was 1.9 (0.4), ranging from 1.5 to 7.1. No spinal hematomas were observed (0% incidence with 95% confidence interval, 0%-0.069%).  

Conclusions: Our series of 4365 patients had uncomplicated removal of epidural catheters despite INRs ranging from 1.5 to 5.9. Removal was only during initiation of warfarin therapy (up to approximately 50 hrs after warfarin intake) when several vitamin K factors are likely to still be adequate for hemostasis.  

(Reg Anesth Pain Med 2011:36: 231–235)  

Postoperative epidural analgesia has been demonstrated to provide superior analgesia to systemic opioids and may improve postoperative outcomes in selected patients and surgical procedures.1,2 However, duration of postoperative epidural analgesia may be limited in some patients owing to planned anticoagulation for thromboembolism prophylaxis. Adjusted dose warfarin is the most common agent used for thromboembolism prophylaxis after total knee and hip replacement surgery,3 and these are common procedures with approximately 680,000 and 437,000, respectively, performed annually in the United States alone (http://hcupnet.ahrq.gov/HcupNet.jsp?id=573%20D61A04FBB&form=MAINSEL&JS=Y&Action=%2E%20Next%3E%2E&MAINSEL=NationalStatistics; accessed December 6, 2010). It is currently controversial when it is safe or necessary to remove an indwelling epidural catheter after initiation of thromboembolism prophylaxis with warfarin. This is an important consideration as early termination of the epidural catheter may deprive the patient of superior analgesia and postoperative recovery, particularly within the first 48 hrs after surgery.4 Conversely, unnecessary efforts to reverse anticoagulation to normalize coagulation before removal of the epidural catheter disrupts thromboembolism prophylaxis and may expose the patient to unnecessary blood products such as fresh frozen plasma. Current guidelines from the American Society of Regional Anesthesia (ASRA) state that an international normalized ratio (INR) of 1.4 is the upper limit of warfarin anticoagulation for safe removal of an epidural catheter,3 which may discourage use of epidural analgesia for postoperative analgesia after total joint replacement. However, these guidelines are based on expert consensus without substantial data, and the guidelines specifically state that there is controversy regarding this recommendation as being "too conservative." Indeed, a recent clinical study demonstrated poor correlation between INR and factor VII levels during initiation of warfarin thromboembolism prophylaxis with continued maintenance of adequate levels for hemostasis despite INR greater than 1.4.5 An accompanying editorial to this study suggested that the ASRA guidelines be reevaluated5 followed by a letter to the editor suggesting that further evidence was still required.6 Specifically, the primary study did not document actual removal of epidural catheters in a large number of patients with INR greater than 1.4. It is a long-standing standard clinical practice at our institutions to remove epidural catheters with INR greater than 1.4 during the early days of warfarin thromboembolism prophylaxis. Thus, we performed this observational, multi-institutional, surveillance study for clinically evident spinal hematomas in patients who had removal of epidural catheters with INR greater than 1.4 to document the suggested data regarding risk-benefit of epidural catheter removal during warfarin therapy.  

METHODS  

Institutional review board approval was acquired from the Hospital for Special Surgery, Rush University Medical Center, and Thomas Jefferson University. Waivers for individual written consent were granted by the institutional review boards because clinical care and data collection were routine, risk from documentation of our standard care was considered minimal, and it  

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was considered impractical to individually consent the 4365 patients that were included in this survey. A total of 1617 consecutive patients were prospectively enrolled from the Hospital for Special Surgery from August 2007 to May 2010, 1594 consecutive patients from Rush from January 1998 to June 2010. One thousand one hundred and fifty-four had data retrospectively collected from Thomas Jefferson from January 1998 to June 2007. Inclusion criteria were patients undergoing total knee or hip replacement surgery with postoperative epidural analgesia, thromboprophylaxis with warfarin, daily measurement of INR, and subsequent removal of epidural catheter with INR greater than 1.4. Perioperative data were collected including patient demographics, surgical procedure, and INR at the time of removal of the epidural catheter.

At the Hospital for Special Surgery, only patients undergoing total knee replacement were enrolled because warfarin is consistently administered only for this procedure. At Rush and Thomas Jefferson universities, both total hip and knee replacement patients were enrolled. At the Hospital for Special Surgery and Rush, nonsteroidal anti-inflammatory drugs (NSAIDs) and aspirin were discontinued for a week before surgery. At Thomas Jefferson, NSAIDs were continued before surgery. Other anti-coagulants were discontinued at an appropriate time before surgery to allow normalization of coagulation tests by the day of surgery. Postoperatively, at the Hospital for Special Surgery and Rush, warfarin was administered based on a daily nomogram designed to achieve an INR between 1.8 and 2.5 by postoperative day (POD). Warfarin was administered beginning the night of surgery, and the mean daily dose was 4.1 to 4.2 mg. At Jefferson, a different nomogram was used in which 10 mg warfarin was administered beginning the night of surgery, no warfarin was administered on POD1, and then a nomogram-based dose was administered to achieve an INR of 2. No other anti-coagulants except NSAIDs were allowed. Blood was drawn

### TABLE 1. Perioperative Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Total (n = 4365)</th>
<th>HSS (n = 1617)</th>
<th>Rush (n = 1594)</th>
<th>TJU (n = 1154)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yrs</td>
<td>68 ± 12</td>
<td>70 ± 10</td>
<td>66 ± 13</td>
<td>67 ± 11</td>
</tr>
<tr>
<td>Sex, F/M</td>
<td>2991/1374</td>
<td>1141/476</td>
<td>1110/484</td>
<td>740/414</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>81 ± 19</td>
<td>80 ± 18</td>
<td>79 ± 19</td>
<td>86 ± 18</td>
</tr>
<tr>
<td>Total knee replacement, n</td>
<td>3486</td>
<td>1617</td>
<td>774</td>
<td>1095</td>
</tr>
<tr>
<td>Total hip replacement, n</td>
<td>800</td>
<td>0</td>
<td>770</td>
<td>30</td>
</tr>
<tr>
<td>Other surgery</td>
<td>79</td>
<td>0</td>
<td>50</td>
<td>29</td>
</tr>
<tr>
<td>Epidural needle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuohy 17 gauge, n</td>
<td>2338</td>
<td>744</td>
<td>1594</td>
<td>1154</td>
</tr>
<tr>
<td>Weiss 17 gauge, n</td>
<td>873</td>
<td>873</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hustead 18 gauge, n</td>
<td>1154</td>
<td></td>
<td>1154</td>
<td></td>
</tr>
<tr>
<td>Epidural catheter 20 gauge, n</td>
<td>4365</td>
<td>1617</td>
<td>1594</td>
<td>1154</td>
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<tr>
<td>No. attempts to place epidural (median/ mode)</td>
<td>n/a</td>
<td>1/1</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Duration of epidural catheter, d</td>
<td>2.1 ± 0.6</td>
<td>2 ± 0.2</td>
<td>2.2 ± 0.7</td>
<td>1.9 ± 0.1</td>
</tr>
</tbody>
</table>

Values are mean ± SD unless otherwise stated.

HSS indicates Hospital for Special Surgery; Rush, Rush University Medical Center; TJU, Thomas Jefferson University Medical Center.

### TABLE 2. Anticoagulation Test Results and Number of Epidural Catheters Removed Per Day

<table>
<thead>
<tr>
<th></th>
<th>POD1</th>
<th>POD2</th>
<th>POD3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>International normalized ratio</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.7 ± 0.3 (1.5–3.5)</td>
<td>1.9 ± 0.4 (1.5–5.9)</td>
<td>1.8 ± 0.4 (1.5–7.1)</td>
</tr>
<tr>
<td>HSS</td>
<td>1.2 ± 0.1 (1.5–3.5)</td>
<td>1.9 ± 0.5 (1.5–5.9)</td>
<td>2.1 ± 0.8 (1.5–7.1)</td>
</tr>
<tr>
<td>Rush</td>
<td>1.6 ± 0.1 (1.5–2.0)</td>
<td>1.7 ± 0.2 (1.5–4.6)</td>
<td>1.8 ± 0.3 (1.5–3.9)</td>
</tr>
<tr>
<td>TJU</td>
<td>2.1 ± 0.4 (1.7–2.3)</td>
<td>1.8 ± 0.4 (1.5–4.9)</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Prothrombin time, sec</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSS</td>
<td>11.5 ± 1.2</td>
<td>18 ± 6.1</td>
<td>20.8 ± 9.7</td>
</tr>
<tr>
<td>Partial thromboplastin time, sec</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSS</td>
<td>29.6 ± 15</td>
<td>43 ± 9</td>
<td>37 ± 8.9</td>
</tr>
<tr>
<td>Platelet count, n/mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSS</td>
<td>220 ± 65</td>
<td>196 ± 63</td>
<td>206 ± 77</td>
</tr>
<tr>
<td><strong>No. epidural catheters removed</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>4090</td>
<td>140</td>
</tr>
<tr>
<td>HSS</td>
<td>5</td>
<td>1595</td>
<td>12</td>
</tr>
<tr>
<td>Rush</td>
<td>34</td>
<td>1342</td>
<td>128</td>
</tr>
<tr>
<td>TJU</td>
<td>1</td>
<td>1153</td>
<td>0</td>
</tr>
</tbody>
</table>

All values are mean ± SD (range).
for routine laboratory processing every morning. Our laboratory reference range for prothrombin time is 9.4 to 11.6, and that for INR is 0.8 to 1.2. Patients are evaluated by the acute pain service at least twice a day and undergo physical therapy twice a day per a clinical pathway. As part of the clinical pathway, the epidural is typically discontinued on POD 2 at noon (approximately 36 hrs after warfarin intake) at the Hospital for Special Surgery, POD 2 in the morning at Jefferson, and on POD 3 at 7:00 am (approximately 50 hrs after warfarin intake) at Rush. At the hospital for Special Surgery, floor nurses may remove the epidural for INR of 1.4 or less. The acute pain service attending removes epidural catheters for INR greater than 1.4. At Rush and Jefferson, all epidural catheters are removed by the acute pain service nurse. For all institutions, neurologic checks are performed every 2 hrs (including at night) for the next 24 hrs for all patients with INR greater than 1.4. Additional prospective data collection included type of epidural needle and catheter, traumatic placement, and daily coagulation tests.

Statistical Analysis
Descriptive statistics were planned with the incidences and 95% confidence intervals (CIs). The primary outcome was incidence of epidural hematoma after removal of the epidural catheter in the presence of an INR greater than 1.4. Because the observed incidence was 0%, we applied the 3/n formula to estimate an upper 95% CI for an observed incidence of 0%.11

RESULTS
A total of 4365 patients were included, and 79% underwent knee replacement and 18% underwent hip replacement (Table 1). Mean age was 68 yrs, and mean weight was 81 kg. Mean (SD) duration of epidural analgesia was 2.1 (0.6) days. Mean (SD) INR at the time of epidural removal was 1.9 (0.4), ranging from 1.5 to 5.9 (Table 2 and Fig. 1). Other coagulation tests were only available from the Hospital for Special Surgery. At the Hospital for Special Surgery, 87% of patients received NSAIDs during warfarin therapy. At Rush, all enrolled patients received a COX-2 inhibitor in addition to warfarin starting from 2004 (56% of patients). At Thomas Jefferson, all patients received either an NSAID or a COX-2 inhibitor in addition to warfarin. No spinal hematomas were observed (0% incidence with 95% CI, 0%-0.069%).

DISCUSSION
In our observational series of 4365 patients, we observed a 0% incidence (95% CI, 0%-0.069%) of clinically evident spinal hematoma after removal of epidural catheters despite INR values from 1.5 to 7.1. Specific aspects of our clinical protocol may have contributed to this null observation. All epidural catheters were removed during initiation of warfarin therapy, concomitant anti-coagulants except NSAIDs were withheld, and neurologic checks were performed for the subsequent 24 hrs. Nonsteroidal anti-inflammatory drugs and COX-2 inhibitors have reversible anti-platelet activity, and concurrent use of these agents was allowed in 87% to 100% of our patients as a multimodal analgesic. The ASRA guidelines consider NSAIDs and COX-2 inhibitors to confer a low risk for spinal hematoma when used by themselves but do warn that data on combinations of anticoagulants is lacking.3 The pharmacology of warfarin has been well described. Brieferly, warfarin is the most common vitamin K antagonist in clinical use. Warfarin inhibits protein C and factors II, VII, IX, and X. Factor VII has the shortest half-life of 6 to 8 hrs, whereas the other factors' half-lives range from 24 to 80 hrs on average. For effective anticoagulation, plasma levels of vitamin K factors have to be decreased to approximately 20% of normal.10 For individual factors, levels are typically decreased to 5% for factor VII, 20% for factor IX, and 30% for factor X for effective anticoagulation.12 During initiation of warfarin therapy, the INR is highly dependent on levels of factor VII owing to its short half-life and is often quite labile. A recent study found weak to modest correlation (R2 = 0.3-0.6) between factor VII activity and INR during the first 3 days of warfarin therapy after total joint replacement. Furthermore, it is likely that other vitamin K factor levels, especially factors II and X, remain adequate despite increases in INR during the first 48 hrs of initiation of warfarin therapy.
anticoagulation requires reduction of levels of factor II (half-life 48–120 hrs) and factor X (half-life 20–42 hrs), which requires 4 to 6 days. Overall, an elevated INR during initiation of warfarin therapy may not accurately indicate anticoagulation. Such discordance during initiation may provide an inherent safety margin for removal of epidural catheters. Of note, these findings only apply to initiation of warfarin. During discontinuation, the normalization of INR reflects rapid recovery of factor VII, whereas other factors with longer half-lives may not have recovered. The ASRA guidelines recommend that epidural catheters not be routinely removed if the INR is greater than 1.4 during initiation of warfarin therapy. In such cases, the catheter may be cautiously removed followed by neurologic checks or the warfarin held, particularly if the INR is greater than 3. Notably, the guidelines also state that such recommendations are controversial and that few data exist regarding patients with indwelling epidural catheters that are subsequently anticoagulated with warfarin. There is 1 series of 1000 lumbar anesthetics performed in patients receiving preoperative oral anticoagulants; however, coagulation status at the time of epidural catheter removal was not reported. A combined series of 651 patients receiving warfarin reported no hematomas after epidural catheter removal with a mean INR of 1.4. Finally, a set of 1030 patients undergoing total knee replacement had epidural catheters removed without complications despite a mean INR of 1.5. There are currently 2 published case reports describing development of a spinal hematoma after removal of an epidural catheter during warfarin therapy, and neither were managed in a similar fashion to our protocol. One patient had her epidural catheter removed when her INR was 6.5. The other patient did not have their epidural catheter removed until after 4 days of warfarin therapy. The stated premise for concern with epidural catheter removal is the potential for the removal process to cause vascular trauma or dislodge a preexisting clot. These considerations are possible; however, epidural catheters may also spontaneously move or become dislodged while awaiting normalization of INR. Furthermore, unnecessary efforts to reverse anticoagulation to normalize coagulation before removal of the epidural catheter disrupt thromboembolism prophylaxis and may expose the patient to unnecessary blood products such as fresh frozen plasma.

Epidural catheters were removed without complications in 89 patients with INR greater than 3. Such an INR value is greater than the typical target for thromboembolism prophylaxis (1.8–2.5) and reflects the liability of warfarin dosing and INR. Warfarin has a narrow therapeutic range and is affected by multiple factors. Patient age, female sex, ethnicity, lower patient weight, liver, cardiac, and renal disease all affect response to warfarin. In addition, there are more than 250 drugs that interact with warfarin including cardiovascular drugs. In patients with enhanced response to warfarin, it may be especially desirable to maintain neurologic monitoring after removal of epidural catheters to quickly diagnose and treat an epidural hematoma.

Finally, estimation of incidences of uncommon events after observation of a zero numerator is imprecise. We used a commonly recommended modification of a Poisson distribution (ln formula) to provide a conservative estimate of maximal risk as noted by upper 95% CI. With this formula, as the n becomes larger, the estimate for 95% CI approaches an exact Poisson solution. Alternative estimates of risk may be calculated by using different frequency distributions (eg, 95% CI of 0.08% with binomial distribution) or more stringent CIs (eg, 99% CI of 0.1% with the 4.6/n formula).

In conclusion, our series of 4365 patients noted uncomplicated removal of epidural catheters during initiation of warfarin therapy despite INRs ranging from 1.5 to 7.1. Our findings do not necessarily contradict the ASRA guidelines because we followed recommendations to cautiously remove catheters and to perform subsequent neurologic checks.

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REFERENCES


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