Electrical Stimulation Versus Ultrasound Guidance for Popliteal-Sciatic Perineural Catheter Insertion
A Randomized Controlled Trial

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Background: Sciatic perineural catheters via a popliteal fossa approach and subsequent local anesthetic infusion provide potent analgesia and other benefits after foot and ankle surgery. Electrical stimulation (ES) and, more recently, ultrasound (US)-guided placement techniques have been described. However, because these techniques have not been compared in a randomized fashion, the optimal method remains undetermined. Therefore, we tested the hypotheses that popliteal-sciatic perineural catheters placed via US guidance require less time for placement and produce equivalent results, as compared with catheters placed using ES.

Methods: Preoperatively, subjects receiving a popliteal-sciatic perineural catheter for foot and/or ankle surgery were randomly assigned to either the ES with a stimulating catheter or US-guided technique with a nonstimulating catheter. The primary end point was catheter insertion duration (in minutes) starting when the US transducer (US group) or catheter-placement needle (ES group) first touched the patient and ending when the catheter-placement needle was removed after catheter insertion.

Results: All US-guided catheters were placed per protocol (n = 20), whereas only 80% of stimulation-guided catheters could be placed per protocol (n = 20, P = 0.106). All catheters placed per protocol in both groups resulted in a successful surgical block. Perineural catheters placed by US took a median (10th-90th percentile) of 5.0 min (3.9–11.1 min) compared with 10.0 min (2.0–15.0 min) for stimulation (P = 0.054). Subjects in the US group experienced less pain during catheter placement, scoring discomfort a median of 0 (0.0–2.1) compared with 2.0 (0.0–5.0) for the stimulation group (P = 0.005) on a numeric rating scale of 0 to 10.

Conclusions: Placement of popliteal-sciatic perineural catheters takes less time and produces less procedure-related discomfort when using US guidance compared with ES.

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Popliteal-sciatic continuous peripheral nerve blocks (CPNBs) provide potent analgesia and other benefits after foot and ankle surgery, as documented by previous randomized controlled investigations.† Most perineural catheter reports from the previous 2 decades have used electrical stimulation (ES) to locate the target nerve via an insulated needle, followed by insertion of either a nonstimulating or stimulating catheter. More recently, ultrasound (US)-guided perineural catheter placement has been described.‡,§

While ES- and US-guided techniques have been directly compared for single-injection peripheral nerve block placement (and suggest possible advantages with US in block placement time, success rates, and patient comfort),‡ no comparison for perineural catheter placement is available. As such, the optimal catheter-placement method and any possible benefits of one technique over the other remain undetermined.

We therefore tested the hypotheses that popliteal-sciatic perineural catheters placed via US guidance require less time for placement and produce equivalent results, as compared with catheters placed using ES. The primary outcome was catheter insertion duration (in minutes) starting when the US probe (US group) or catheter-placement needle (ES group) first touched the patient and ending when the catheter-placement needle was removed after perineural catheter insertion.

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. 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 popliteal-sciatic CPNB for postoperative analgesia. Exclusion criteria included known neuropathy of any etiology in the surgical extremity; pregnancy; incarceration; and inability to communicate with the investigators and hospital staff.

Protocol

After written, informed consent, subjects were randomized to 1 of 2 treatment groups—ES or US guidance—using a computer-generated randomization table based in a secure, password-protected, encrypted central server (www.PAINRE.com; General

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Clinical Research Center, Gainesville, Fla). All catheters were placed by an attending physician with extensive experience in both placement techniques or a regional anesthesia fellow/resident under the direct supervision and guidance of the attending physician.

All subjects had a peripheral intravenous catheter inserted and were placed in the prone position. Standard noninvasive monitors were applied, and oxygen was administered via a face mask. Midazolam and fentanyl (intravenous) were titrated for patient comfort, while ensuring that patients remained responsive to verbal cues. The area that would be subsequently covered by the catheter dressing was shaved, if necessary. Landmarks were drawn for all subjects; the area was cleaned with chlorhexidine gluconate and isopropyl alcohol (ChloraPrep OneStep; Medi-Flex Hospital Products, Inc, Overland Park, Kan), and a clear, sterile, fenestrated drape was applied. The nerve stimulator (ES group) or US (US group) was readied for use.

ES Technique

Subjects randomized to the ES technique had a sciatic nerve located with a nerve stimulator attached to an insulated needle using a slightly modified technique of a method described previously. A local anesthetic skin wheal was raised 1 cm directly caudad to the apex of the popliteal fossa (bounded by the semimembranosus muscle medially and the biceps femoris muscle laterally), but not more than 10 cm cephalad to the popliteal fossa skin crease. An 8.9-cm, 17-gauge, insulated needle (StimuCath; Arrow International, Reading, Pa) was inserted through the skin wheal, with the long axis of the needle at a 45-degree angle to the skin/journey and the bevel directed cephalad. The needle was connected to a nerve stimulator (Stimuplex-DIG; B. Braun Medical, Bethlehem, Pa) initially set at 1.2 mA, 2 Hz, and an impulse duration of 0.1 millisecond. If the sciatic nerve was not identified after 5 to 8 cm of insertion, depending on patient body habitus, the needle was withdrawn and redirected laterally, then medially, until discrete, stimulated foot/toe plantar flexion occurred with a current amplitude between 0.30 and 0.60 mA.

The 19-gauge catheter was then placed through the length of the needle and the nerve stimulator connecting wire transferred from the needle to the catheter, which has a conducting wire through its length to deliver current to its tip. The stimulating current was allowed to be increased up to 0.80 mA, and the catheter was advanced 5 cm beyond the needle tip. If plantar flexion decreased as the stimulating catheter was advanced, the catheter was withdrawn into the needle, the needle redirected or rotated, and the catheter advanced.

Once a catheter had been successfully advanced 5 cm past the needle tip, the needle itself was withdrawn over the catheter, and the catheter stylet was removed. The catheter was tunnelled subcutaneously 5 to 7 cm in a lateral direction using the included needle stylet and 17-gauge insulated needle. The injection port was attached to the end of the catheter, the nerve stimulator attached to the injection port, and the minimum current resulting in muscle contraction noted. The catheter was secured with sterile liquid adhesive, an occlusive dressing, and an anchoring device (StatLock; Venetic International, San Diego, Calif) to affix the catheter hub to the patient. After negative aspiration, 40 mL of anesthetic solution was injected via the catheter with gentle aspiration between divided doses. The injectate contained ropivacaine 1.5% and epinephrine 2.5 to 5.0 μg/mL.

US-Guided Technique

Subjects randomized to the US-guided technique had their target nerve located using US guidance alone. With a high-frequency linear array transducer (HFL38; SonoSite MicroMaxx, 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 was obtained, a local anesthetic skin wheal was raised lateral to the US transducer. An 8.9-cm, 17-gauge, Tuohy-tip needle (FlexTip; Arrow International) was inserted through the skin wheal inplane beneath the US transducer and directed medially toward the sciatic nerve, with the bevel directed posteriorly. Local anesthetic solution (40 mL, ropivacaine 1.5% with epinephrine 2.5–5.0 μg/mL) was injected in divided doses circumferentially around the target nerve via the needle.

A 15-gauge, flexible, epidural-type catheter (FlexTip; Arrow International) was then placed through the length of the needle and advanced 5 cm beyond the needle tip. Once a catheter had been inserted, the needle itself was withdrawn over the catheter. The injection port was attached to the end of the catheter, and catheter tip position was inferred by injecting 1 mL of air via the catheter under US, slightly withdrawn when necessary, and another 1 mL of air injected—this process was repeated, as necessary (the positive and negative predictive values of this test are currently unknown, and whether it influenced accurate catheter placement in this study similarly remains unknown). The catheter was not tunnelled further but was dressed and secured in a similar manner as in the ES technique.

Outcome Measurements

Time for catheter placement was the primary outcome and began when the US probe (US group) or catheter-placement needle (ES group) first touched the patient and ended when the catheter-placement needle was removed after catheter placement. Therefore, the time required for tunneling ES-guided catheters was not included in this measurement. A research coordinator with no other concurrent responsibilities recorded all times. If no evoked motor response (ES group) or visual identification of the target nerve (US group) could be achieved within 15 mins, the placement was considered a failure, and the primary end point was recorded as 15 mins. If a catheter could not be placed per protocol within 30 mins, the placement was considered a failure, and the primary end point was recorded as 30 mins. In such cases, the subject had a catheter-placement attempt using the alternative method. Subjects who did not have a catheter placed as per their randomized group protocol were removed from further study.

Secondary Outcomes

Immediately after the procedure, patients were asked to note their discomfort with catheter placement on a numeric rating scale of 0 to 10 (0 = no pain, 10 = the worst pain imaginable). Fifteen minutes after local anesthetic injection, block onset was evaluated and scored in the affirmative if motor control was nearly abolished during either plantar or dorsiflexion, and there was decreased sensory perception on the plantar aspect of the foot as compared with the contralateral limb. Subjects with a successful surgical block were retained in the study; those with a failed surgical block had their catheters removed and were removed from the study. Given that the primary outcome of this study was the time for catheter insertion—completed before entering the operating room—the subsequent surgical anesthesia was not standardized among subjects.

In the recovery room—or before admission to the recovery room if the initial surgical block duration required extension—the perineural catheter was filled with a bolus of 20 mL of 0.5% ropivacaine with epinephrine 2.5 to 5.0 μg/mL, after negative aspiration. The time of this bolus was recorded.
Perineural catheters were attached to portable infusion pumps (Pain Pump 2 BlockAid; Styker Instruments, Kalamazoo, Mich) set to deliver an infusion of 0.2% ropivacaine (basal rate of 8 mL/hr; patient-controlled bolus of 4 mL; 30-min lockout interval). Patients used an oral opioid (oxycodone, 5-mg tablets) for breakthrough postoperative pain inadequately treated with the perineural ropivacaine infusion/bolus. Although study-related procedures ended on postoperative day 1, all patients received daily telephone follow-up from a health care provider throughout the duration of their perineural infusions through the day after catheter removal as is standard practice at our institution.

Assessment of Catheter Placement Success
With the use of the US-guided protocol, it is theoretically possible to inject mevipacaine via the needle and produce a successful surgical block but has the perineural catheter inaccurately placed. Therefore, to help document the accurate positioning of perineural catheters placed with US, the ropivacaine bolus described above was delivered via the catheter. Subjects were contacted the following day and asked for the time that their invasive surgical block resolved. Because the duration of anesthetic action for lower-extremity blocks are less than 7 hrs for mevipacaine and more than 7 hrs for ropivacaine, the catheter was considered accurately placed if the time from the initial surgical block until the time of block resolution was greater than 7 hrs.

In addition to procedure-related pain scores, subjects were also surveyed on the day after surgery regarding fluid leakage occurrence and average and worst pain since surgery on a 0- to 10-point numeric rating scale.

Statistical Analysis
Sample size calculations were centered around the hypothesis that when inserting a popliteal-sciatric perineural catheter, the use of US guidance is associated with a decreased time of placement compared with ES guidance. To this end, we chose the time for catheter placement as the outcome measure to estimate a probable sample size. We considered a 5-min difference in placement time to be clinically relevant. Based on an SD of each group of 5 mins and assuming a 2-sided type I error protection of 0.05 and a power of 0.80, approximately 17 patients in each group were required (StatMate 2.0; GraphPad Software, San Diego, Calif). To allow for variability in the SD of each group and subject dropouts, we enrolled a total of 40 subjects.

### TABLE 1. Population Data and Procedural Information

<table>
<thead>
<tr>
<th></th>
<th>US (n = 20)</th>
<th>ES (n = 20)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>46 (39–55)</td>
<td>47 (26–56)</td>
<td>0.62</td>
</tr>
<tr>
<td>Sex, no. female/no. male</td>
<td>9/11</td>
<td>8/12</td>
<td>0.79</td>
</tr>
<tr>
<td>Height, cm</td>
<td>175 (169–178)</td>
<td>174 (166–178)</td>
<td>0.20</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>100 (80–120)</td>
<td>79 (67–93)</td>
<td>0.02</td>
</tr>
<tr>
<td>Minimum current via needle, mA</td>
<td>NA</td>
<td>0.5 (0.5–0.5)</td>
<td>NA</td>
</tr>
<tr>
<td>Minimum current via catheter, mA</td>
<td>NA</td>
<td>0.5 (0.4–0.7)</td>
<td>NA</td>
</tr>
</tbody>
</table>

Values are reported as median (25th–75th percentiles) or number of subjects, as indicated.

NA indicates not applicable.

### TABLE 2. Primary Surgical Procedures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>US (n = 20)</th>
<th>ES (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achilles tendon repair</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Ankle arthrodesis or ORIF</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Ankle arthroplasty</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Ankle ligament repair/debridement</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Calcaneal osteotomy or ORIF</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Midfoot osteotomy or ORIF</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Wide mass excision foot/ankle</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

ORIF indicates open reduction and internal fixation.

Normality of distribution was determined using the Kolmogorov-Smirnov test (InStat 3.6; GraphPad Software). Continuous, normally distributed data are reported as mean (SD). Categorical data are reported as median (percentiles) or percentages, when appropriate. For normally distributed data, single comparisons were performed using the t test. For continuous data in distributions other than normal, the Mann-Whitney U test was used. The Fisher exact test was used for comparisons of categorical data. A 2-sided P < 0.05 was considered statistically significant for the primary outcome. Significant findings in secondary outcomes should be interpreted as suggestive, requiring confirmation in a future trial before considering them as definitive.

### RESULTS

Forty patients enrolled, and all were randomized to 1 of the 2 treatment groups. The demographic, morphometric, and surgical characteristics of each group are presented in Tables 1 and 2. All perineural catheters in the US group were placed by trainees compared with 19 (95%) of 20 in the ES group. Of subjects randomized to ES (n = 20), 4 (20%) failed to have a catheter placed as per the ES protocol (all were subsequently successfully placed using the US-guided protocol), and the remaining 16 (80%) had both successful catheter placement and surgical block onset, as defined by the study protocol. Of the 4 ES catheter-placement failures, 3 resulted when no evoked motor response could be elicited with the stimulating needle within 15 mins, and 1 resulted when the catheter could not be advanced 5 cm past the needle tip while retaining an evoked motor response within 30 mins. Of subjects randomized to US (n = 20), all had surgical block onset and a successful catheter placement, as defined by the study protocol (P = 0.106 compared with ES group).

![FIGURE 1. Time required for catheter placement according to method. Four catheters of the nerve stimulation group could not be placed per protocol and were subsequently placed successfully using the US technique (marked by †).](image-url)
TABLE 3. Secondary Outcomes

<table>
<thead>
<tr>
<th></th>
<th>US (n = 20)</th>
<th>ES (n = 20)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venous puncture, n</td>
<td>0</td>
<td>2</td>
<td>0.487</td>
</tr>
<tr>
<td>Fluid leakage at site, n</td>
<td>6</td>
<td>1</td>
<td>0.104</td>
</tr>
<tr>
<td>Worst pain, POD 1 (0–10)</td>
<td>7.5 (1.8–10.0)</td>
<td>6.0 (0–9.0)</td>
<td>0.300</td>
</tr>
<tr>
<td>Average pain, POD 1 (0–10)</td>
<td>4.5 (0–7.1)</td>
<td>3.5 (0–5.0)</td>
<td>0.232</td>
</tr>
</tbody>
</table>

Values are reported as median (10th–90th percentiles) or number of subjects, as indicated. POD indicates postoperative day.

Primary Outcome

Perineural catheters placed by US took a median (10th–90th percentile) of 5.0 mins (3.9–11.1 mins) compared with 10.0 mins (2.0–15.0 mins) for ES (n = 20, P = 0.034, Fig. 1).

Secondary Outcomes

Subjects in the US group experienced less pain during catheter placement, scoring a median of 0.0 (0.0–2.1) compared with 2.0 (0.0–5.0) for the ES group (P = 0.005). There were no statistically significant differences in the number of venous punctures, degree of fluid leakage, or postoperative pain scores between the 2 treatment groups (Table 3).

Adverse Events

There were no adverse events related to study procedures, perineural catheter placement, or outpatient perineural local anesthetic infusion.

DISCUSSION

This randomized controlled study provides evidence that popliteal-sciatic perineural catheters may be placed more quickly, on average, with US guidance compared with ES (with stimulating catheters) with similar analgesic results. In addition, procedure-related patient discomfort is lower when using US as compared with ES. Although investigators have previously suggested possible benefits of placing perineural catheters using US,3–5 the data of the current study are the first to document and quantify these previously theoretical advantages.

Catheter Placement Time

The median times of 5 mins achieved by US is clinically relevant in the present era of operating room efficiency. This difference is likely an underestimate for 2 reasons: (1) our protocol for determining placement time for the ES group did not include the time required for tunneling or the bolus injection of local anesthetic via the catheter after placement needle removal; and (2) given that the local anesthetic bolus (mepivacaine) in the US-guided technique is administered via the needle before catheter placement, we speculate that the anesthetic block onset may be more rapid,6 further decreasing the interval from the start of block performance to anesthesia-ready time. The latter is based on our subjective perception and clinical experience and requires further investigation.

Additional procedures that affect placement time were excluded from the primary outcome measurement as well. For example, the times to retrieve and set up the US and nerve stimulator were not included for this study. At our institution, all peripheral nerve blocks and perineural catheters are placed in a regional anesthesia induction area (“block room”), with both of these pieces of equipment at each bedside. Given that the US remains untethered throughout the day and the nerve stimulator requires fewer than 5 secs to turn on, the difference in equipment preparation between US and ES at our institution is less than 10 secs—irrelevant, given the primary outcome precision of the current study. However, the 5-min time advantage of the US-guided technique could easily be negated by preparation time if a nerve stimulator was continuously available, while a US machine had to be retrieved, set up, and powered on for each procedure. It is obviously impossible in a single clinical study to account for the nearly limitless number of scenarios at all institutions, and practitioners need to be cognizant of this fact when applying the results of our study to their own practices.

Placement Success Rate

Deserving comment is the failure to place 4 (20%) of the 20 catheters in the ES group, which were subsequently all successfully placed by US. Catheter placement was deemed a “failure” when a motor response could not be evoked within 15 mins, the electrical current via the needle could not be reduced to less than 0.6 mA with an evoked motor response within 15 mins, or the stimulating current via the catheter could not be reduced to less than 0.6 mA while retaining an evoked motor response with the catheter inserted 5 cm beyond the needle tip within 30 mins even after adequate needle stimulation was achieved. These criteria may be unnecessarily restrictive and therefore may have directly affected the ES group success rate. However, there is evidence that strict catheter-placement criteria provide definitive benefits,14,22 and the protocol used in the current study is nearly identical to one used previously, which resulted in high success rates.13,22

We can only speculate on why the present study had an 80% success rate for ES-guided catheter placement, whereas previous investigations with nearly-identical protocols reported success rates of 93% and 96%,15,22 One possible explanation is that nearly all catheters for the present study were placed by trainees (residents and fellows), whereas previous investigations exclusively relied on experienced attending physicians. Alternatively, differences in patient populations between previous studies and the present study may have influenced the success rate. Lastly, the time limitation of 15 to 30 mins for needle/catheter placement of the current study may explain the difference compared with previous investigations without similar time limitations.

Combined US Guidance–Nerve Stimulation

For the purpose of this study, we elected to compare CPNBB placement using ES alone to US guidance alone to clearly define the advantages and disadvantages of each technique and estimate the difference in procedural time between techniques. It is worth mentioning the possibility that using a combination of both approaches may offer additional benefits over either technique alone.14–18 However, to date, this supposition remains controversial and uninvestigated for perineural catheter placement.19–21

Study Limitations

One limitation of our study is that subjects and investigators were not masked to treatment group assignment. Our results pertain specifically to the techniques and equipment used in this study—using other approaches and/or catheter designs would undoubtedly alter the findings.13–22 We can speculate that using a combination of stimulating/infiltrated needles and nonstimulating catheter alone may have taken less time than using a stimulating catheter as in our study, possibly producing a similar procedure time to US guidance alone.20 Procedural times for US-guided and stimulation-guided, single-injection, popliteal-sciatic nerve blocks, without perineural catheter placement, have not demonstrated a statistically significant difference. For

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this study on perineural catheters, we elected to use stimulating catheters as there is evidence that for sciatic catheters placed in the popliteal fossa without US, stimulating catheters result in superior postoperative analgesia and decreased opioid requirements. At the time of this writing, we are not aware of any randomized studies comparing the insulated needle and non-stimulating catheter technique to US guidance.

Importantly, the 2 methods of perineural catheter placement compared in this study were different in many ways and clearly distinguish one method versus the other (eg, local anesthetic was injected via the needle in the US group and via the catheter for the ES group). Such differences were accepted before study initiation as we used our current clinical protocols for both US- and ES-guided perineural catheter placement. However, the optimal insertion techniques for both US and ES are currently undefined, and undoubtedly, our choices affected the study results.

Another limitation is the use of trainees to place all but one of the perineural catheters included in this study. This theoretically may have led to prolonged procedural times. However, each of the trainees involved in the placement of perineural catheters for this study was supervised one-on-one by an attending physician who was facile with both placement techniques to minimize the training effect. In fact, the use of trainees to perform the procedures may have actually been an advantage in retrospect, demonstrating the relative ease of acquiring US-guided regional anesthesia skills while still performing CPNBs in a timely fashion. Of interest, subjects randomized to the US group were heavier in a statistically significant degree compared with those in the ES group (median of 100 vs 79 kg, *P* = 0.02). Our past experience suggests that this difference should have biased the results in favor of the ES group, and therefore, the finding that US resulted in a 5-min time savings may be an underestimation when comparing the 2 techniques. Lastly, the results of this study should not be inferred to other perineural catheter insertion sites as perineural anatomy directly affects catheter insertion and inflation characteristics.

In summary, placement of popliteal–sciatic perineural catheters takes less time and is less painful for patients when performed under US guidance rather than ES. Although differences in postoperative analgesia between the 2 techniques were not detected, the risk of a type II error is high, given that these were secondary end points, and these results require confirmation with a future study.

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REFERENCES


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