Ultrasound-Guided Popliteal Block Through a Common Paraneural Sheath Versus Conventional Injection

A Prospective, Randomized, Double-blind Study

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Background and Objectives: The macroscopic anatomy of a common paraneural sheath that surrounds the sciatic nerve in the popliteal fossa has been studied recently in human cadavers. It has been suggested that an injection through this sheath could be an ideal location for local anesthetic administration for popliteal block. The aim of the present study was to evaluate the hypothesis that popliteal sciatic nerve blockade through a common paraneural sheath results in shorter onset time when compared with conventional postbifurcation injection external to the paraneural tissue. To illustrate the macroscopic anatomy of the paraneural tissue, we performed histological examinations of a human leg specimen.

Methods: Following institutional review board approval and written informed consent, 89 patients undergoing an ultrasound-guided popliteal block for foot or ankle surgery were included in the study. They were prospectively randomized to receive a single injection of local anesthetic at the site of bifurcation through a common paraneural sheath (group 1) or 2 separate circumferential injections of the tibial and common peroneal nerves distally to sciatic nerve bifurcation (group 2).

Results: Patients in group 1 had a 30% shorter onset time of both sensory and motor block. This was associated with a more extensive proximal and distal longitudinal spread of local anesthetic in this group. Nerve diameter and cross-sectional area remained unchanged in both groups after injection; which is consistent with extraneural injection. A greater proportion of patients in group 1 required a single needle pass for block performance.

Discussion: An ultrasound-guided popliteal sciatic nerve block through a common paraneural sheath at the site of sciatic nerve bifurcation is a simple, safe, and highly effective block technique. It results in consistently short onset time, while respecting the integrity of the epineurium and intraneural structures.

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Clinical Study

The study protocol was registered at clinicaltrials.gov (ID no. NCT01568476). There were no changes to the clinical study protocol after registration. After institutional review board approval, patients scheduled to undergo elective foot or ankle surgery and eligible for a popliteal block were invited to participate in this prospective study. Inclusion criteria were American Society of Anesthesiologists physical status I, II, or III; 18 to 85 years of age; weight of 50 to 120 kg; and height of 150 cm or greater. Exclusion criteria were allergy to local anesthetics, coagulopathy, malignancy or infection in the popliteal area, significant peripheral neuropathy or neurological disorder, pregnancy, and a history of...
of alcohol or drug dependency. After providing written informed consent, patients were randomized into 2 study groups according to a computer-generated list of random numbers. Randomization codes were held by an independent investigator not involved in block procedures. Group allocation was concealed in sealed opaque envelopes until the surgical date. Patients and investigators performing outcome assessments were blinded to group allocation.

One hour before the expected surgical time, peripheral intravenous access was established, and an infusion of normal saline started at a maintenance rate. Routine electrocardiogram, noninvasive blood pressure, and pulse oximeter monitors were applied, and baseline readings obtained. Midazolam 1 mg to 3 mg was intravenously administered for anxiolysis as necessary. Patients were placed in the prone position. All regional blocks were performed by staff, fellow anesthesiologists, or senior residents under staff supervision. The skin over the popliteal fossa was sterilized with disposable swabs of 2% chlorhexidine in 70% isopropyl alcohol. A Philips CD50 ultrasound unit (Philips, Andover, Massachusetts) or SonoSite M-Turbo ultrasound unit (SonoSite Inc, Bothell, Washington) with a high-frequency (5–12 or 6–13 MHz) linear array transducer was used. A 50-mm, 22-gauge stimulating needle (B. Braun, Bethlehem, Pennsylvania) was used for every patient. Skin was infiltrated with 2 to 3 mL of 2% lidocaine. A standard local anesthetic solution of equal parts of lidocaine 2% plain and bupivacaine 0.5% with 1:200,000 epinephrine was used for a total volume of 30 mL. The sciatic nerve was identified in a transverse plane, between the semitendinosus and semimembranosus muscles medially, and the biceps femoris laterally. The nerve was followed distally along its course, until the tibial and common peroneal nerves start to diverge.

Group 1

The block was performed at the site of sciatic nerve bifurcation. Given the large size of the sciatic nerve, the paranuclear sheath is substantial at this level and recognizable with ultrasound as an outer layer of mixed echogenicity surrounding the nerve (Figs. 1A and B). As the 2 terminal nerves start to diverge from each other, there is a natural point of cleavage that allows easy penetration of the paranuclear sheath with a short bevel needle in an out-of-plane approach. The needle end point was to lie between the TN and CPN within the common paranuclear sheath and external to the epineurium of each individual nerve. After negative aspiration, the standard anesthetic solution was injected as a single injection within the sheath compartment in 5-mL increments for a total volume of 30 mL, ensuring local anesthetic spread between and around the 2 nerves.

Group 2

The TN and CPN were followed distally along their course until they clearly become 2 separate entities no longer sharing a common paranuclear sheath (Figs. 2A and B). At this point, the block needle was advanced in either an out-of-plane or in-plane approach as considered necessary by the attending anesthesiologist. Following negative aspiration, 15 mL of standardized local anesthetic solution was injected around each TN and CPN separately.
ensuring circumferential local anesthetic spread around each nerve, for a total volume of 30 mL. At this level, even though a paraneural sheath accompanies each nerve separately, it is intimately related to each nerve’s epineurium and difficult to distinguish consistently on ultrasound image. Therefore, the operators did not specifically attempt to puncture the paraneural tissues, but rather they sought circumferential spread of local anesthetic as is standard practice for many peripheral nerve blocks.

The following data were recorded during the block procedure by an unblinded observer: procedure time, number of skin punctures, nerve diameter before and after injection, proximal and distal longitudinal spread of local anesthetic, and occurrence of any immediate block-related complications. Longitudinal local anesthetic spread was assessed by scanning proximally along the course of the sciatic nerve and distally along the 2 terminal branches. An upper and lower limit of spread as assessed by this dynamic scan were marked on the patient’s skin with a surgical marker, and both proximal and distal distances were measured from the skin puncture site using a surgical measuring tape. In addition, once the block procedure was complete, an independent observer blinded to group allocation assessed sensory and motor block progression every 5 minutes for 45 minutes or until complete block. Sensory function was assessed as sensation to pinprick in both the TN (plantar surface of the foot) and CPN (dorsum of the foot) territories. Sensation to pinprick was graded as 0 = no sensation to pinprick, 1 = decreased sensation to pinprick, or 2 = normal pinprick sensation. Motor function (plantar flexion for TN and dorsiflexion for CPN) was graded as 0 = no movement (complete block), 1 = movement present but weak (partial block), and 2 = normal movement. A composite sensory-motor score was obtained for each patient at each assessment time point by adding both sensory and motor scores in each nerve territory. A score of 8 represents full sensory and motor baseline function. A score of 0 represents complete loss of sensory and motor functions in the distribution of both target nerves. A thigh tourniquet was used for every patient during surgery, so after completion of the study assessments, patients received either a spinal or general anesthetic at the discretion of the attending anesthesiologist. Patients were contacted on the phone 24 hours and 1 week postoperatively to document any new motor or sensory deficits.

**Histological Examination**

To illustrate the anatomy of the sciatic nerve and its paraneural sheath, we performed a histological analysis of the area of interest in a human leg surgical specimen obtained from an above-knee amputation at the level of the mid-thigh. A separate research ethics board approval and approval by the local Department of Pathology were obtained. A detailed description of the technical aspects is included in Appendix 1.

**Sample Size Calculation and Statistical Analysis**

The mean onset time of sensory block for ultrasound-guided injections using similar local anesthetic doses distally to sciatic nerve bifurcation is approximately 21 ± 10 minutes. Based on our empirical clinical observations, we hypothesize a 30% reduction of the onset time when the block is performed through the common paraneural sheath at the site of bifurcation. Based on prior studies, we assume an SD of 10 minutes. For a 2-tailed α = 0.05 and a power of 80%, we estimate a required sample

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![FIGURE 3. Consort chart.](image-url)
TABLE 1. Demographics

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (n = 39)</th>
<th>Group 2 (n = 45)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, male-female ratio, n</td>
<td>20:19</td>
<td>25:20</td>
<td>0.36</td>
</tr>
<tr>
<td>Age, mean ± SD, y</td>
<td>42 ± 16</td>
<td>39 ± 14</td>
<td>0.42</td>
</tr>
<tr>
<td>Height, mean ± SD, cm</td>
<td>169 ± 12</td>
<td>171 ± 13</td>
<td>0.84</td>
</tr>
<tr>
<td>Weight, mean ± SD, kg</td>
<td>82 ± 21</td>
<td>82 ± 20</td>
<td>0.64</td>
</tr>
<tr>
<td>Body mass index, mean ± SD, kg/m²</td>
<td>29 ± 8</td>
<td>29 ± 7</td>
<td>0.65</td>
</tr>
<tr>
<td>Outpatient-impatient ratio</td>
<td>1.55</td>
<td>1.46</td>
<td>0.78</td>
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</table>

size of 40 patients per group. To allow for a 10% patient dropout, 89 patients were randomized. Continuous data, including age, height, weight, body mass index, block onset time, procedure time, local anesthetic spread, and nerve size, were summarized as mean ± SD and were compared using unpaired Student t test. Categorical data, such as sex, postoperative disposition, the incidence of complete block at 30 minutes, and the incidence of postoperative neurological symptoms, were expressed as either ratio or percentage, and distribution was compared using Mann-Whitney U test. SPSS for Windows, version 15.0 (SPSS Inc, Chicago, Illinois), was used for analysis.

RESULTS

Ninety-six patients were screened for participation in the study. Seven patients were excluded before randomization because of at least 1 exclusion criteria (n = 4) or because of logistical reasons (n = 3). The remaining 89 patients were randomized to either group 1 (n = 45) or group 2 (n = 46). Four patients in group 1 and 1 patient in group 2 were excluded after randomization (Fig. 3). Eighty-four patients completed study assessments and were included in the analysis. Both an intention-to-treat and a per-protocol analysis were performed with no change in the results with either approach.

Patient demographics were similar in both groups (Table 1). One patient in each group received a partial unintentional intraneural injection as determined by subepineural administration of local anesthetic with increase in nerve size. This was observed during the early phase of the injection, and the needle was repositioned to be extraneurally after less than 5 mL had been injected in either case. Neither of the 2 patients reported paresthesia at the time of injection, and neither patient sustained neurological deficits postoperatively. Even though intraneural injection was unintended, this may occur in clinical practice. Therefore, both patients completed all study assessments, and their data were included in the final analysis. Sensory and motor block onset times were approximately 30% shorter in group 1 versus group 2 (Table 2), and the combined sensory-motor score was lower in group 1 at every time point until 35 minutes after injection, denoting a faster block progression (Fig. 4). Procedure time (from the start of scanning to end of injection) was similar (about 6 minutes), and nerve size remained essentially unchanged in both groups throughout and at the end of injection (Table 3). A greater proportion of blocks were achieved with a single skin puncture in group 1 (87% vs 68%, P = 0.05). Four patients in group 1 and 1 patient in group 2 had residual sensory block by 24 hours. Neurological function had returned to baseline in all patients 7 days postoperatively at the time of the telephone interview.

The histological preparations show that the paraneural tissue is a large circumferential pad of well-vascularized adipose and connective tissue surrounding the sciatic nerve. At the site where the TN and CPN start to diverge, this paraneural tissue is shared by both TN and CPN (Figs. 5A and B). An injection of dye within this common paraneural sheath resulted in spread within the sheath, around both nerves, and external to the epineurium of the individual nerves, therefore preserving the integrity of the intraneural structures (Figs. 5 and 6). The dye spread diffusely and preferentially in the adipose tissue component of the paraneural sheath (Fig. 6). Beyond and distal to the point of nerve bifurcation, the paraneural sheath divides so that the TN and CPN are invested by their own individual sheath (Figs. 7A and B).

DISCUSSION

Sciatic nerve block at the popliteal fossa reduces postoperative pain and opioid requirements and improves patient satisfaction following outpatient foot and ankle surgery.5-7 Popliteal sciatic nerve block has been associated with variable success rates, often requiring high doses of local anesthetic, and a prolonged onset time, even with ultrasound guidance.8-10

TABLE 2. Results

<table>
<thead>
<tr>
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<th>Group 1 (n = 39)</th>
<th>Group 2 (n = 45)</th>
<th>P</th>
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<tbody>
<tr>
<td>Time to complete sensory block, mean ± SD, min</td>
<td>14 ± 9</td>
<td>21 ± 10</td>
<td>0.006</td>
</tr>
<tr>
<td>Time to complete motor block, mean ± SD, min</td>
<td>15 ± 11</td>
<td>23 ± 10</td>
<td>0.007</td>
</tr>
<tr>
<td>Complete block by 30 min, %</td>
<td>76</td>
<td>49</td>
<td>0.026</td>
</tr>
<tr>
<td>Procedure time, mean ± SD, min</td>
<td>8 ± 4</td>
<td>9 ± 3</td>
<td>0.77</td>
</tr>
<tr>
<td>Proximal local anesthetic spread, mean ± SD, cm</td>
<td>9.6 ± 3</td>
<td>8.2 ± 3</td>
<td>0.036</td>
</tr>
<tr>
<td>Distal local anesthetic spread, mean ± SD, cm</td>
<td>4.8 ± 2</td>
<td>3.7 ± 2</td>
<td>0.036</td>
</tr>
<tr>
<td>Total local anesthetic spread, mean ± SD, cm</td>
<td>14.1 ± 4</td>
<td>11.7 ± 4</td>
<td>0.008</td>
</tr>
<tr>
<td>Single skin puncture, %</td>
<td>87</td>
<td>68</td>
<td>0.05</td>
</tr>
<tr>
<td>Residual sensory block at 24 h, n (%)</td>
<td>4 (11)</td>
<td>1 (2)</td>
<td>0.122</td>
</tr>
<tr>
<td>Incidence of neurological symptoms at 7 d, n (%)</td>
<td>0</td>
<td>0</td>
<td>Not applicable</td>
</tr>
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Possible reasons postulated for such long onset time include a large nerve size (up to 2 cm in diameter) and a larger proportion of nonneuronal tissue as the sciatic nerve travels distally. It has been shown that blocking both terminal branches separately, distal to sciatic nerve bifurcation, shortens onset time for both posterior and lateral approaches. Circumferential local anesthetic spread has also been shown to affect onset time favorably.

Another possible reason for this slow onset is the existence of a substantial external paranuclear layer of connective and adipose tissue that surrounds the sciatic nerve along its course, which may constitute a relative barrier to local anesthetic spread. This external layer of paranuclear tissue has been recognized for many years, although inconsistent terminology has been used. Vloka et al named it “common epineurial sheath,” suggesting somehow that this layer may be part of or related to the epineurium. The term “paranuclear sheath” has been recently proposed by Andersen et al to describe this layer of extraneural tissue based on anatomic-sonographic correlation in human cadavers. In the study of Andersen et al, injection through this common paranuclear sheath resulted in extensive longitudinal spread of the local anesthetic around the nerves while remaining external to the epineurium of both terminal nerves, suggesting this may be an ideal location for local anesthetic deposition.

A recent study by Tran et al reported the effectiveness of what they called a “subepineurial” injection at the site of sciatic nerve bifurcation, suggesting these were intraneural injections. However, in contrast with this nomenclature, there was no change in nerve diameter upon injection, and the accompanying figures also suggest that these injections were in fact external to the epineurium (ie, into the paranuclear sheath). Consistent terminology with regard to nerve boundaries and surrounding tissues is important beyond semantics to ensure a common language when comparing different approaches or techniques.

This prospective clinical study aimed to establish the block characteristics of popliteal nerve block performed through this common paranuclear sheath (as described by Andersen) at the site of sciatic nerve bifurcation and to better characterize this sheath histologically in a human leg specimen. The paranuclear sheath around the sciatic nerve exists all along the thigh. Although local anesthetic could conceivably be injected through this sheath at any level, the site where the 2 terminal nerves start to diverge offers a natural point of cleavage between the nerves, where the sheath becomes sonographically more apparent. It appears on high-frequency ultrasound as a common layer of mixed echogenicity external to both the TN and CPN. This sheath can be easily punctured at the point of divergence between the 2 terminal nerves, and the local anesthetic injected as a single bolus to “bathe” both nerves fully, within this sheath compartment (Figs. 1 and 5). In our experience, an out-of-plane approach is ideally suited to penetrate this common paranuclear sheath at the site of bifurcation where the TN and CPN usually lie side by side.

Patients in the control group (group 2) received a conventional separate injection of both TN and CPN distal to sciatic nerve bifurcation with circumferential local anesthetic spread, as this has been associated with the shortest block onset times previously described. Although in group 1 an out-of-plane approach seems ideally suited to puncture the sheath at the bifurcation site, we feel the needle trajectory (in-plane

### TABLE 3. Nerve Size Before and After Injection

<table>
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<th>Group 1 (n = 39)</th>
<th>Group 2 (n = 45)</th>
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<tbody>
<tr>
<td></td>
<td>Preinjection</td>
<td>Postinjection</td>
<td></td>
</tr>
<tr>
<td>TN diameter, mm</td>
<td>6.7 ± 1.8</td>
<td>6.7 ± 1.8</td>
<td>0.981</td>
</tr>
<tr>
<td>TN area, mm²</td>
<td>40 ± 17</td>
<td>40 ± 18</td>
<td>1</td>
</tr>
<tr>
<td>CPN diameter, mm</td>
<td>6.1 ± 1.6</td>
<td>5.9 ± 2.0</td>
<td>0.657</td>
</tr>
<tr>
<td>CPN area, mm²</td>
<td>33 ± 16</td>
<td>32 ± 23</td>
<td>0.963</td>
</tr>
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</table>

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or out-of-plane) is not as crucial when blocking 2 individual nerves separately (group 2). Depending on the specific patient anatomy, an in-plane or an out-of-plane approach may be preferable. Thus, we left the needle orientation for group 2 at the discretion of the attending anesthesiologist.

The results confirm our hypothesis that blockade through a common paraneural sheath at the site of sciatic nerve bifurcation is associated with faster onset of sensory (and motor) block than distal blockade (Table 2). One possible reason for this faster onset and predictable success is that this space of loose connective tissue provides a sort of conduit around the nerves. The longitudinal spread of the local anesthetic solution was 30% more extensive in group 1 versus group 2, resulting in a larger surface area of contact with the local anesthetic solution (Table 2). Even though on first appearance the results from our study seem to contradict previous findings comparing proximal to distal injections,3,4 the key difference from previous studies is that here the paraneural sheath is specifically identified and penetrated to deposit the local anesthetic in a more intimate contact with the external surface of the nerves' epineurium.

Nerve size (diameter and cross-sectional area) remained unchanged in both groups after local anesthetic injection, which is consistent with extraepineural (extraneural) needle placement (Table 3). This is desirable to minimize the possibility of mechanical nerve injury and contribute to safety.

In addition, this technique is simple to perform. As the 2 nerves typically lie side by side in a medial to lateral sense, with the patient in the prone position, a blocking needle advanced in an out-of-plane approach punctures the paraneural sheath in the plane of separation between the 2 nerves. Eighty-seven percent of blocks in group 1 were achieved with a single needle puncture (vs 65% in group 2), and minimal or no needle manipulation was required.

Our results are very similar to the findings of Tran and colleagues,15 which further suggests to us that we are indeed describing a similar technique with different nomenclature rather than 2 conceptually different blocks.

Limitations of the present study include the fact that, like most procedure-related studies, it is not possible to blind the operator to group allocation. To minimize the possibility of bias,
16 different operators (most of whom were unrelated to the study) performed the block procedures. In addition, assessment of functional function and documentation of study outcomes were carried out by an independent investigator blinded to group allocation whenever feasible as described. Despite these measures, performance bias may not be completely ruled out.

Another limitation is that we studied analgesic blocks. The administration of concomitant general or spinal anesthesia does not allow us to comment on the suitability of these blocks to provide surgical anesthesia, or to study the rate of "conversion to general anesthesia."

In conclusion, even though no neurological deficits were reported in any patient, nerve injury is a rare complication of peripheral nerve blockade, and this study is not powered to detect clinically meaningful differences with regard to safety.

In contrast, the results of this study suggest that an injection through a common paraneural sheath at the site of sciatic nerve bifurcation is simple and highly effective. It results in a faster onset of sensory and motor blockade than previously reported approaches without an increase in the incidence of intraneural injection. Although there is likely more than 1 safe and effective approach to any nerve block, a single injection through the common paraneural sheath of the sciatic nerve complies with most of the metrics associated with the "best" local anesthetic deposition site for popliteal block. Our data suggest that this is possibly due to an optimal local anesthetic spread within this common sheath, ultimately surrounding the epineurium of both nerves and resulting in enhanced longitudinal spread.

REFERENCES


APPENDIX 1

Technical Aspects of Histological Study

Using a similar technique and equipment as described for the clinical study, the sciatic nerve was identified under ultrasound and followed distally from the midthigh to the popliteal fossa, where the site of bifurcation, the TN, CPN, and common paraneural sheath were identified. An insulated 50-mm, 22-gauge regional anesthesia needle (Stimuplex; B. Braun) was advanced under ultrasound guidance through the paraneural sheath and placed between the 2 nerves (as in group 1). Ten milliliters of black Surgipath Tissue Marking & Margin Dye solution (Leica, Buffalo Grove, Illinois) were injected at this site. Following injection, the superficial tissues of the popliteal fossa were dissected from the skin down to the vicinity of the sciatic nerve. The sciatic nerve was excised from the macroscopically apparent bifurcation point down to 3 cm distally. The excision was performed “en block” to include the immediate paraneural tissues. The sample was fixed and embedded in paraffin, and 6-μm sections were stained with hematoxylin/eosin and prepared for histology as per standard institutional practice. The sections were then scanned with Aperio digital slide scanner at 20× magnification for further histological analysis.