Correlation between Evoked Motor Response of the Sciatic Nerve and Sensory Blockade

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Background: Incomplete sensory blockade of the foot after sciatic nerve block in the popliteal fossa may be related to the motor response that was elicited when the block was performed. We investigated the appropriate motor response when a nerve stimulator is used in sciatic nerve block at the popliteal fossa.

Methods: Six volunteers classified as American Society of Anesthesiologists' physical status I underwent 24 sciatic nerve blocks. Each volunteer had four sciatic nerve blocks. During each block, the needle was placed to evoke one of the following motor responses of the foot: eversion, inversion, plantar flexion, or dorsiflexion. Forty milliliters 1.5% lidocaine was injected after the motor response was elicited at < 1 mA intensity. Sensory blockade of the areas of the foot innervated by the posterior tibial, deep peroneal, superficial peroneal, and sural nerves was checked in a blinded manner. Motor blockade was graded on a three-point scale. The width of the sciatic nerve and the orientation of the tibial and common peroneal nerves were also examined in 10 cadavers.

Results: A significantly greater number of posterior tibial, deep peroneal, superficial peroneal, and sural nerves were blocked when inversion or dorsiflexion was seen before injection than after eversion or plantar flexion (P < 0.05). Motor blockade of the foot was significantly greater after inversion. Anatomically, the tibial and common peroneal nerves may be separate from each other throughout their course. The sciatic nerve ranged from 0.9–1.5 cm in width and was divided into the tibial and common peroneal nerves at 8 ± 3 (range, 4–13) cm above the popliteal crease.

Conclusions: Inversion is the motor response that best predicts complete sensory blockade of the foot. Incomplete blockade of the sciatic nerve may be a result of the size of the sciatic nerve, to separate fascial coverings of the tibial and common peroneal nerves, or to blockade of either the tibial or common peroneal nerves after branching from the sciatic nerve. (Key words: Anesthetic technique, regional; sciatic. Anatomy: sciatic nerve; popliteal fossa.)

BLOCKADE of the sciatic nerve in the popliteal fossa provides satisfactory analgesia for operative procedures of the foot.[1] To locate the sciatic nerve, we use a peripheral nerve stimulator[2,3] to elicit one of the following motor responses in the foot: inversion, eversion, plantar flexion, or dorsiflexion. To assure proximity of the needle to the sciatic nerve, the local anesthetic is injected only if the motor response is elicited at <1 mA.[2,4,5] Despite this, we have noted that sensory blockade of the foot is sometimes incomplete. We have theorized that, in these cases, the blockade of the sciatic nerve was incomplete or that only one of the major branches of the sciatic nerve was blocked. Thus we assessed, in a blinded manner, the adequacy of sciatic nerve blockade in the popliteal fossa in relation to the motor response that was elicited by the nerve stimulated during needle placement. To better explain our findings, we also examined the anatomy of the sciatic nerve and its branches in 10 cadavers.

Materials and Methods

The study was approved by the Institutional Review Board of Northwestern University. We studied six volunteers classified as American Society of Anesthesiologists' physical status I after they gave written informed consent. Monitoring during the study included blood pressure, electrocardiogram, and pulse oximetry.

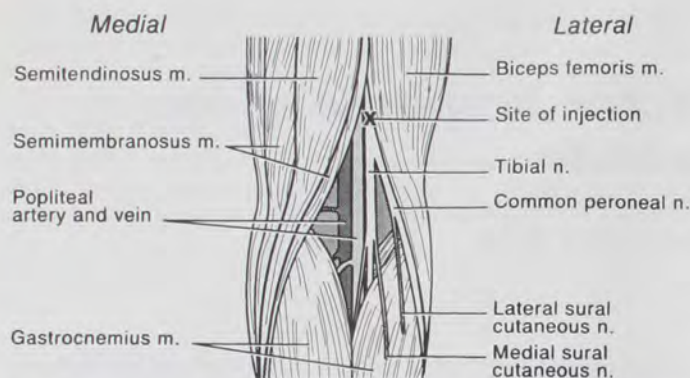After baseline sensory and motor examinations of the

BENZON *ET AL.*

Fig. 1. Anatomy of the popliteal fossa and technique of sciatic nerve blockade (see text for details of the technique).

foot, blockade of the sciatic nerve in the popliteal fossa was performed according to the technique of Rorie *et al.*[1] Each volunteer was positioned prone and the popliteal fossa was aseptically prepared and draped. An insulated 22-gauge regional block needle was inserted through a skin wheal at a point 7 cm superior to the crease behind the knee and one cm lateral to a line that bisected the superior part of the popliteal fossa (fig. 1). The needle was connected to the negative (cathodal) electrode of the nerve stimulator[2,3] (Braun Stimuplex-DIG; B. Braun Medical, Bethlehem, PA), and the stimulating current was set between 2–3 mA. The needle was inserted at a 45-degree angle to the skin of the popliteal fossa, with the tip of the needle pointing cephalad, and advanced to a depth of 2.5–4 cm until maximum motor response, either eversion, inversion, plantar flexion, or dorsiflexion of the foot was elicited. The stimulating current was then decreased to elicit a motor response with the smallest possible current.[2] The needle was considered to be close to the nerve when the stimulating current was < 1 mA.[2,5] The proximity of the needle to the nerve was confirmed when an injection of 1 or 2 ml local anesthetic caused an immediate cessation of the elicited motor response.[2,6,7] Forty milliliters 1.5% lidocaine was then injected.

One of the investigators who was not involved in performing the block used a pin prick to assess sensory blockade of the skin subserved by branches of the sciatic nerve, namely the posterior tibial, superficial peroneal, deep peroneal (also called the anterior tibial), and the sural nerve (fig. 2).[8–10] Assessments of sensory blockade were done every 2–3 min for 30 min and then every 15 min until there was complete sensory recovery. The occurrence of a qualitative change in response to pin prick in a nerve territory was considered to be the onset of sensory blockade of that nerve.

The extent of sensory blockade of each nerve was classified as follows. (1) Complete: Sensory blockade of the entire territory of a nerve was considered as equal to complete blockade of the subserving nerve. (2) Incomplete: Patchy sensory blockade of the nerve territory was considered an incomplete block of the subserving nerve. (3) No block: The absence of any sensory blockade and no blockade of the nerve. The number of nerve territories (*i.e.*, nerves) that were completely blocked, incompletely blocked, or not blocked was tabulated.

If a sciatic nerve block resulted in complete blockade of the territories subserved by the posterior tibial, deep peroneal, superficial peroneal, and sural nerves, then the number of completely blocked nerves was counted as four with that elicited motor response. If there is a similar degree of success in all six volunteers, then the number of nerves blocked is 24 for that elicited motor response.

The degree of motor blockade was checked every 5 min for 30 min and graded on a three-point scale: 0 = normal strength, 1 = reduced strength, 2 = no strength.[11]

Each volunteer underwent four sciatic nerve blocks, one for each of the following elicited motor responses of the foot: eversion, inversion, plantar flexion, and dorsiflexion. Only one elicited motor response was studied per session, with an interval of at least 1 week between study sessions.

The sequence of elicited motor response was not randomized, nor was the desired motor response predetermined before each study session. Rather, we studied the motor response that was elicited first during each study session, ignoring any previously studied motor response for that volunteer. When this did occur, we redirected the needle either medially or laterally until we elicited one of the motor responses remaining to be studied. Medial or lateral redirection of the needle depended on (1) knowledge of the foot movement that results from stimulation of the different nerves (*i.e.*, inversion is caused by stimulation of the tibial and deep peroneal components of the sciatic nerve, eversion results from stimulation of the superficial peroneal nerve, plantar flexion from stimulation of the posterior tibial nerve, and dorsiflexion from stimulation of the deep peroneal nerve[12,13]), and (2) knowledge of the medial location of the tibial nerve and lateral location of the common peroneal nerve, within the sciatic nerve. For

Fig. 2. Cutaneous nerve innervation of the foot (adapted from Brown[10]).
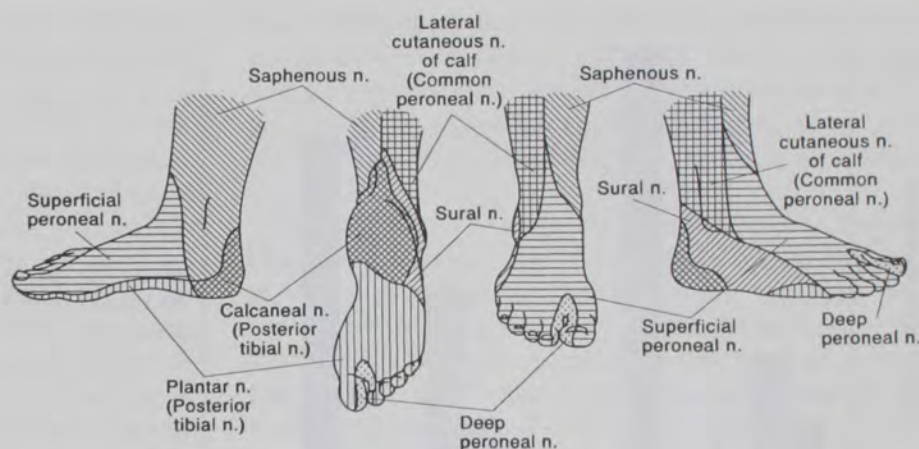
example, if elicited plantar flexion had already been studied, then the needle was redirected slightly laterally to stimulate the tibial and deep peroneal nerves eliciting inversion, or further laterally to stimulate the superficial peroneal nerve, eliciting eversion. If elicited eversion had already been studied, then the needle was redirected medially to stimulate both the deep peroneal and tibial nerves and elicit inversion, or even more medially to stimulate the tibial nerve and elicit plantar flexion.

The times of onset and the number of nerves that were completely blocked, incompletely blocked, and not blocked are non-normally distributed interval data. Therefore these data are reported as medians and ranges. Statistical differences were sought using the Friedman statistic; *post hoc* comparisons were performed using the Wilcoxon signed-rank test[14] with Bonferroni correction for multiple application to the same data. All other data are reported as mean ± SD. The criterion for rejection of the null hypothesis was $P < 0.05$.

Results

The six volunteers included four men and two women, aged 28–48 (33 ± 7.6) yr; they were 162.5–174 (169.4 ± 7) cm tall and weighed 48–102 (72 ± 18) kg. The distance from the popliteal skin crease to the apex of the fossa was 12–13 (12.3 ± 0.5) cm. Twenty-four blocks were performed; every volunteer had four blocks, one block after elicited eversion, inversion, plantar flexion, and dorsiflexion.

The vital signs of the volunteers were stable throughout the study. All the volunteers were sleepy during the study despite the absence of sedative or analgesic agents. They did not exhibit other signs of local anesthetic systemic toxicity.

The sum of the number of nerves blocked (posterior tibial, deep peroneal, superficial peroneal, and sural nerves) after elicited inversion and after elicited dorsiflexion were significantly greater ($P < 0.05$) than the number of nerves blocked after elicited eversion or elicited plantar flexion (fig. 3). There was no statistical difference in the number of nerves blocked between elicited inversion and elicited dorsiflexion or between elicited eversion and elicited plantar flexion.

The onsets of sensory blockade were significantly faster ($P < 0.05$) after elicited inversion (median, 5; range, 2–10 min) compared to elicited eversion (15; 5–>30 min) and elicited plantar flexion (13.5; 2–>30 min). The onsets of sensory blockade after elicited dorsiflexion (6.5; 2–23 min) were significantly faster ($P < 0.05$) than the onsets of blockade after elicited eversion and elicited plantar flexion. There was no significant difference in the onsets of sensory blockade between elicited inversion and elicited dorsiflexion and between elicited eversion and elicited plantar flexion.

Motor blockade was greatest after elicited inversion (median, 2; range, 2–2), followed by dorsiflexion (2; 1–2), eversion (1; 1–2), and plantar flexion (1; 0–1). Motor blockade was significantly greater ($P < 0.05$) after elicited inversion compared with elicited eversion or elicited plantar flexion and after elicited dorsiflexion compared with elicited plantar flexion. There was no difference in the degree of motor blockade between elicited inversion and elicited dorsiflexion.

The results of our cadaver dissections are included in the Discussion section.
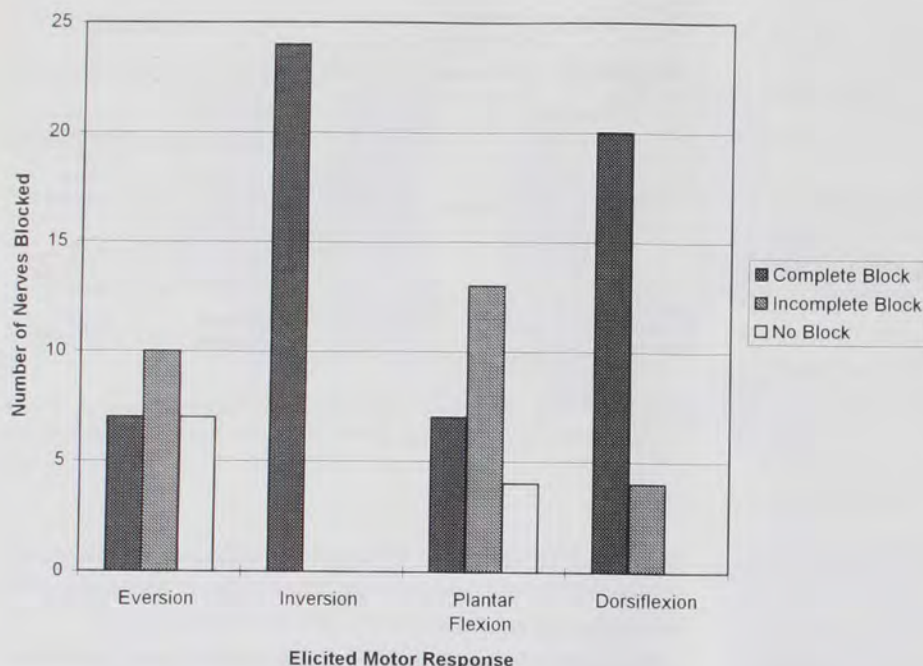
Fig. 3. Total number of nerves that were completely blocked, incompletely blocked, or not blocked after four study sessions in six volunteers. Each volunteer had four blocks, and four nerves (posterior tibial, deep peroneal, superficial peroneal, and sural nerves) can be blocked during each study session. Therefore, the maximum total number of nerves that can be blocked with each elicited motor response in the six volunteers is 24. See the text for statistical comparisons.

Discussion

Eliciting a paresthesia is a recommended technique for blocking the sciatic nerve in the popliteal fossa.[1] An alternative is to use a nerve stimulator and elicit motor response in the foot as an indication of the proximity of the needle to the nerve. Because each major branch of the sciatic nerve subserves different muscle groups,[12,13] the location of the needle is reflected in the particular motor response obtained when the stimulating current is applied. Thus we performed this study to identify which motor response of the foot best predicts complete sensory blockade of all the branches of the sciatic nerve, and hence the foot.

We showed that inversion is the elicited motor response that best predicts complete sensory blockade of the foot. Inversion of the foot is due to the action of both the tibialis posterior muscle, which is innervated by the tibial nerve, and the tibialis anterior muscle, which is innervated by the deep peroneal nerve.[12,13] The completeness of blockade of the foot with elicited inversion thus is due to the proximity of the needle to both these branches of the sciatic nerve or to the sciatic nerve itself before it gives rise to its major branches. Eversion is due to action of the peroneus muscles, which are innervated by the superficial peroneal nerve.[12,13] This explains the incomplete sensory blockade with elicited eversion; only the areas supplied by

the superficial peroneal nerve and the sural nerve were blocked in most cases.

Dorsiflexion of the foot is due to action of the muscles supplied by the deep peroneal nerve.[12,13] In our study, complete sensory blockade in 20 of 24 nerve territories was obtained with elicited dorsiflexion. In cadaver dissections, we found that the deep peroneal nerve occupies the medial position within the common peroneal nerve; that is, it lies between the tibial nerve medially and the superficial peroneal nerve laterally. Medial and lateral spread of the injected local anesthetic was probably adequate to block the tibial, deep peroneal, and the superficial peroneal nerves.

Plantar flexion results from action of the muscles supplied by the tibial nerve or the muscles supplied by the superficial peroneal nerve.[12,13] Sensory blockade with elicited plantar flexion thus may appear as blockade of the tibial nerve and its branches or as blockade of the superficial peroneal nerve and its branches. This was confirmed in our clinical study. Numbness after plantar flexion involved either the areas supplied by the posterior tibial nerve, the superficial peroneal nerve, or the sural nerve (the sural nerve is formed mainly by the tibial nerve and receives a sural communicating branch from the common peroneal nerve).

The ability of the local anesthetic to anesthetize the sciatic nerve and all its major branches thus appears to depend on the anatomic relation between the injecting

needle and the sciatic nerve and its major branches. With the needle at the deep peroneal nerve, near the superficial peroneal and tibial nerves, eliciting dorsiflexion, 40 ml local anesthetic was adequate to block both branches of the sciatic nerve. When the needle was located more laterally, near the superficial peroneal nerve eliciting eversion, or more medially, near the tibial nerve eliciting plantar flexion, it was not adequate to block the tibial and common peroneal nerves. Our cadaver dissections showed that the tibial nerve was located medially and the superficial peroneal nerve was located laterally within the sciatic nerve. The size of the sciatic nerve (0.9 - 1.5 cm), the thickness of its epineurium,[15] and the presence of fat in the popliteal space[8] may explain the inability of the local anesthetic to completely block the nerve when the injection is done with the needle at either side of the nerve. Inadequate sensory blockade of the sciatic nerve has been noted after elicitation of paresthesia involving only one of the major branches of the nerve.[8] Conversely, a faster onset and a more complete blockade of the sciatic nerve has been noted when action of the muscles supplied by the tibial and common peroneal nerves was elicited.[11]

Several authors recommend inserting the needle 5 - 10 cm above the crease at the popliteal fossa.[1,5,8,10] Insertion of the needle at this level is no guarantee that it is proximal to where the sciatic nerve gives off its major branches. We found in our cadaver dissections that the sciatic nerve may divide at any point between 4 and 13 cm above the popliteal crease. We also found that the tibial and common peroneal nerves may be two separate nerves throughout their course, each with its own fascia. Thus elicitation of inversion as the motor response assures blockade of both major branches of the sciatic nerve regardless of the level of insertion of the needle.

All the volunteers became sleepy, presumably from a slow increase in the plasma levels of lidocaine from absorption of the 600 mg lidocaine that we used. This dose was an overdose, especially in the smaller volunteers, based on a recommended maximum dose of 5 mg/kg for plain lidocaine and 7 mg/kg for lidocaine with epinephrine.[16] Other investigators have used 600 mg plain lidocaine,[6] and 650 - 680 mg lidocaine with epinephrine[17,18] in their peripheral nerve blocks without clinical toxicity. Of note, use of 35 mg/kg lidocaine has been reported for liposuction.[19] Doses higher than recommended have also been used for bupivacaine.[20-22] One study reported toxic blood levels of bupivacaine.[21] The absence of clinical signs of toxicity in these stud-

ies[6,17-22] shows that local anesthetic toxicity is influenced by several factors, including the dose and the rate of injection, the concentration of the drug used, the use of vasoconstrictors, the vascularity of the site injected, and the vasoactivity of the local anesthetic drug.[22]

The volume of local anesthetic recommended for this block ranges from 35 to 45 ml.[1,8] Since the completion of the study and based on our results, we have performed blocks with inversion as the elicited motor response and observed complete sensory blockade of the foot with 30 ml lidocaine. (We also found that 30 ml is effective with elicited inversion/plantar flexion, a similarly effective combined motor response that we did not assess in this study.) The feasibility of using a smaller volume and a lower concentration (1%) of lidocaine (thus reducing the risk of toxicity), with elicited inversion as the motor response, needs to be investigated.

In summary, we found that elicited inversion is the motor response that predicts prompt and complete sensory blockade of the foot when sciatic nerve block in the popliteal fossa is performed. Sensory blockade after elicited dorsiflexion is complete in most, but not in all, cases. Sensory blockade after elicited plantar flexion or elicited eversion is incomplete. Thus we recommend using elicited inversion as the motor response when trying to block the sciatic nerve in the popliteal fossa.

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