

# Intraneural Injection with Low-Current Stimulation During Popliteal Sciatic Nerve Block

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**BACKGROUND:** Prevention of an intraneural injection of a local anesthetic during peripheral nerve blockade is considered important to avoid neurologic injury. However, the needle-nerve relationship during low-current electrical nerve localization is not well understood.

**METHODS:** We postulated that intraneural needle tip location is common during low-current stimulation popliteal sciatic nerve blockade. Twenty-four consecutive ASA class I-III patients scheduled for foot or ankle surgery under popliteal sciatic nerve block using a combined ultrasound and nerve stimulator-guided technique were prospectively studied. The end point for needle advancement was predetermined to be either an elicited motor response between 0.2 and 0.5 mA (100  $\mu$ s/2 Hz) or an apparent intraneural location of the needle tip as seen on ultrasound, whichever came first. The injection occurred at either end points provided the injection pressure was <20 psi. The injection was considered intraneural when injectate resulted in both the swelling and compartmentalization of the nerve within the epineurium.

**RESULTS:** Elicited motor response could be obtained only upon entry of the needle into the intraneural space in 20 patients (83.3%). In the remaining four patients (16.7%), a motor response with a stimulating current of 1.5 mA could not be obtained even after the needle entry into the intraneural space. An injection in the intraneural space occurred in all patients who had motor-evoked response at current 0.2–0.4 mA. All 24 blocks resulted in adequate anesthesia for foot surgery. No patient developed postoperative neurologic dysfunction.

**CONCLUSION:** The absence of motor response to nerve stimulation during popliteal sciatic nerve block does not exclude intraneural needle placement and may lead to additional unnecessary attempts at nerve localization. Additionally, low-current stimulation was associated with a high frequency of intraneural needle placement.

(Anesth Analg 2009;109:673–7)

Preventing an intraneural injection of a local anesthetic (LA) during peripheral nerve blockade is considered important to avoid neurologic injury.<sup>1,2</sup> However, recent reports suggest that an intraneural injection may not inevitably lead to a neurologic complication.<sup>3</sup> The recent introduction of ultrasound guidance for needle placement during peripheral nerve block has significantly contributed to our understanding of the needle-nerve relationship, because of the ability to visualize needle position and monitor the spread of LA.<sup>4</sup> In this

study, we combined nerve stimulator-guided localization of the sciatic nerve in the popliteal fossa with ultrasound monitoring to determine the location of the needle tip at the point when an evoked motor response of the sciatic nerve was obtained during low-current intensity nerve stimulation (a minimum current between 0.2 and 0.5 mA) to determine the likelihood of an intraneural needle placement during popliteal sciatic nerve block.

## METHODS

After IRB approval and written informed patient consent, 24 consecutive ASA class I-III patients (17–64 yr) scheduled for foot or ankle surgery under combined ultrasound and nerve stimulator-guided popliteal sciatic nerve block were recruited in the study for over a 3-mo period. Patients with a history of allergy to LA, infection at the site of injection, coagulopathy, neurologic deficit in the ipsilateral extremity, or patients who refused to participate were excluded. All patients received a 20-gauge IV catheter and an infusion of lactated Ringer's solution. The popliteal sciatic nerve block was performed after premedication consisting of midazolam 1–4 mg and alfentanil 250–500  $\mu$ g. The premedication was adjusted for individual

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Accepted for publication February 25, 2009.

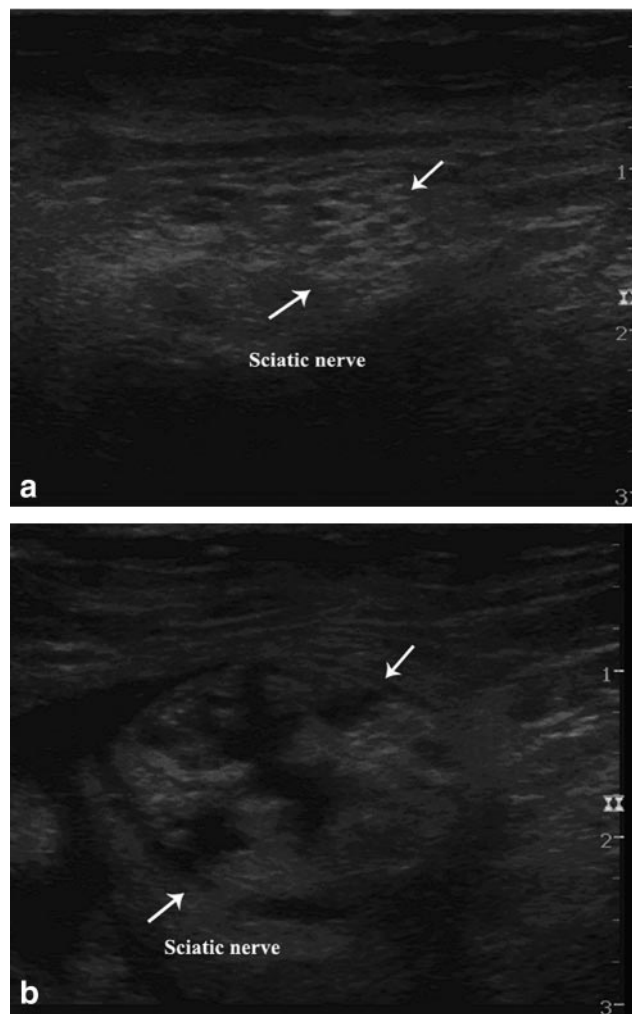
Drs. Hadzic and Gadsden have advised for B. Braun, GE Healthcare, Sonosite, and AstraZeneca. Dr. Hadzic is a shareholder of Macosta Medical USA.

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DOI: 10.1213/ane.0b013e3181aa2d73

patients to decrease their anxiety and discomfort from the procedure, while maintaining meaningful patient contact. With the patient in a supine position with his or her leg elevated and after skin disinfection, an ultrasound probe (LOGIQe equipped with a 38-mm linear array, 5–13-MHz probe; General Electric, Milwaukee, WI) was positioned in the popliteal fossa to visualize the sciatic nerve in cross-section. After locating the optimal point for needle insertion (lateral aspect of the leg just cephalad to where the sciatic nerve bifurcates into the common peroneal and tibial nerves), a 10-cm long, 21-gauge needle (Stimuplex, BBraun Medical, Bethlehem, PA) connected to a nerve stimulator (Life-Tech, Tracer III, NL-3, Stafford, TX) was advanced toward the sciatic nerve using an in-plane technique at an initial current setting of 1.5 mA (100  $\mu$ s/2 Hz). The end point for needle advancement was predetermined to be either an elicited motor response of the foot (plantar flexion, foot inversion, dorsiflexion, or foot eversion) between 0.2 and 0.5 mA, or an intraneural location of the needle tip as assessed with ultrasound imaging, whichever came first. The injection occurred at either end points provided, and the injection pressure was <20 psi. When an elicited motor response was obtained, an attempt was made to decrease the stimulating current to 0.2–0.5 mA while maintaining the motor response with the needle in a fixed position. After decreasing the stimulating current to the point of twitch extinction, LA was injected using 20-mL syringes connected to an in-line injection pressure monitor (BSmart™, Concert Medical, Norwell, MA) at a rate of approximately 20 mL/min. The spread of LA confirmed the position of the needle tip, using in-plane ultrasound imaging. In the absence of an injection pressure of >20 psi or pain on injection, 30–40 mL of LA without additives was injected in an incremental fashion with negative aspiration every 5 mL. When the initial injection pressure was >20 psi or when the patient experienced pain or paresthesia, the needle was either rotated 45° clockwise or slightly withdrawn (1 mm), and the injection was reattempted. The type and concentration of LA was chosen to best fit the clinical indication for the popliteal sciatic nerve block. Clinical motor and sensory testing were performed (plantar or dorsiflexion and pinprick to sole of foot) to assess block success. However, popliteal sciatic nerve block was defined as being successful when adequate surgical anesthesia was obtained using popliteal sciatic nerve block as the sole anesthetic with mild intraoperative sedation (propofol 15–50  $\mu$ g · kg<sup>-1</sup> · min<sup>-1</sup>). A supplemental saphenous block was performed by simple local infiltration of 10 mL of 0.5% ropivacaine just above the medial ankle.

Before and after ultrasound images were independently reviewed by two faculty members with experience in ultrasound-guided popliteal sciatic nerve block and who were blinded to the details of the nerve block



**Figure 1.** (a) Sciatic nerve in popliteal fossa before injection of the local anesthetic. (b) Sciatic nerve in the popliteal fossa after injection of the local anesthetic. The sciatic nerve appears swollen after the injection; the local anesthetic is seen as echo-lucent irregular areas within the sciatic nerve. Leakage outside the nerve is also seen to the left of the image.

procedure, a concurrence between the two reviewing faculty members was required to label the injection as intraneural. Ultrasound video clips of the sciatic nerve in the popliteal fossa were captured before and after injection (Fig. 1a). The antero-posterior diameter of the sciatic nerve was measured to evaluate nerve expansion due to intraneural injection. An injection was considered perineural when it occurred outside the epineurium and intraneural when the injection occurred within the epineurium and when injectate resulted in both swelling and compartmentalization of the nerve (Fig. 1b). The patients were followed up at 24 and 48 h after popliteal sciatic nerve block to assess complete recovery of the sensory-motor blockade either by examination (12 inpatients) or by phone call at home (12 outpatients).

Temperature sensation was tested with an alcohol swab on the dorsum and plantar surfaces of the foot, and recovery of motor function was assessed by the presence of toe dorsiflexion and plantar flexion on inpatients.

**Table 1.** Demographic Information of the Patients, Surgical Procedures, and Local Anesthetic Used for Sciatic Block in the Popliteal Fossa

Case no.	Age (yr)	Sex	Weight (kg)	Surgery	Local anesthetic and concentration (%)	Volume of local anesthetic (mL)	Intraoperative opioid fentanyl ( $\mu$ g)	Nerve diameter before injection (mm)	Nerve expansion (%)	Minimum current (mA) in patients with motor response
1	51	F	108	Bunion removal	Rop 0.5/Mep 1.5	20/20	25	6.4	75	0.40
2	50	M	76	Ankle hardware removal	Rop 0.5	30	0	7.1	69	0.42
3	58	F	76	Bunion removal	Rop 0.5	40	0	7.6	61	0.40
4	36	M	88	Achilles repair	Rop 0.5/Mep 1.5	10/20	25	7	41	0.35
5	32	F	66	Ankle ORIF	Rop 0.5	40	0	8.9	40	0.40
6	39	M	81	Achilles repair	Rop 0.5	40	0	8.4	39	0.55
7	38	M	80	Achilles repair	Rop 0.5	40	0	6.1	74	0.40
8	25	F	78	Ankle ORIF	Rop 0.5	30	25	7.2	40	0.45
9	58	F	58	Right foot debridement	Mep 1.5	40	25	8.8	38	0.45
10	34	M	76	Ankle arthroscopy	Rop 0.5	40	0	8.1	37	0.40
11	36	M	77	Achilles repair	Rop 0.5/Mep 1.5	15/20	0	6.8	44	0.40
12	42	M	103	Ankle hardware removal	Mep 1.5	35	0	7.1	51	0.75
13	35	M	72	Ankle ORIF	Rop 0.5	40	50	7.3	33	0.60
14	17	M	76	Metatarsal ORIF	Rop 0.5	30	0	7.5	36	1.00
15	31	M	76	5th toe ORIF	Mep 1.5	40	100	8	73	1.20
16	59	M	72	STSG left foot	Mep 1.5	30	0	7.3	34	1.00
17	28	F	73	Bunion	Rop 0.5	35	0	9	38	0.50
18	23	M	85	Ankle ORIF	Mep 1.5	40	0	7.8	35	0.55
19	50	F	61	Bone spur excision	Mep 1.5	30	0	7.2	46	0.90
20	49	F	97	Tendon repair	Rop 0.5	35	0	6.9	32	0.45
21	39	M	111	Woundqa closure-leg	Rop 0.5	40	100	7.8	32	
22	64	M	112	Foot debridement	Mep 1.5	35	0	7.4	42	
23	59	M	121	Foot debridement	Mep 1.5	30	0	5.9	31	
24	59	M	120	Foot debridement	Mep 1.5	30	0	6.3	41	
Mean	42.2		85.1					7.4	45	
SD	13.2		18.2					0.84	14	

Injection into the intraneural space occurred in all patients who had motor-evoked response at current 0.2-0.4 mA.

All nerves exhibited compartmentalization.

Mep = mepivacaine; Rop = ropivacaine; sd = standard deviation; ORIF = open reduction internal fixation; STSG = split thickness skin graft.

Outpatients were asked over the telephone if they experienced any deficit in sensation in their foot, and they were instructed also to wiggle their toes and visually observe for any deficit not previously present. The presence of any sensory or motor deficit or paresthesia in the distribution of the sciatic nerve was considered as nerve injury.

## RESULTS

Demographic data, the LA used, and the type of surgery are displayed in Table 1. All 24 blocks resulted in adequate anesthesia for foot surgery. Seven patients (29.1%) were administered fentanyl ranging from 25 to 100  $\mu$ g. The rest of the patients did not require intraoperative opioids. In 20 patients (83.3%), entry of the needle into an intraneural location coincided with the onset of an elicited motor response. Of these, elicited motor responses were present with a minimum stimulating current ranging from 0.35 to 1.2 mA (mean  $0.58 \pm 0.25$  mA) (Table 1). Ultrasound imaging indicated

intraneural needle location for all of these patients upon imaging review. The mean of the nerve diameter before injection was  $7.4 \pm 0.84$  mm, and the mean of nerve expansion percentage after intraneural injection was  $45\% \pm 14\%$ ; all nerves exhibited compartmentalization of the nerve. In the remaining four patients (16.7%), a stimulating current of 1.5 mA failed to elicit a motor response even after needle entry into the intraneural space, as viewed by ultrasound imaging. Thus, the needle was judged as being placed intraneurally, and further attempts to elicit a motor response were halted as the end point was already reached. There were five instances (21%) in which injection pressures of  $>20$  psi were encountered; two of these patients simultaneously reported a paresthesia. All five of these patients exhibited elicited motor responses, which extinguished between 0.2 and 0.5 mA. Rotation of the needle clockwise or counterclockwise or slight needle withdrawal allowed the injection to proceed with  $\leq 15$  psi. There were no patients with postoperative neurologic dysfunction.

## DISCUSSION

For a successful peripheral nerve block, the needle tip is ideally placed in close proximity of the targeted nerve(s) and into a tissue plane that allows for the deposited LA to stay in contact with the nerve.<sup>5</sup> The incidence of an intraneural injection after nerve stimulation or paresthesia is not known. The recent introduction of the ultrasound-guided nerve blockade has been invaluable in fostering our understanding of the needle-nerve relationship during motor stimulation or LA injection. The results of this study demonstrate that intraneural needle placement and intraneural injection of LA during popliteal sciatic nerve block are not rare occurrences during low-current nerve stimulation techniques and do not invariably lead to clinically significant nerve injury within the first 48 h.

Several clinical studies have suggested that an evoked motor response may be absent even when the needle is positioned in close proximity to a nerve as determined by eliciting paresthesias (mechanical-electrical phenomenon presumably resulting from a needle-nerve contact) or by ultrasound monitoring.<sup>4,6–8</sup> Indeed, in our series of 24 patients no motor response was obtained even upon the needle entering the intraneural space in 16.7% of patients. The implication of this finding is that when a nerve stimulator alone is used to localize the sciatic nerve in the popliteal fossa, a motor response may not be present even with an intimate needle-nerve relationship, necessitating additional (unnecessary) attempts at eliciting the motor response.

Similar to clinical reports, studies in laboratory animals have demonstrated that even with an intraneural needle placement under direct vision an evoked motor response may be absent.<sup>4,7</sup> In this study, commensurate with a common clinical practice, we used an evoked motor response at 0.2–0.5 mA as an end point and were able to elicit a response in 83.3% of patients, but only when the needle was positioned intraneurally.<sup>9</sup>

The neurologic sequelae of sensory and motor loss after the injection of various drugs into the peripheral nerves have been well documented in the experimental studies.<sup>10</sup> However, the site of injection is critical in determining the risk of injury as intraneural injections can be either extrafascicular or intrafascicular. Intraneural-extrafascicular injections are characterized by the spread of injectate within the epineurium, and imminent leakage of fluid outside the epineurium into the neighboring connective tissues,<sup>4,5</sup> not necessarily resulting in nerve injury.<sup>3,11,12</sup> In contrast, intrafascicular injections lead to at least some degree of neurologic impairment.<sup>1,10,13</sup> Although real-time imaging using ultrasound is useful in guiding needle placement, ultrasound does not allow differentiation between intrafascicular and extrafascicular needle tip location. Importantly, the location of the needle tip can often be ascertained only after a small volume of LA is injected. This may limit the usefulness of ultrasound in preventing an intrafascicular injection as fascicles are small

structures and can rupture after the injection of even minute volumes of LA ( $\leq 0.5$  mL).<sup>1,2,10,13</sup> High injection pressures during injection of LA,<sup>1,12–15</sup> low-current stimulation,<sup>4,7</sup> and pain upon injection suggest an intraneural or intrafascicular needle placement and may carry a risk of nerve injury.<sup>16,17</sup> If so, then the five instances in which high injection pressures and low-current stimulation with two instances of paresthesias occurring in this study could have been attempts at intrafascicular injection.

Our report has several inherent limitations. First, we enrolled a relatively small number of patients. Second, a single operator advanced the needle, viewed the ultrasound image, and determined when the elicited motor response occurred and at what point it extinguished. Theoretically, it would have been better to simultaneously have one observer (blinded to the elicited motor response) view the ultrasound image obtained while the needle operator performed a nerve stimulator-based technique. However, a third person would be required to adjust the current and a fourth person to hold the ultrasound transducer to ensure complete blinding of everyone. As such, this method would be technically impractical. Finally, the absence of sensory and motor deficits in the outpatient group is based on the phone interviews within 48 h; no neurological evaluations were done to exclude minor or subclinical neurologic deficit. For these reasons, this study cannot draw definite conclusions regarding the risk of neurologic complications after an intraneural injection during popliteal sciatic nerve block. However, currently, there is no standard for the length of follow-up in identifying complications related to peripheral nerve block. A single study suggests that some patients develop late symptoms of paresthesias-dysesthesias between day 15 and 23 after interscalene block.<sup>18</sup> In another study, however, all the patients developed neurologic symptoms within 48 h postoperatively.<sup>19</sup>

In summary, intraneural needle placement appears to be a common occurrence during low-current nerve stimulator-guided popliteal sciatic nerve localization. The absence of a motor response to nerve stimulation with currents of up to 1.5 mA (100  $\mu$ s/2Hz) may not exclude an intraneural needle placement. As such, the absence of response may lead to additional unnecessary attempts at nerve localization even when the needle is placed in sufficient proximity of the nerve that is to be blocked.

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