Intensity of the Stimulating Current May Not Be a Reliable Indicator of Intraneural Needle Placement

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Background and Objectives: The current intensity at which a motor response is elicited with an intraneural needle placement has been inadequately studied. We hypothesized that electrical current delivered through an intraneurally placed needle does not always result in an evoked motor response. Our secondary objective was to determine the relationship between electrical current intensity and needle-to-nerve distance.

Methods: Twenty pigs were given general anesthesia and the sciatic nerves (SN) were exposed bilaterally. Electrical nerve stimulation was applied 2 cm, 1 cm, 0.5 cm, 0.2 cm, and 0.1 cm away from the SN, transepineurally, and intraneurally (in the subepineurium). Stimulation was started at 2.0 mA and decreased to the minimal current at which visible motor response was obtained. Two blinded observers agreed on the intensity and type of motor response. Specific response of SN was defined as a distal motor response (hoof twitch); nonspecific response was defined as a local muscle twitch (no hoof response).

Results: At a distance of 0.5 cm to 2 cm away from the SN, only nonspecific muscle responses were observed. Specific SN responses were obtained starting at 0.1 cm away from the nerve and transepineurally with currents of 0.92 ± 0.33 mA (median 1.00 mA; range 0.24-1.48 mA) and 0.39 ± 0.33 mA (median 0.3 mA; range 0.15-1.4 mA), respectively. With the needle tip positioned intraneurally, specific motor response could be obtained at 0.56 ± 0.54 mA (median 0.3 mA; range 0.08-1.80 mA). Five (12.5%) intraneurally positioned needles only elicited a specific motor response at 0.8-1.8 mA.

Conclusions: Specific response to nerve stimulation with currents <0.2 mA occurred only when the needle tip was positioned intraneurally. However, motor response could be absent with intraneural needle placement at a current intensity of up to 1.7 mA. Reg Anesth Pain Med 2008;33:207-210.

Key Words: Nerve localization, Nerve stimulation, Stimulating current.

Electrical nerve stimulation is a common means of localizing peripheral nerves during administration of nerve blocks.1 Recently however, accuracy, reproducibility, and safety of electrical localization have been challenged.2-4 Clinical reports suggest that response to electrical stimulation may be absent even when the needle makes contact with peripheral nerves.5-7 Conversely, motor response to stimulation with current intensity of <0.2 mA may indicate intraneural placement of the needle.8 In this study, in an open sciatic nerve (SN) model in pigs, we sought to determine the needle-to-nerve relationship using a progressively decreasing current intensity and needle-to-nerve distance. We hypothesized that electrical current delivered through an intraneurally placed needle does not always result in an evoked motor response. Our secondary objective was to determine the relationship between electrical current intensity and needle-to-nerve distance.

Methods

The study was conducted in accordance with the principles of laboratory animal care and was approved by the Laboratory Animal Care and Use
Committee of the University of Sarajevo. Twenty healthy pigs of both sexes were studied. General anesthesia was induced with ketamine 4 mg/kg intramuscularly. After endotracheal intubation, anesthesia was maintained using a mixture of isoflurane (1.5%-3%) in oxygen.

The initial side, left vs right, for the experiment was randomly assigned by sealed envelopes. Using an aseptic technique, the SNs were exposed bilaterally at the midlevel of the gluteus muscle. Upon skin incision, blunt dissection was used to expose the SN. A constant-current electrical nerve stimulator (NL-3, Life-Tech, Stafford, TX) was used to apply the stimulating current through an insulated 25-gauge needle in common clinical use (PB-25SCS, Life-Tech, Stafford, TX). The nerve stimulator used in the study was outfitted with a fresh battery and its accuracy was confirmed on an oscilloscope using a 1 kilo-ohm (kΩ) resistive load. The stimulation was attempted with needles placed in tissue at 2 cm, 1 cm, 0.5 cm, 0.2 cm, and 0.1 cm away from the SN, and the needle-to-nerve distance was measured using calipers. The electrical current was also applied transepineurally (needle positioned outside the nerve on the epineurium) and finally, intraneurally (needle positioned underneath the epineurium and in the middle of the nerve bundle). The exposed wound tissue was intermittently closed between the stimulations to avoid tissue dehydration. The gluteus muscle was kept closed prior to the stimulation phase and all experiments were completed within 15 minutes from the start of nerve stimulation.

The following electrical stimulation pattern was followed in all experiments: the stimulation was started with a current intensity of 2 mA, and decreased in steps of 0.2 mA from 2 to 0.6 mA, then the current was decreased in steps of 0.1 mA from 0.6 to 0.1 mA, to the current intensity at which visible motor response was obtained. A 15-second interval was allowed to pass between stimulations at 2 consecutive distances. The current duration was 100 microseconds and the frequency was 1 Hz.

Two types of motor responses were sought: Type I, a specific motor response of the sciatic nerve characterized by a distal hoof twitch; and Type II, a nonspecific local muscle twitch (gluteus or other), leading to the leg movement but without hoof response.

Two blinded observers graded and agreed upon the strength of the response, and classified the response as either Type I or Type II. The wounds were then closed in layers, dressed, and the animals were awakened and allowed to recover.

### Statistical Analysis

Descriptive analyses were performed by using SAS version 8.0 (SAS Institute Inc., Cary, NC). Continuous variables were summarized as both mean ± SD, and median plus range. Spearman coefficient was used to present nonparametric correlation.

Sensitivity was defined as the proportion of stimulations with transepineural or intraneural needle placement, in which a minimum current of ≤0.2 mA led to the Type I response. Specificity was defined as the proportion of stimulations with needle-to-nerve distance of ≥0.1 cm, in which a minimum current of ≤0.2 mA did not result in a Type I motor response.

### Results

With the needle tip positioned at a distance of 0.5 cm to 2 cm away from the SN and using a current of up to 2 mA, there was no Type I motor response to stimulation of the SN in any of the nerves. However, a Type II local response mimicking SN twitch (but no hoof response) was obtained in 50% of all stimulation attempts. The current intensity required to elicit a Type II motor response ranged from 1 mA to 2 mA. A Type I motor response was obtainable only when needles were positioned at a distance of 0.1 cm from the nerve or closer (Table 1). Starting at a distance of 0.1 cm away from the nerve and moving toward intraneural needle placement, as the needle-to-nerve

<table>
<thead>
<tr>
<th>Needle Placement</th>
<th>Number of Attempts</th>
<th>Type I Response, n (%)</th>
<th>Minimum Current (mA)</th>
<th>Mean ± SD</th>
<th>Median (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraneural</td>
<td>40</td>
<td>40 (100)</td>
<td>0.56 ± 0.54</td>
<td>0.3 (0.08-1.80)</td>
<td></td>
</tr>
<tr>
<td>Transepineural</td>
<td>40</td>
<td>38 (95)</td>
<td>0.39 ± 0.33</td>
<td>0.3 (0.15-1.40)</td>
<td></td>
</tr>
<tr>
<td>0.1 cm away from SN</td>
<td>40</td>
<td>28 (70)</td>
<td>0.92 ± 0.33</td>
<td>1.00 (0.24-1.48)</td>
<td></td>
</tr>
<tr>
<td>Between 0.2 and 0.5 cm away from SN</td>
<td>40</td>
<td>0 (0)</td>
<td>2.00</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>1.0 cm away from SN</td>
<td>40</td>
<td>0 (0)</td>
<td>2.00</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>2.0 cm away from SN</td>
<td>40</td>
<td>0 (0)</td>
<td>2.00</td>
<td>2.00</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE.** Type I response is defined as a specific motor response of the sciatic nerve characterized by a distal hoof twitch. Abbreviation: SN, sciatic nerve.
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distance became closer, the current intensity required to obtain a Type I response became lower; correlation coefficient $r = 0.81$.

With the needle tip positioned 0.1 cm away from the epineurium, a Type I response was obtained in 28 (70%) attempts of nerve stimulation with a current intensity of $0.92 \pm 0.33$ mA (median 1.00 mA; range 0.24-1.48 mA). With needle tip positioned on the surface of the epineurium, a Type I response was obtained in 38 (95%) attempts with a current of $0.39 \pm 0.33$ mA (median 0.3 mA; range 0.15-1.4 mA). Finally, with needles inserted intraneurally, a Type I response was observed in all (100%) attempts with a current of $0.56 \pm 0.54$ mA (median 0.3 mA; range 0.08-1.80 mA). Of note, in 35 (87.5%) of the intraneurally placed needles, a Type I response could be elicited with low current intensity ranging from 0.08 mA to 0.4 mA. However, in 5 (12.5%) of the stimulation attempts, a Type I response could be obtained only with higher current intensity (0.8-1.8 mA).

**Discussion**

Our data from this surgically exposed SN stimulation model in pigs suggest that evoked motor response to low current intensity nerve stimulation may not follow a predictable pattern dependent on needle-to-nerve distance. If the results of our experimental SN stimulation model in pigs are applicable to clinical practice, specific motor response during low current intensity electrical localization of the SN may be absent even when the needle is placed intraneurally. Some clinicians believe that a current intensity of $<0.2$ mA indicates intraneural needle placement and suggest needle reposition to avoid an intraneural injection. Voelckel et al. support this clinical assumption in their study of sciatic nerve blocks in pigs. In their study, infiltration with lymphocytes and polymorphonuclear granulocytes were detected within and around the SN in 50% of the pigs that had a SN block with a current of $<0.2$ mA. In contrast, none of the pigs that had sciatic nerve block after a motor response was elicited with current intensity $>0.2$ mA developed signs of inflammation on postmortem findings. Although intraneural placement of the needle in our study resulted in evoked motor response with as little as 0.08 mA in 1 nerve, the response was absent in some animals even with a current intensity of up to 1.7 mA. Consequently, sole reliance on motor response in this study was unable to detect intraneural needle placement in 5 (12.5%) of the intraneurally placed needles.

The results of our study are in agreement with the recent clinical reports of inability to obtain a motor response even when a needle is apparently in close proximity to the nerve. For instance, Urmey and Stanton reported that motor response was absent in 70% of patients in whom they elicited paresthesias. The debate that followed this study suggested that electrical stimulation is not fail safe because it can be absent when the needle contacts the nerve. Some experts felt that this was possible because the needle was accidentally repositioned before the current was applied, whereas others postulated that the absence of motor response was due to the different locations of the motor and sensory fibers within the nerve sheath, thereby elicitation of paresthesia may not necessarily translate into the ability to electrically stimulate the nerve. Using direct visualization of the brachial plexus at the level of the axilla, Perlas et al. found that nerve stimulation was more sensitive than paresthesia as an indicator of needle-to-nerve contact. In their report, at the point at which the needle tip was seen to contact the nerve, paresthesia was absent in 62% of needle-to-nerve contacts. However, nerve stimulation with current intensity of up to 0.5 mA was absent in 25% of needle-to-nerve contacts, whereas all needle-to-nerve contacts resulted in stimulation with currents of 1 mA or higher. The findings of our study agree with the data from the studies of Urmey and Stanton, and Perlas et al. Motor response can indeed be absent with currents significantly higher than the suggested 0.2 mA when the needle is in immediate vicinity of the nerve or even inserted intraneurally.

There are several possible explanations of how a peripheral nerve may fail to respond to nerve stimulation. One is that a peripheral nerve can become hyperpolarized during nerve stimulation and fail to respond when in close relationship to the tip of the needle. Another possibility is that current may not flow preferentially from the needle electrode toward the nerve. In other words, traditionally it has been taught that an insulated needle creates an electrical field at its tip that depolarizes the nerve before the tip mechanically touches the nerve. However, the living tissues are a complex inductor-capacitor circuit comprised of a multitude of resistances and capacitances that make the determination of the actual current flow vectors nearly impossible. Therefore, depending on the changing value in tissue impedance (breathing pattern, blood flow, state of hydration, etc.), the current can be shunted toward other areas along its course toward the return electrode. Finally, subtle changes in the position of the needle tip during the experiment may also have affected our results.
The main limitation of our study is that it was carried out in an open sciatic nerve model. Electrical conductivity in actual living tissue may vary from that in an open model. Another possible limitation of our study is that the stimulation was begun with a current of “high” intensity (2.0 mA), and progressively lowered as the needle was moved closer to the nerve; this may have resulted in hyperpolarization and skewed our data. We chose to start the stimulation with a higher current and progressively decrease the current as the needle was advanced closer to the nerve in order to more closely mimic nerve localization in clinical practice.

Our findings in an experimental, open, SN model in pigs suggest that electrical stimulation with currents of low intensity (<0.2 mA) is a highly specific but relatively insensitive indicator of an intraneural needle placement. If our findings are applicable to clinical practice, sole reliance on nerve stimulation to decrease the risk of an intraneural injection may not be reliable.

References