No. VII

Nerve Location –
The Art and Science of Finding
Peripheral Nerves.

The Art of
Regional
Anesthesia

Chairman: Dr. Nicholas Denny, UK

Including lectures presented by:
David Tew, MD, BSc, FRCA, UK
Jose de Andrés, MD, PhD, E
William F. Urmey, MD, USA
Zbigniew Koscielniak-Nielsen, MD, PhD, FRCA, DK

B. Braun Satellite Symposium
XXII. ESRA Congress Malta, 12th September 2003
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XVII. ESRA Congress, Geneva, September 1998

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– The way ahead?”  
B. Braun Satellite Symposium Barcelona, May 2002
Peripheral Nerve Location using Nerve Stimulators

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Local anaesthetic blockade of peripheral nerves was first accomplished using infiltration or direct vision at operation. Then, percutaneous techniques were developed in which paraesthesia was sought as an endpoint. These three techniques are still used successfully today.

In the 1960's several researchers developed electrical nerve stimulation techniques to aid percutaneous location of peripheral nerves. In subsequent decades with the advent of microprocessors - small, accurate, battery operated, hand held devices were introduced which now offer very sophisticated help in finding peripheral nerves.1,3.

Pros and cons

**Peripheral nerve stimulator (PNS) is helpful because:**

1. It provides objective evidence that the needle tip is close to the nerve (and no intention to make physical contact with the nerve)
2. It is not usually painful (whereas paraesthesia may be so)
3. Amount of charge required is related to distance from nerve which improves accuracy
4. It may be used in the unconscious patient e.g. anaesthetised children
5. The nature of the endpoint is a valuable training aid.

**PNS is limited because**

1. It is only applicable to peripheral nerves (not relevant to central axis blockade)
2. The aim is to stimulate motor nerves which largely limits its use to mixed peripheral nerves (its use for pure sensory nerves has been described, but is unusual in clinical practice)
3. It has implications for staff and equipment costs
4. It cannot be used after paralysis with neuro-muscular blocking drugs

PNS is not a substitute for a proper anatomical knowledge of the nerves being sought. It is a powerful tool for guiding the needle through the final 5 mm or so of an approach to a nerve but in normal clinical practice will give little indication of proximity to a nerve from distances greater than 1cm.

**Electrophysiology**

**Energy**

The amount of electrical energy required to propagate a nerve impulse is a product of the stimulus strength (mAmps) and current duration (msecs). For any nerve type there is a minimum current strength required, to generate an impulse – the rheobase. Below this level, an impulse will not be generated; no matter for how long the current is applied.

The chronaxie is the stimulus duration needed for impulse generation using a current strength of twice the rheobase.

Comparison of chronaxies is a useful way of comparing the sensitivities of different nerve fibres.

Myelinated fibres are more sensitive requiring less electrical energy for stimulation and having shorter chronaxie than unmyelinated fibres.

<table>
<thead>
<tr>
<th>Nerve fibre type</th>
<th>Chronaxie in msecs</th>
</tr>
</thead>
<tbody>
<tr>
<td>unmyelinated C</td>
<td>0.4 - 1</td>
</tr>
<tr>
<td>myelinated A K</td>
<td>0.17</td>
</tr>
<tr>
<td>myelinated A H</td>
<td>0.05 – 0.1</td>
</tr>
</tbody>
</table>

Inspection of the table above will reveal that selecting a short impulse duration of 0.1 msecs will allow motor nerve stimulation without initiating painful C fibre activity – a fact exploited in modern PNS devices.

**Polarity**

Less electrical energy is required if the cathode (negative) is close to the nerve since with a negative stimulating needle the direction of current flow (of itself) induces some depolarisation making it easier to stimulate the nerve.

The reverse is true with an anodal (positive needle) since the direction of flow in this instance (again of itself) induces hyperpolarisation of the target nerve close to the needle tip. This makes it more difficult to stimulate the nerve and a higher current is therefore required to produce an action potential.

In most modern PNS the needle is negative by default and cannot be changed by the operator.

**Distance**

Coulomb's law relates the effect on a nerve of constant current stimulus and the distance of the stimulus source from the nerve:

\[
\text{Stimulus intensity required} \propto \frac{1}{(\text{distance})^2}
\]

As a result, provided the current is not excessive, a nerve will only be stimulated when the needle is close to it. Consequently confusing muscle twitches are unlikely to occur when the needle tip is too far from the nerve. The initial current should therefore be set at 1-2 mA (with an impulse duration of 0.1 msec and a negative needle). Theoretically this would be expected to produce a response when the needle is some 5 to 10 mm from the nerve.

With most needles a muscle twitch initiated at a current of around 0.5 mA suggests that the needle tip is 1-2 mm from the motor nerve and that injection of local anaesthetic solution is likely to provide a satisfactory block.

If a muscle twitch is generated at a current strength of less that 0.2mA, there is strong possibility that the needle has penetrated the epineurium. This is too close and there is a risk of intraneural
injection, which may cause temporary or permanent nerve damage. It is therefore important to check that the muscle twitch disappears at or before a current of 0.2mA.

**Stimulus frequency**
As the needle is advanced, a muscle twitch provoked by the stimulating current warns that the needle is approaching the target nerve. If the frequency of the stimulating current is too low (and the speed of the advancing needle too high) then the nerve may be impaled between impulses. If the frequency is too high, painful muscle twitches (approaching tetany) may be induced. A frequency of 2 Hz is a good compromise and a needle advancement speed of around 1 mm per sec is suggested when in close proximity to the nerve.

**Summary**
A peripheral nerve stimulator should provide as a minimum

1. a square wave impulse with a duration of 0.1 msec
2. the negative lead connected to the stimulating needle
3. 2 Hz frequency
4. initial current level of 1-2 mA seeking the nerve
5. a final current level of 0.3 – 0.6 mA positioning the needle tip
6. current delivery down to 0.1-0.2 mA ensure no stimulation

Additional safety features include

1. accurate current delivery in the range 0-5 mA
2. constant current square wave pulse
3. display of current flowing in the patient and that delivered internally from the device
4. open circuit alarm
5. excess impedance alarm
6. low battery alarm
7. internal malfunction alarm

**Avoiding intraneural injection**

While it is important to place local anaesthetic accurately, it is vital to minimise the chance of causing nerve damage. The following list of seven points may help to avoid intraneural injection.

1. Equipment checks
2. Appropriate anatomical knowledge
3. Threshold – no muscle twitch at or below 0.2 mA if not STOP
4. Twitch disappears immediately injection starts if not STOP
5. Minimal resistance to injection if not STOP
6. Watch the patient for signs of pain on injection if so STOP
   - awake - verbal report
   - asleep - reflex action
7. If things do not feel/look right then STOP (don’t persist in numerous attempts)

Many case reports detailing damage resulting from local anaesthetic blockade reveal, on careful reading, problems arising from points 1 to 7 listed above.

**The future**
There is still much debate about how close the needle tip should be to the target nerve with the principle questions being:

How close is close enough (will it work ?) and how close is too close (will it cause damage ?). We are just beginning to see studies aimed at answering these questions.

Similarly, electronic advances mean that the manufacturers are able to offer us increasingly complex stimulators (at a price) and at a time when their products are coming under increasing scrutiny they are looking to the clinicians to help determine the balance between cost and useful function.

The role of adjuncts such as ultrasound guidance are being explored and novel strategies such as percutaneous electrode guidance (PEG) are being developed so the next decade promises to be interesting.

**Reference**

3. A Hadzic et al. Nerve Stimulators used for peripheral nerve blocks vary in their electrical characteristics. Anesth 2003;98:969-74

**Nerve stimulator:**
*Stimuplex® HNS II* (B. Braun Melsungen)

**Stimulation needles:**
*Stimuplex® D, 15°* (B. Braun Melsungen)
Jose de Andrés MD, PhD¹, Xavier Sala-Blanch, MD²

The Application of Ultrasonography in finding Peripheral Nerves

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INTRODUCTION

Plexus nerve block is the procedure where the success of the regional anesthetic technique is most dependent upon the correct positioning of the local anesthetic solution within the proximity of the corresponding nerve trunk. With the aim of verifying block and increasing the corresponding success rate, different mechanical aids have been used for nerve detection, being peripheral nerve stimulation the most commonly used¹.

In the last years, and based on accumulated experience in other fields, the use of ultrasonography or ultrasound (US), has produced a conceptual change in the way the peripheral nerve is located. This change is based on the fact that the technique is performed under direct puncture visualization, and therefore constitutes a much more anatomical approach. During ultrasound guidance, the structures through which the needle is inserted are identified, and the plexus is directly localized; consequently, a reduction in complications and side effects is more likely attributable to optimized puncture than to an actual improvement in the clinical results. Ultrasound-aided nerve blocks have been reported in the anaesthetic literature since 1978, but an increase in interest from the mid-1990s has produced, probably as a result of improvements in ultrasound equipment and the better knowledge of the related benefits with its application to plexus localization²-²¹.

Principles of ultrasound in the practice of nerve location

Sound is a vibratory phenomenon where frequency defines the number of vibrations, oscillations or cycles per second (measured in Hertz, where 1 Hz = one oscillation per second). Ultrasound is defined as sound at a frequency above the human auditory threshold (over 20,000 Hz). The piezoelectric principle allows the generation of ultrasound with applications to imaging techniques. This effect is based on the capacity of certain crystals (piezoelectric crystals) to generate mechanical energy in the form of ultrasound waves in response to the application of electric energy, and vice versa. Echogenicity is the capacity of structures standing in the way of the ultrasound beam to reflect the waves back to their source. This capacity depends not only on the characteristics of the ultrasound waves but also on the properties of the medium through which the sound travels. The interface is the limit or contact zone between two distinct media that transmit sound at different velocities. The acoustic impedance is in turn defined as the resistance of the medium to the passage of sound. When an ultrasound beam penetrates a given structure, the beam intensity decreases as a result of attenuation on one hand, and wave reflection on the other. Attenuation represents the loss of wave amplitude (energy) on traveling through a medium, and depends on the wavelength, the density of the medium or tissue, and the heterogeneity (number and type) of the interfaces present (attenuation being 1 dB/MHz on average). Wave reflection in turn conditions the formation of ultrasound images; it is proportional to the difference in acoustic impedance between two media that form an interface standing in the way of the ultrasound beam. In terms of reflectivity, the resulting images can be regarded as hyperechogenic, normoechogenic or hypoechogenic. In turn, hypoechogenic structures may appear anechogenic (anechoic) when ultrasound is completely attenuated, or trans-sonorous when the waves are neither attenuated nor reflected back towards the emitting source.

Water is the body element that best transmits ultrasound waves, generating a black (anechoic) image. Thus, highly cellular tissues containing abundant water can be expected to be hypoechogenic, while more fibrous tissues containing less water and a larger number of interfaces are characteristically hyperechogenic. The ultrasound characteristics of the different body tissues are²¹,²²:

<table>
<thead>
<tr>
<th>Tissues</th>
<th>Ultrasound image</th>
<th>Artifacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venous vessels</td>
<td>Compressible, anechoic</td>
<td>Pulsatile, anechoic</td>
</tr>
<tr>
<td>Arterial vessels</td>
<td>Hyperechoic</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>Hypoechoic</td>
<td></td>
</tr>
<tr>
<td>Muscle:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perimysium</td>
<td>Hyperechoic</td>
<td></td>
</tr>
<tr>
<td>Muscle tissue</td>
<td>Hypoechoic</td>
<td></td>
</tr>
<tr>
<td>Tendons</td>
<td>Intensely hyperechoic</td>
<td></td>
</tr>
<tr>
<td>Cartilage</td>
<td>Fine band, anechoic</td>
<td></td>
</tr>
<tr>
<td>Nerves</td>
<td>Hyperchoic</td>
<td></td>
</tr>
<tr>
<td>Bone</td>
<td>Intensely hypoechoic line, with</td>
<td></td>
</tr>
<tr>
<td></td>
<td>acoustic shadow</td>
<td></td>
</tr>
<tr>
<td>Air (lung)</td>
<td>Anechoic</td>
<td></td>
</tr>
</tbody>
</table>

Modern clinical ultrasound equipment typically operates in the 2.5–20 MHz frequency range. The higher the frequency the better the spatial resolution, but at the expense of reduced depth penetration. Lower frequencies provide better depth penetration but at lower spatial resolution. Additional features, such as pulsed-wave and colour Doppler imaging, allow the identification of vessels and the blood velocities in those vessels.

Clinical experience with ultrasound guided plexus anesthesia

Most of the clinical studies of ultrasound in regional anesthetic published in the literature, have looked at one or more of the various approaches to the brachial plexus²,³,⁸,¹⁴,¹⁷,¹⁸,²⁰, some using ultrasound to identify and mark the skin over blood vessels³,⁶ and others using it to guide the needle or catheter to the nerve. Nevertheless some other studies have focused in the practice of lumbar plexus⁹,¹⁰ or in the review of its classical landmarks application²¹,²⁴.

Friedl⁷ presented a technique for accessing the brachial plexus at axillary level, using a linear 7.5 MHz transducer - recommending its application when the brachial artery cannot be well identified by clinical examination, to avoid neurological deficits due to direct puncture and injection of anesthetic into the nerves. Yang et al.¹², using high-resolution ultrasound guidance with a broadband L10 5 MHz transducer (HDI 3000; ATL Bothell, WA), inserted a catheter into the interscalene brachial plexus sheath, and evaluated location using radiography and CT after the injection of contrast material. Successful neural blockade at 20 min. and postoperative analgesia were achieved in all patients. On the other hand, 6 of 15 patients who consented to regional anesthesia required general anesthesia because blockade proved incomplete. Kapral et al.¹¹, using a 5-7 MHz transducer, reported a 95% surgi-
calf anesthesia rate with both the supraclavicular and axillary techniques - while anesthesia was only partial in the remaining 5% of cases. No complications attributable to the techniques were observed.

Ootaki et al\(^\text{13}\) using real-time ultrasound guidance for plexus block at infraclavicular level, concluded that the approach can be used as an alternative to the anatomical reference or landmark-guided technique. Attached to the ultrasound transducer (7.0 MHz), and for effective needle manipulation, the authors used a needle guide, keeping needle pass within the ultrasound beam (UAGV021A-Toshiba). For plexus block, a 23G 60-mm needle was inserted toward the medial aspect of the subclavian artery under real-time ultrasound guidance, and the local anesthetic was injected near the subclavian artery, 15 mm medial and 15 mm lateral to the vessel. Complete sensory block was achieved in 100% of patients for the musculocutaneous and median antebrachial cutaneous nerves, in 96.7% for the median nerve, and in 95% for the ulnar and radial nerves. In turn, complete motor block was achieved in 100% of patients for the musculocutaneous nerve, in 96.7% for the median nerve, in 90% for the ulnar nerve, and in 93.3% for the radial nerve. No complications were recorded.

Greher et al\(^\text{18}\) have revisited the landmarks proposed by Kilka et al\(^\text{25}\) in the performance of vertical infraclavicular brachial plexus block. According their results originally proposed landmarks are not ideal in all sizes of patient, and may decrease the margin of safety by allowing the close approach of a needle to the pleura and vessels. Their recommendation is that ultrasound guidance be used when performing this block or that their modification of the anatomical landmarks be used if ultrasound is not available. Recently, Sandhu et al\(^\text{17}\) have published the largest prospective series published on ultrasound-guided brachial plexus block. In this study authors used 2.5 MHz visualized the axillary artery and the three cords of the brachial plexus posterior to the pectoralis minor muscle, and the deposit of the local anaesthetic around each of the three cords. This paper suggest that ultrasound guidance has the potential to improve success rate, time of onset and of performance of the block, and to decrease complications such as vascular puncture. Nevertheless limitations of the technique, have been arised by Nadig et al\(^\text{26}\) as regards the definition provided for a 2.5 MHz probe instead of the commonly used 7.5 MHz probe, regarding the capacity to identify small structures such as the cords of the brachial plexus.

In conclusion, ultrasound guidance for accessing the brachial plexus is undoubtedly finding a place in plexus anesthesia - for the teaching of anesthetic techniques, application to concrete clinical situations (involving patients in which the classical anatomical landmarks for blind puncture are difficult to identify), or for systematic application in clinical practice. According the accumulated results the use of ultrasound can diminish accidental puncture of blood vessels and the pleura. The most currently used device for nerve location today is a nerve stimulator. Certainly, the use of a nerve stimulator does not eliminate the risk of nerve damage, but has been claimed to reduce. Perhaps in the close future the combined use of nerve stimulator and ultrasound maintaining same levels of success might help more specifically in preventing nerve damage.

References
4.-Abramowitz HB, Cohen CH. Use of Doppler for difficult axillary block.
Transcutaneous Electrical Nerve Stimulation

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Conventionally, location of a nerve or neural plexus for local anesthetic blockade has involved searching for the nerve by invasive needle exploration. This sometimes requires multiple needle passes to elicit the sought-after response from the nerve, such as a paresthesia or motor response to electrical nerve stimulation. With appropriate technique, such responses constitute evidence that the tip of the block needle is in contact with or very close to, the targeted nerve. When using electrical nerve stimulation to seek a motor response, a weak direct current (DC) electrical current is supplied to the block needle by an oscillating (square-wave) current generator (i.e., a nerve stimulator). The current is pulsed, typically at a frequency (f) of 1 – 2 Hz. A starting current amplitude (ampereage) of 1 – 2 mA with a pulse duration of 0.1 to 0.2 ms is typically applied to the block needle, which is inserted through the skin and underlying tissues toward the targeted nerve. When approximate motor contractions, which correspond to the muscular innervation of the designated nerve occur, the current is slowly decreased in ampereage while the needle is used to search for the nerve. Motor contractions that occur at low ampereage (usually 0.2 – 0.5 mA) indicate that the needle tip is very close to or contacting the nerve. Injection can thus be made in the immediate vicinity of the nerve, the objective, resulting in anesthesia or analgesia, with a very high success rate.

Conventional methodology for nerve location therefore begins by identification of anatomical landmarks. These landmarks constitute an approximate starting point for invasive needle exploration. The endpoint of the needle search can be an anatomical endpoint (e.g., transtectorial axillary block or ultrasonographic imaging) or a functional endpoint (e.g., sensory response to mechanical stimulation, i.e. paresthesia, or motor response to electrical nerve stimulation).

The problem with designated anatomical landmarks is that they are variable from patient to patient and do not always correlate with the location of the underlying nerve or neural plexus. In addition, landmark measurements are often complicated, requiring linear measurements with a ruler, bisecting lines, and frequently a “one size-fits all” philosophy. For many blocks, accepted descriptions of the technique include insertion of the block needle a number of centimeters from a designated palpable landmark, neglecting patient size or body habitus. Dexterity and delicate proprioception are often required to be successful at block placement. Finally, search with a sharp needle can pierce or damage vessels, nerves, or other underlying anatomical structures.

Transcutaneous electrical stimulation, by contrast to an imaging technique such as ultrasonography, utilizes a functional endpoint, a motor or sensory response to electrical stimulation of the underlying nerve. Transcutaneous electrical stimulation to elicit a motor response has been used to assist in determination of the optimal entry point for needle insertion, thereby narrowing the invasive search for the nerve with the needle. Ganta et al. (1) reported on the use of a modified electrocardiographic electrode of 0.5 cm diameter with adherent gel to assist in the performance of interscalene block. The electrode was coupled to a nerve stimulator and was “passed along the skin” to locate the optimal entry point for needle insertion. Urmey (2) proposed the use of an exploring skin electrode on a theoretical basis to help find the interscalene groove in patients with difficult anatomy.

Use of transcutaneous stimulation to elicit a sensory response (paresthesia) to electrical nerve stimulation of a purely sensory nerve (the lateral femoral cutaneous nerve) was reported by Shannon et al. (3). These investigators used a handheld electrical nerve stimulator to elicit sensory paresthesias, following which they made measurements to determine the nerve’s location and injected, based upon these measurements, to block the nerve. Similar to Ganta et al., Shannon et al. used an electrode that was approximately 0.5 cm diameter.

Urmey and Grossi recently described a technique called percutaneous electrode guidance (PEG) of the block needle (4). PEG utilizes transcutaneous electrical stimulation to noninvasively pre-locate the desired nerve or neural plexus. By contrast to the above transcutaneous techniques, the PEG technique uses an unprecedented cylindrical transcutaneous electrode with a minute (less than 1 mm) metallic tip. The electrode is used to indent the skin and underlying subcutaneous tissues toward the nerve, thus decreasing the tissue electrical impedance as well as the distance to the targeted nerve or nerves. The electrode is electrically shielded and sterile. This technique was recently improved and simplified, while maintaining the original concept (5). The stimulator needle tip was used as both the cutaneous and invasive electrode by encasing the needle in a rounded plastic nonconductive sterile encasement that converts the needle tip itself, to a smooth cutaneous electrode. (Figure 1). The needle can be extended through the encasement toward the targeted nerve (Figure 2).
Figure 2. Simplification of the percutaneous electrode guide. The insulated block needle is transformed to a smooth-tipped cutaneous electrode probe by encasement in a sterile nonconductive cylinder. (A) The probe is used to indent the skin to prelocate the nerve or plexus by cutaneous stimulation at higher amperage and pulse duration. (B) After prelocation, the amperage and pulse duration are decreased and the needle is advanced to the underlying nerve or plexus. From Urmey WF and Grossi P. Reg Anesth Pain Med 2003: 28: 253-5.

Scientific Fundamentals Underlying Percutaneous Electrode Guidance

The ability to electrically stimulate a peripheral nerve or neural plexus is:
1) directly proportional to the electrical current amplitude (I), i.e. the amperage applied to the stimulator electrode or needle
2) proportional to the pulse duration of the square wave of current generated by the nerve stimulator
3) inversely proportional to the electrode-to-nerve distance
4) inversely proportional to the electrical impedance (mostly resistance and capacitance) of the tissues that lie between and around the electrode and the targeted nerve or nerves.

Current Flow (Amperage)

Use of higher amperage to stimulate peripheral nerves (e.g. 2-5 mAmp) allows one to elicit a motor response at a greater distance from the nerve. As an electrode approaches the nerve, motor response to electrical stimulation can be achieved at lower amperage. Motor response to stimulation with current below 0.5 mA with conventional pulse duration of 0.1 – 0.2 mA signifies that the needle’s tip is in very close proximity to the nerve. The relationship of current flow (I) to voltage (V) and tissue resistance (R) is governed by equation 1 below.

(Equation 1) \( I = \frac{V}{R} \)

Therefore, by starting at higher amperage, either transcutaneously or invasively, maximizes sensitivity (ability to elicit motor response). This principal is used for monitoring of the neuromuscular junction by cutaneous electrodes and comparably very high (~50 mA) currents during general anesthesia where specificity is of less importance. For peripheral nerve blockade, 2-5 mA currents increase sensitivity and ultimate specificity is achieved by stimulation at very low currents < 0.5 mA.

Electrical Pulse Duration

Electrical pulse duration is the duration in milliseconds of the periodic pulse square wave used to stimulate the nerve or plexus. Increasing the duration of the electrical pulse increases the total flow of electrons calculated by the area under the curve (Figure 3). Increasing pulse duration therefore results in increased ability to stimulate the nerve that is directly proportional to the pulse duration increase (without change in other variables). Similar to current flow (amperage), high pulse duration 0.3 – 1.0 ms results in higher sensitivity for transcutaneous or initial invasive pre-location of the nerve. By contrast, lower pulse duration, e.g. 0.1 ms maximizes specificity for ultimate invasive location of the nerve or neural plexus.

Electrode to Nerve Distance

The distance or length (L) between the electrode (needle tip) and the sought-after nerve is a major determinant of the ability to achieve a motor response to electrical stimulation at a given electrical current and pulse duration. This is governed by equation 2 below.

(Equation 2) \( R = \frac{r L}{A} \)

where R is the electrical resistance, r is the tissue resistivity, L is the electrode-to-nerve distance, and A is the conductive area.

Thus, by Equations 1 and 2, it requires higher current flow to stimulate a nerve at a distance. It is the converse of this property that is exploited when using a nerve stimulator needle to block nerves. Since increase in distance from needle tip electrode to nerve diminishes the motor response, the converse, i.e. ability to elicit a motor response at a very low amperage and pulse duration, signifies that the tip of the needle electrode is extremely close to or touching the nerve. Similarly, it can be seen that higher current is required for a smaller conductive area. Therefore, stimulation with a smaller electrode (needle tip) increases specificity and indicates proximity to the nerve.

Therefore, for transcutaneous stimulation which occurs at a greater distance, higher electrical current and/or pulse duration is required. To locate a nerve or plexus transcutaneously at relatively low current amperage (2 – 5 mAmp), it helps to decrease the
distance of the electrode to nerve by indentation of the overlying skin and subcutaneous tissues toward the targeted nerve, and to use a pinpoint electrode to maximize specificity.

**Tissue Electrical Impedance**

The final variable which effects the ability to elicit a motor response to electrical nerve stimulation is the electrical impedance of the skin and underlying tissues. In general, the higher the water/lipid ratio of the tissue, the lower the electrical impedance. Skin is characterized by very high electrical impedance. Condensing the tissues by indentation of the skin toward the nerve, serves to decrease electrical impedance, or conversely stated, increases the electrical conductance of the tissues, making it easier to elicit a motor response at a given amperage and pulse duration.

**Electrical Pulse Frequency**

The frequency (f) of the square-wave electrical pulse generated by the nerve stimulator is typically set at 1 or 2 Hz. Increasing the frequency to 2 Hz gives more rapid or constant feedback with little added discomfort to the patient. However, if frequency is increased further, nerve stimulation becomes increasingly more uncomfortable. Frequencies that achieve tetanus (usually set at 50 or 100 Hz on commercially available nerve stimulators) result in severe pain and therefore should not be used for nerve location.

**Principles of PEG**

The PEG concept acts to optimize the above variables in such a way as to make transcutaneous stimulation and therefore pre-location of the target-nerve or nerves possible at relatively low amperage (< 5 mAmp). The use of a smooth-tipped electrode allows indentation of the skin without significant discomfort. Indentation of the skin acts to minimize distance to the nerve and to decrease electrical impedance by compressing the underlying tissues, which increases electrical conductance (Figure 4).

By contrast to traditional needle tip location, where a very short pulse duration is desirable for precise location with the needle-tip, cutaneous stimulation benefits from longer pulse durations (0.2-1.0 msec). Higher pulse duration allows for motor response at lower amperage. Indentation of the skin (in some cases several centimeters is necessary) brings the cutaneous electrode into fairly close proximity of the nerve or neural plexus. Since much of the locating is done by the probe, which indents the skin toward the nerve, the needle tip typically travels only a short distance to the nerve (Table 1).

**Table 1. Block characteristics.** From Urmey WF and Grossi P. Reg Anesth Pain Med 2002;27:261-7.

<table>
<thead>
<tr>
<th>Patient N°</th>
<th>Nerve Block</th>
<th>Minimal Electrode Current</th>
<th>Minimal Needle Motor Response</th>
<th>Needle Motor Response</th>
<th>Needle Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intercalene block</td>
<td>2.3 mA</td>
<td>Deltoid, 0.21 mA</td>
<td>Deltoid, 0.4 cm</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Intercalene block</td>
<td>2.8 mA</td>
<td>Deltoid, 0.70 mA</td>
<td>Biceps, 0.6 cm</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Intercalene block</td>
<td>2.8 mA</td>
<td>Biceps, 0.25 mA</td>
<td>Biceps, 0.6 cm</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>A. Midhumeral median nerve block</td>
<td>2.3 mA</td>
<td>Hand median 0.21 mA</td>
<td>Hand median 0.4 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. Axillary median nerve block</td>
<td>1.3 mA</td>
<td>Hand ulnar 0.31 mA</td>
<td>Hand ulnar 0.4 cm</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>A. Axillary block (median nerve - conventional)</td>
<td>2.0 mA</td>
<td>Hand median 0.29 mA</td>
<td>Hand median 0.5 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. Axillary block (median nerve - transcoracor-brachialis)</td>
<td>3.0 mA</td>
<td>Hand median 0.29 mA</td>
<td>Hand median 1.0 cm</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Femoral nerve block</td>
<td>8.2 mA</td>
<td>Quadriceps, 0.20 mA</td>
<td>Quadriceps, 1.1 cm</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>A. Femoral nerve block</td>
<td>3.4 mA</td>
<td>Quadriceps, 0.44 mA</td>
<td>Quadriceps, 0.8 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. Popliteal fossa peroneal</td>
<td>4.7 mA</td>
<td>Patellar motion</td>
<td>Patellar motion</td>
<td></td>
</tr>
</tbody>
</table>

*Patient noted simultaneous paresthesia to shoulder†Transmuscular approach

**Initial Clinical Experience with the PEG Technique**

Urmey and Grossi(4) reported the first clinical cases of peripheral or plexus blocks utilizing the PEG technique. The authors used a cylindrical cutaneous electrode with a 1 mm diameter metallic conductive tip. After positioning the probe and indenting the skin over the target nerve, specific motor responses were sought. At the point of maximal motor response at minimal cutaneous probe amperage (2 Hz, 0.2 msec) the cutaneous stimulator was turned off and a standard commercial nerve stimulator needle (BBraun, Melsungen, Germany) was passed through the probe to the nerve.

This method was used in 7 patients. The block characteristics are shown in Table 1. Since the nerves were pre-located with the cutaneous electrode, the needle was introduced in each case with beginning amperage of 0.5 mAmp (normally acceptable as an

Figure 4. Cross section illustration of percutaneous electrical stimulation at the anatomical level of the axilla. In this example, ulnar nerve indentation (A) is followed by median nerve stimulation (B). From Urmey WF. Tech Reg Anesth Pain Manag 2002; 6: 145.
endpoint). In only one case was it necessary to increase the needle amperage above 0.5 mAmp (Patient 2, Table 1). Targeted nerves were found easily within seconds of the start of indentation and exploration of the skin with the cutaneous electrode. Minimal transcutaneous stimulation current in mAmp correlated directly with the measured needle depth (beyond the probe tip). Maximal needle protrusion depth in these initial patients was 2 cm. Thus the technique is more useful for blocking superficial nerves or plexuses. These include 1) brachial plexus block, 2) midhumeral block, 3) wrist block, 4) femoral nerve block, 5) popliteal fossa block and, 6) posterior tibial nerve block.

PEG is in its infancy and has tremendous potential to make peripheral nerve blocks less intimidating to the beginning practitioner. PEG may decrease time for block performance and increase safety of peripheral nerve blockade by decreasing the number of invasive needle passes. The probe has been successfully used to teach in workshop settings. Further clinical studies are certainly indicated.

References
Stimulating PNB Catheters: Are they clinically relevant?

Ass. Professor, Head of Orthopedics Anesthesia, Rigshospital, Copenhagen, Denmark

Most anaesthesiologists assume that PNB catheters lie parallel and close to the nerves located by stimulating needles. This belief is based on the fact that most peripheral nerves are surrounded by a loose connective tissue and on the belief in concept of neurovascular sheaths. However, recent researches questioned the existence of a tubelike, tight, fascial sheaths around brachial and lumbar plexuses (1,2). More or less blind insertions resulted often in aberrant placement of the excessive lengths of catheters (3) with subsequent poor or patchy block, and/or failure of post-operative analgesia in up to 10% of patients (4). Unpublished reports and expert opinions suggest that the secondary block failure during continuous LA infusion reaches 30-40%. This is in accordance with the very recent study of Pham-Dang et al. (4), where 37% of catheters initially did not achieve the desired perineural positions. These are alarming numbers, which may be reduced by more controlled catheter insertion.

Stimulating catheters usually contain current conducting stylet allowing continuous stimulation during insertion. Loss of twitches during advancement indicates aberrant position and prompts for correction. Indeed, after one or two corrections 98% of stimulating catheters can be placed perineurally (4). The combination of Tuohy type insertion needle with stimulating catheter may even increase this number. Therefore, the quality of post-operative analgesia should be improved and the local anaesthetic consumption reduced.

Several questions need to be answered before we replace ordinary catheters with the new stimulating ones.

1. What are the limits of electrical charge needed for a successful perineural placement?
2. How saline expansion of the perineural space influences this charge?
3. Which design of catheter tip (single or multiple holes) gives best clinical results?
4. Will Tuohy type needle facilitate correct catheter positioning?
5. Are there any dangers of nerve damage during repositioning of these catheters?
6. Do they improve the quality of post-operative care?

In these hard times of evidence based medicine and economic cuts we must answer these questions by large randomised clinical studies. Improved post-operative patient care (better analgesia, improved rehabilitation and shortened sick-leave) will no doubts justify the slightly higher costs of stimulating catheters.

References.
Biographies

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