NERVE STIMULATION FOR PERIPHERAL NERVE BLOCKADE. ANAESTHESIA TUTORIAL OF THE WEEK 149

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QUESTIONS

Before continuing, try to answer the following questions (single best answer). The answers can be found at the end of the article, together with an explanation.

1. What is Rheobase?
   a. The length of time the current must be applied to the nerve to initiate an impulse
   b. The minimum current required to initiate an impulse in the nerve
   c. Repolarisation of the nerve
   d. All of the above

2. An ideal nerve stimulator should
   a. be dedicated for use for peripheral nerve blocks
   b. be a constant current generator
   c. be a constant voltage generator
   d. display the set current *and* the actual current delivered to the patient

3. The use of the peripheral nerve stimulator is based on
   a. Coulomb's law
   b. Newton's law
   c. Poisseulle's law
   d. Charles' law

INTRODUCTION

The aim of any regional anaesthesia technique is to locate a nerve or compartment containing nerves and deposit local anaesthetic around the nerve or in that compartment in order to block nerve conduction. Various techniques can be used to achieve this aim. The main techniques in use are paraesthesia, nerve stimulator and more recently ultrasound.

Historically, nerve blocks were performed using anatomical landmarks as a guide as to where to insert the needle and then eliciting paraesthesia. (When the locating needle touched the nerve the patient experienced a sensation like 'pins and needles' or an 'electric shock like sensation.) The disadvantages of using a paraesthesia technique is the theoretical increase in the risk of nerve damage by the needle touching the nerve (implied by the resulting paraesthesia), its reliance on a subjective sensation that patient experiences and the lack of an objective response that the anaesthetist can use. In addition, the sensation of paraesthesia may by uncomfortable and unacceptable for some patients.

Nerve stimulators have sought to add an objective end point to aid nerve location. They apply a small amount of direct current (DC) to the needle, which when it is close enough, is transmitted to the nerve. The nerve is then stimulated to produce a motor response. An appropriate motor response corresponding to the motor innervation of the desired nerve to be blocked has been shown to improve the success rate of a block.

In recent years, ultrasonography has revolutionized the way nerve blocks are being performed. It has an added advantage over other techniques of being able to visualize the nerves and the needle during the performance of a nerve block. The cost of the machine and training are the two major issues which limit the use of this technique currently. Although the science behind nerve stimulation has been questioned in recent years, nerve stimulators have continued to play a key role in the development and practice of ultrasound guided regional anaesthesia. The basics of ultrasound and ultrasound guided blocks will be covered in future tutorials from ATOTW.

It is important to understand the electrophysiology of the nerve stimulator and be familiar with the equipment to be able to perform peripheral nerve blocks safely and effectively.

PERIPHERAL NERVE STIMULATORS (PNS)

History

The use of nerve stimulators to carry out nerve blocks can be dated back to the middle of the last century. Kulenkampff described the brachial plexus block in 1928 and Perthes used electrical stimulation to locate the brachial plexus. But the technique was crude and the equipment cumbersome and it did not gain wide acceptance. In 1955 Pearson demonstrated that motor nerves could be located by electrical stimulation with an insulated needle. In 1962, Greenblatt and Denson devised a portable transistorized nerve stimulator which stimulated further use of nerve stimulators in regional anaesthesia. This equipment was still expensive and not readily available. Finally in 1969 Wright reported the Block- Aid monitor for nerve blocks which popularized the technique making it more feasible.

Initially non-insulated needles were used for nerve stimulation but now insulated needles are usually used.

Percutaneous nerve stimulation is a novel method of non-invasive location of nerves and Urmey described the use of electrically sheathed skin electrode probe (Percutaneous electrode guidance-PEG) in mapping out the nerve's anatomical course and subsequently guide the block needle towards it.[i]

Electrophysiology

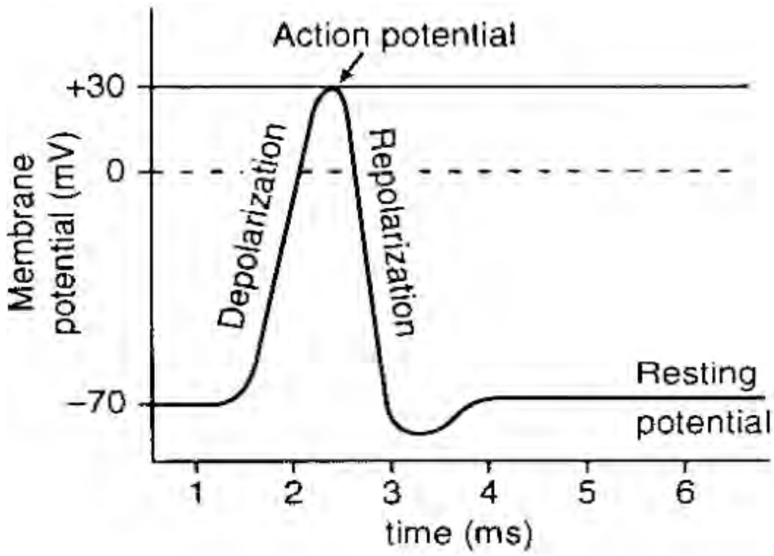

Figure 1. Nerve action potential

Neurons, like every other cell in the body, rest in a state with a negative electric potential inside the cell relative to the outside. This is called the resting membrane potential and is about -70mV. When a neuron is "stimulated" a transient change in the ion permeability of the membrane (an increase in the conductance of the sodium channels) occurs. If the stimulus is strong enough it depolarises the membrane sufficiently to set off an action potential which then propagates along the nerve to stimulate the muscle and causes a contraction. Figure 1 shows a nerve action potential,

If the stimulus is **not** strong enough, even if it is applied for a long time it will not produce an action potential. Conversely if a strong stimulus is applied for only a very short time this will not produce an action potential. **The stimulus needs to be strong enough *and* it needs to be applied for sufficient time to produce an action potential**.

Current

The minimum **current** required to initiate an action potential in the nerve is called the **Rheobase**. Below this level the current cannot initiate an impulse even if it is applied for a prolonged duration.

Chronaxie is the length of time the current must be applied to the nerve to initiate an impulse when the current level is **twice the rheobase**. It can be used to describe the excitabilities of different tissues.

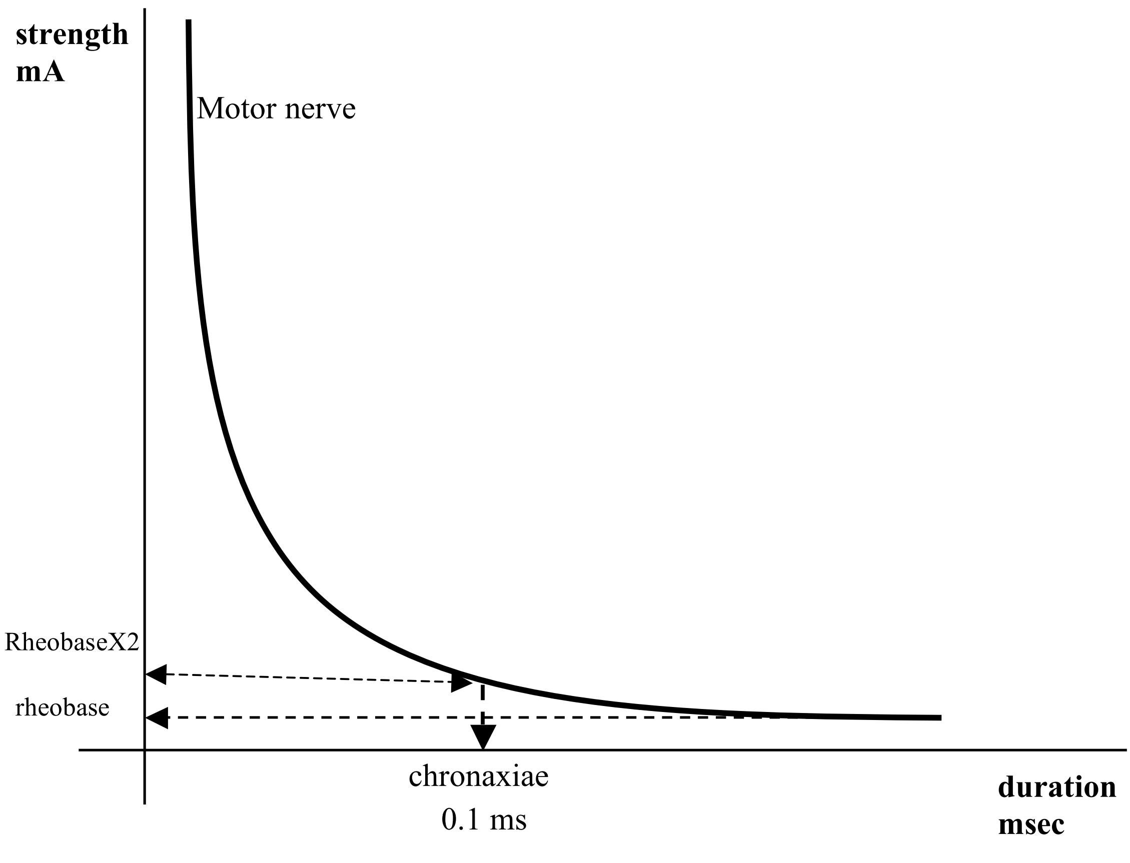

Figure 2. Strength-duration curve for a motor nerve. At a current equal to the rheobase the current has to be applied for a relatively long time. A current twice the rheobase value needs to be applied for a much shorter time to achieve a response.

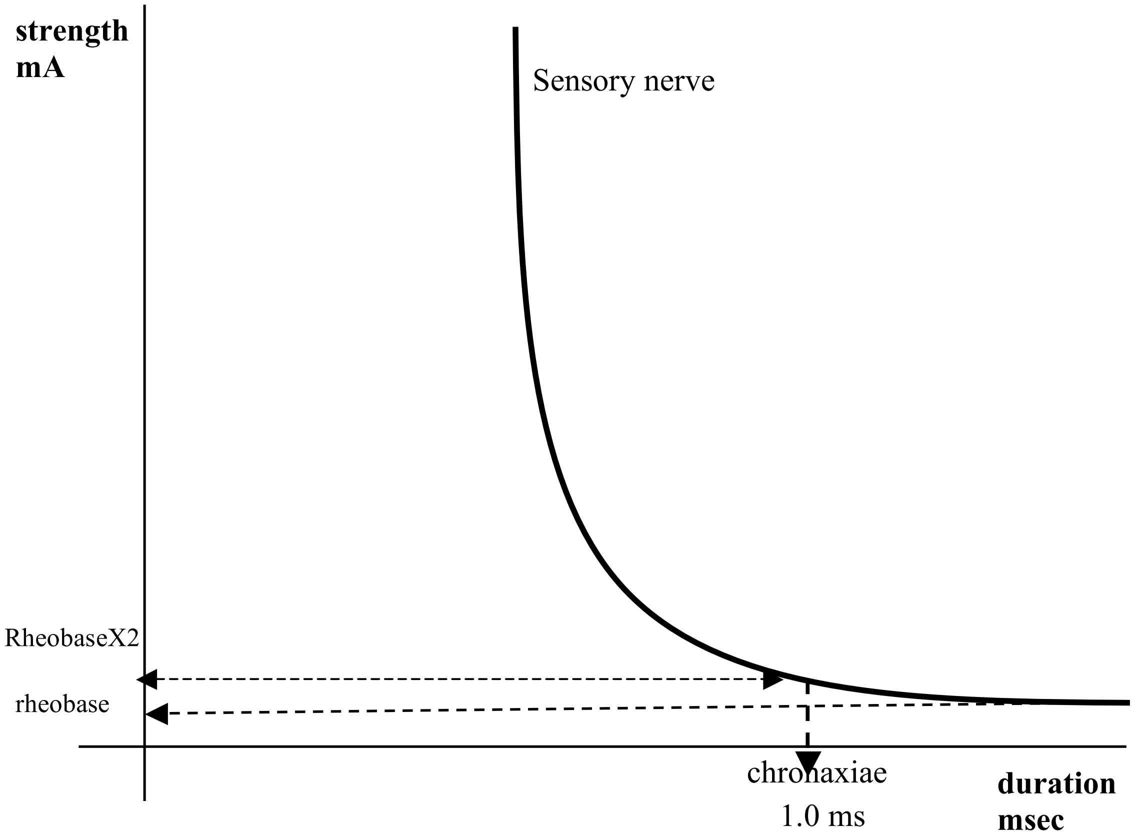

Figure 3. Strength-duration curve for a sensory nerve.

The chronaxie varies in different nerves depending on their sensitivities and their refractory periods (Table 1). Faster conducting nerves like the Aα motor nerve fibres have a smaller chronaxie due to a shorter refractory period than the slower conducting sensory nerves like Aδ or the unmyelinated C sensory nerve fibres. Motor nerves have a shorter chronaxie than sensory nerves. Therefore it is possible to stimulate a motor nerve but not the sensory nerve by using a current of smaller chronaxie (shorter time). This means a motor response can be seen without producing pain. However, the patient may still feel some sensory stimulation such as tingling.

Table 1. Chronaxie of different nerves

	Nerves	Chronaxie time (msec)
Unmyelinated	*C*	*0.40*
Myelinated	*Aδ*	*0.17*
Myelinated	*Aα*	*0.05-0.10*

The **threshold current** is the lowest current which produces a motor response. A value between 0.2-0.5 mA has been suggested to ensure a successful block, but a value of current can not be taken as a reliable indicator of the distance of the needle from the nerve. It has been demonstrated using ultrasound that it possible to be in close proximity to the nerve and yet not being able to elicit motor responses even at currents as high as 1.5mA.

Nerve stimulators are designed to be constant current generator ie: the current between the anode and cathode of the nerve stimulator is kept constant irrespective of the impedance/resistance of the tissue surrounding the nerve. The current output can range from 0.01mA to 5mA. The current output is controlled by a dial on the PNS or a foot operated paddle connected to it. Recently, remote controlled knobs to manipulate the settings are also available.

Distance
Coulomb's law can be summarized as E= K(Q/r2), where E is the stimulus intensity, K is a constant, Q is the minimum current from the needle tip and r is the distance of the stimulus source from the nerve. Rearranging the equation, Q ∝ r2, we can see that the minimum current required to stimulate the nerve is directly proportional to the square of its distance from the nerve. Hence, at a low current intensity, the nerve will only be stimulated when the needle is very close to it. For example, if the distance of the needle from the nerve decreases from 4mm to 1mm, the minimum current required to stimulate the nerve will be reduced by one sixteenth and therefore the ability to stimulate the nerve at a very low currents is an indication of proximity to the nerve.

Polarity
Most modern peripheral nerve block stimulators have the cathode being as the needle. ie; the needle is negative. It is better to have the needle as the cathode because if the needle is positive (the anode) then the nerve will get hyperpolarised and a larger current will be needed to depolarise the nerve and obtain a response.

Frequency
The ideal electric parameters for comfortable stimulation is 1 to 2 Hz. A higher frequency will give more frequent feedback to the operator, but often causes greater discomfort to the patient. If too low a frequency is used then there is a risk of nerve impalement between current impulses.

Stimulating needles
Initially non-insulated needles were used for nerve stimulation but now insulated needles are recommended and more commonly used. An insulated needle has the whole of the shaft insulated except for the tip.

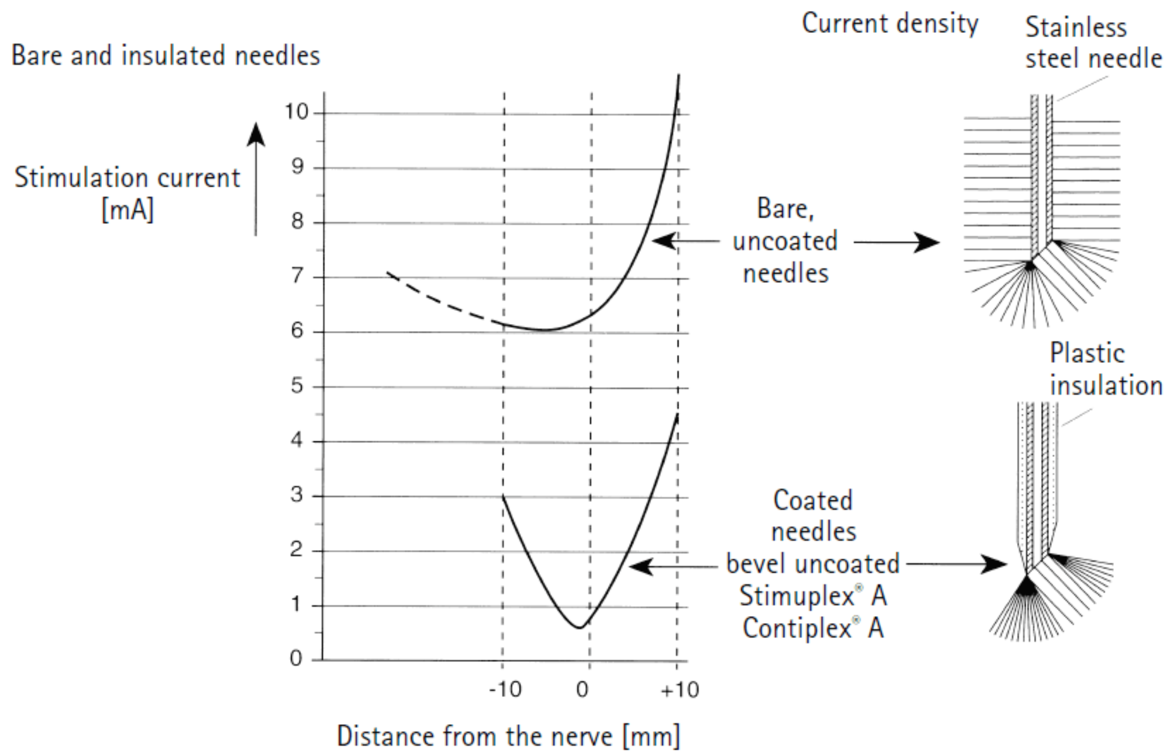

Figure 4. Comparison of non-insulated and insulated needle and their respective stimulation currents. (Reproduced from stimuplex HNS-11 manual with permission from B Braun, UK)

Figure 4 shows that with bare uninsulated needles current leaks out all along the shaft of the needle. Insulated needles only emit current from the needle tip. Therefore a higher stimulation current is required for uninsulated needles compared to a coated/ insulated needle to elicit a response from the nerve. The fact that the current only comes out at the tip also means that insulated needles are more focused and you have an idea of where the tip is based on the nerve stimulated. As the needle moves away from the nerve there is a rapid increase in the stimulating current with an insulated needle (Fig4) as opposed to a more gradual change in simulating current with increasing distance with non- insulated needles which results in greater accuracy. With a non-insulated needle the motor response may only be elicited after the needle tip is beyond the nerve due to the current leaking from the shaft.

Needles are available from a number of manufactures in different lengths (25-150 mm) and guages (20 to 25G). The length of needle used will depend on the depth of the nerve to be blocked. Many needles have markings on them allow measurement of how far the needle is inserted under the skin. The needle tip may angled at 15 or 30 degrees.

Catheters can be inserted for continuous nerve blocks *through* specially designed insulated needles which have Tuohy tip (e.g. Contiplex Tuohy, BBraun) or a *catheter over needle* technique. With some catheters the current is can also be emitted from the tip of the catheter to aid determining final catheter position. These are called stimulating catheters and there are different ones available from the different manufacturers.

Using a PNS for a PNB

General preparation as described in tutorial "Peripheral nerve blocks – getting started" (tutorial 134) should be followed. (http://totw.anaesthesiologists.org/2009/05/18/peripheral-nerve-blocks-getting-started-134/)

The equipment needs to be checked prior to starting and set to the desired initial current (1-2mA), pulse duration (0.1ms) and frequency (2Hz). The needle is connected to the cathode of the machine and the anode is connected to the patient via an ECG electrode which is placed on the patient. The local anaesthetic syringe is connected to the flexible tubing of the needle and the needle and tubing is flushed with local anaesthetic solution.

The point of needle insertion is determined by anatomical landmarks. It is important to make sure the circuit is complete as soon as the needle is inserted. The machine may have a flashing light or audible bleep or some other mechanism to indicate that the circuit is complete. The needle is then advanced until the desired motor twitch is obtained. The current is then reduced until no motor response is seen. The displayed current on the nerve stimulator is noted. A current between 0.2-0.5 mA is accepted as an ideal threshold current. Below 0.5 has been shown to give a high success rate. Below 0.2mA may mean that the needle tip is IN the nerve and should be withdrawn before injection.

Once the nerve has been located satisfactorily, aspirate the syringe to ensure that the needle is not intravascular, then local anaesthetic can be injected in increments of 5mls without moving the needle tip. The motor twitch should disappear as soon as 0.5 ml to 1 ml of local anaesthetic is injected. This is thought to be either due mechanical displacement of the nerve from the needle (Raj test) or due to change in the electrical conductivity around the nerve. Failure of the twitch to disappear, pain on injection of solution or high injection pressures suggests intraneural placement of the needle tip and warrants small withdrawal of the needle tip (0.5 -1mm).

Ideal electrical characteristics of a peripheral nerve stimulator

1. Constant current generator
2. Monophasic rectangular output pulse i.e. the current flows in one direction only. The shape of the current output is rectangular, though there is no evidence to show superiority of any one shape of current output.
3. Ability to vary pulse duration (0.1-1ms)
4. Digital display of actual flowing current
5. Safety features like circuit disconnection alert, impedence alerts, low battery and malfunction alert
6. Leads should be clearly marked to avoid confusion as to which is cathode and anode. In modern machines, stimulators can only connect to the cathode of nerve stimulator.

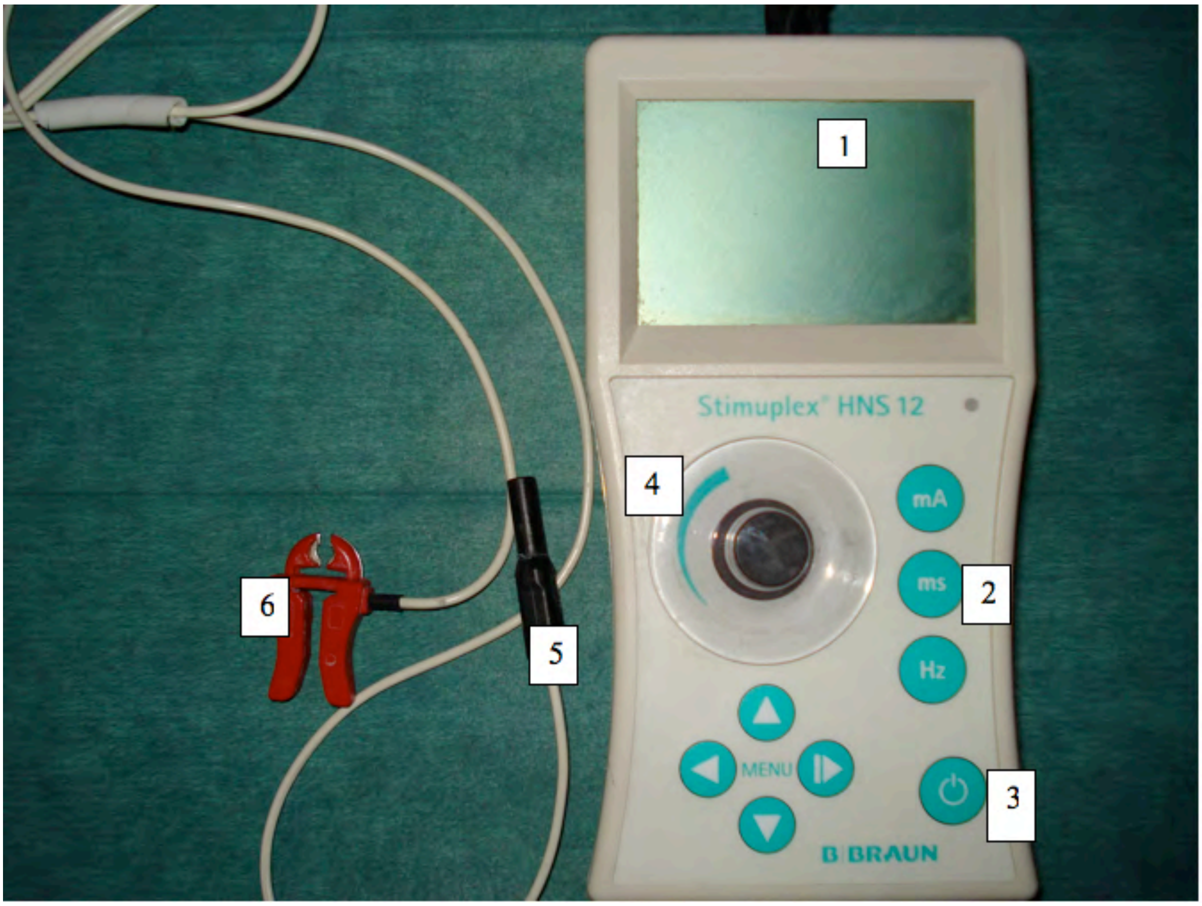

Figure 5. A typical electronic nerve stimulator – the B-Braun Stimuplex HNS12

1. Screen displaying the set and delivered current and other features like frequency, duration of stimulus
2. Buttons to choose to alter current, duration of stimulus and frequency
3. On/ Off button
4. Dial to increase and decrease settings
5. Black coloured cathode which is connected to the needle
6. Red coloured anode terminal which is connected to an ECG electrode placed on the skin of the patient remote from the site of needle insertion.

IMPORTANT POINTS

- A PNS is a useful aid to locate nerves for peripheral nerve blocks
- The usual PNS settings are pulse duration 0.1ms, frequency 2Hz and current starting at 1mA
- A threshold current of less than 0.5mA usually results in a successful block
- A current less than 0.2mA, increased resistance on injection or pain on injection may suggest intraneural needle placement

ANSWERS TO QUESTIONS

1.b. The minimum or threshold current required to initiate an impulse in the nerve for propagation is called the Rheobase. Below this level the current cannot initiate an impulse even if it is applied for a prolonged time. Chronaxie is the length of time the current must be applied to the nerve to initiate an impulse when the current level is twice the rheobase and is used to describe the excitabilities of different tissues.

2.b. Nerve stimulators are designed so that the current between the anode and cathode of the nerve stimulator is kept constant (constant current generator) irrespective of the impedance of the tissue surrounding the nerve.

3.a. The use of the peripheral nerve stimulators is based on the Coulomb's law. Coulomb's law can be summarized as E= K(Q/r2), where E is the stimulus intensity, K is a constant, Q is the minimum current from the needle tip and r is the distance of the stimulus source from the nerve. Rearranging the equation, we can see that the minimum current required to stimulate the nerve is directly proportional to the square of its distance from the nerve. Hence, at low current intensity, the nerve will be stimulated only when the needle is close to it.

WEBLINKS

http://totw.anaesthesiologists.org/2009/05/18/peripheral-nerve-blocks-getting-started-134/
http://nysora.com/regional_anesthesia/equipment/3114-nerve_stimulator.html
http://www.bbraun.com

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