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Equipment and Clinical Practice: Aids to Localization of Peripheral Nerves

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Introduction

Prior to the beginning of the discussion on localization of peripheral nerves, one must consider the location and circumstances under which one is performing these peripheral nerve blocks. It is imperative to ensure the presence of standard monitoring equipment (EKG, blood pressure, pulse oxygenation), wall oxygen, emergency medications (e.g., phenylephrine, ephedrine, epinephrine), resuscitation equipment (bag valve mask, laryngoscopes, and endotracheal tubes), and intralipid rescue prior to performance of a nerve block.

Identifying nerve location begins by identifying standard anatomical landmarks, which are used as a basis for subsequent invasive needle exploration. The successful endpoint used may be anatomical (transarterial axillary block), ultrasonographic (real-time imaging), or functional [a sensory paresthesia or a motor response to electrical nerve stimulation (NS)].

In the 1960s, electrical nerve stimulation techniques were developed. Even more recently, small, battery-operated, portable handheld devices have been introduced [1–3]. The theory behind the use of the nerve stimulator is that an identifiable specific muscle twitch can be observed by nerve stimulation during needle advancement to provide a reference for the appropriate distance of the needle to the nerve. The technique is further described below. After its invention, this technique enjoyed widespread use, with a proven clinical efficacy and safety record. Electrical stimulus of the nerve is based on factors such as conductive area of the electrode, resistance to electrical stimulation, distance between skin and nerve, current flow, and pulse duration (Fig. 10.1) [4].

Although ultrasound had previously been applied in other areas of clinical practice, after the advent of the peripheral nerve stimulator, the use of ultrasound to locate both peripheral nerves and their surrounding structures became progressively more widespread in the world of regional anesthesia. This allows the user to have concrete visual feedback to avoid damage to surrounding structures, including nerves and vasculature, while locating the needle tip at all times. It also allows visualization of the spread of local anesthetic [5].

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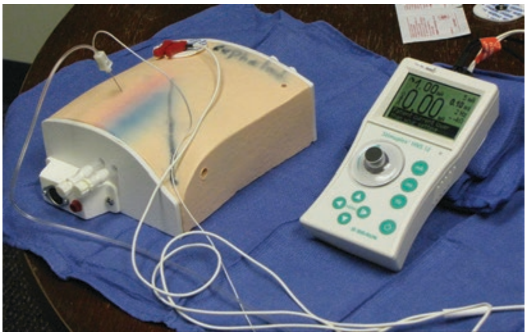

Fig. 10.1 Nerve stimulator, with stimulating needle/ground lead, attached to a simulated model

Peripheral Nerve Stimulation

A nerve stimulator works by applying a weak, direct current (DC) electrical current to a stimulating needle by an oscillating current generator. Assuming that a square pulse of current is used to stimulate the nerve, the total energy (charge) applied to the nerve is the product of the current intensity and the pulse duration. Ohm's law ($V = IR$) assists us in calculating the current generated by the stimulator [6]:

$$\text{Voltage output} / \text{impedance} = \text{current output (Ohm's law)}$$

or

$$V / R = I.$$

Technique

The nerve stimulator is first connected to a stimulating needle. A current is passed through the needle at an amplitude/intensity of 1–2 mA, a frequency (*f*) of 1–2 Hz, and a pulse duration of 0.1–0.2 ms. The needle is then inserted through the skin and slowly advanced toward the expected anatomical location of the targeted nerve. In each anatomical location, an expected twitch will be observed based on targeting specific nerves to be stimulated. When the desired motor response is elicited, the current intensity is gradually decreased until it is abolished. If the motor contraction is abolished at a relatively higher intensity (>0.6 mA), the needle should be advanced until a further motor response is elicited. This process should be repeated until the motor response disappears at approximately 0.4 mA. This indicates that the needle tip is in close enough proximity to the nerve (1–2 mm) to inject the desired local anesthetic. If a muscle twitch is generated at a current strength of less than 0.4 mA, the stimulating needle may have penetrated the epineurium, thus risking a subsequent intraneural injection. It is therefore important to ensure that the muscle twitch disappears at or higher than a current of 0.4–0.5 mA.

As a side note, it is possible for a current to be generated through a muscle leading to direct generalized muscle stimulation; this should not be confused with a neural stimulation as an intramuscular injection likely would not provide an accurate nerve block.

In practice, the PNS should not be used as a substitute for proper knowledge of anatomy, as no motor response will occur if the needle tip is greater than 1 cm from the targeted nerve. PNS should be used to refine the search endpoint, guiding the needle through the final 5 mm or so.

Another limitation of the PNS technique is that PNS is limited in application to mixed peripheral nerves because a motor response endpoint is desired. Although pure sensory nerves may be stimulated, ultimately obtaining a sensory paresthesia, this is not commonly performed clinically.

Electrophysiology

Energy

The amount of electrical energy required to propagate a nerve impulse is the product of the stimulus strength (mA) and current duration (ms). For any nerve type, there is a minimum current strength required in order to generate an impulse—this is referred to as the rheobase. Below this minimum level, an impulse will not be generated. The chronaxie is defined as the stimulus duration needed for impulse generation, when employing a current strength of twice the rheobase.

Myelinated fibers are much more sensitive and require less electrical energy for stimulation than unmyelinated fibers. Therefore, if less electrical energy is required to propagate a motor nerve impulse, this means that either the stimulus strength required may be lower than that for a sensory nerve or the current duration may be lower than that required for a sensory nerve (lower rheobase or shorter chronaxie). The clinical relevance of this concept and application to peripheral nerve stimulator use is that the goal of nerve stimulation is to stimulate muscular contractions while avoiding painful sensory nerve stimulation. Since the chronaxie of A alpha fibers is 50–100 μs while A delta fibers require 170 μs and C fibers require 400 μs, it would be wise to use shorter impulse durations (<0.17 ms) in order to attempt to stimulate only the A alpha fibers. Alternatively, one may use a weaker stimulus strength with a longer pulse duration (e.g., >0.5 mA) to elicit the same motor response. If either current intensity or pulse duration becomes too high, uncomfortable paresthesia-like sensations often occur.

Polarity

A nerve impulse is propagated when a threshold potential is reached, causing depolarization of the nerve. Typically, the nerve has a resting potential of around −60 mV, with negative charges inside the cell and positive charges on the outer membrane. To cause a decrease in the potential difference between the inside and outside of the cell, a negative charge should be introduced outside the cell. Therefore, less electrical energy would be required if the negatively charged cathode is close to the nerve, inducing direct depolarization. The reverse is true with an anodal (positive) needle since the direction of flow would induce hyperpolarization of the target nerve. This, in turn, requires a higher current to stimulate the nerve. For these reasons, the needle polarity is designated negative by default. The site of placement of the positive (return) electrode, however, is probably irrelevant, as long as quality grounding electrodes are used and good electrical contact is made.

Distance

The relationship between the constant current stimulus intensity and the distance from the nerve is governed by Coulomb's law:

$$I = K\left(\frac{Q}{r^2}\right),$$

where I is the stimulus intensity, K is a constant, Q is the minimal current needed for stimulation, and r is the distance from the stimulus to the nerve.

Rearranging this formula, we get:

$$\frac{I}{K} = \frac{Q}{r^2}$$

and

$$\frac{I}{K} r^2 = Q.$$

Since $\frac{I}{K}$ is a constant:

$$r^2 \sim Q.$$

This means that as distance from the nerve increases, the charge required to stimulate the nerve increases by the square of the increased distance, requiring a very high current intensity as the needle moves further away from the nerve.

Stimulus Frequency

As the needle is advanced, a muscle twitch by the stimulating current indicates that the needle is approaching the target nerve. If the frequency of impulses is too low, the nerve may be inadvertently penetrated. If the frequency is too high, painful muscle twitches (tetany) may be induced. A frequency of 2 Hz (cycles/s) is a good compromise as well as a suggested needle advancement speed of approximately 1 mm/s [12].

Summary

A peripheral nerve stimulator should provide as a minimum:

1. A square wave impulse with a duration of 0.1 ms.
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 0.4–0.6 mA, positioning the needle tip close to the nerve.
6. Current delivery down to 0.1–0.2 mA, to ensure no intraneural stimulation.

Additional safety features include:

1. Accurate current delivery in the range of 0–5.0 mA.
2. Constant current square wave pulse.
3. Display of current flowing into the patient as well as that delivered internally from the device.
4. Open circuit alarm.
5. Excessive impedance alarm.
6. Low battery alarm.
7. Internal malfunction alarm [6].

New Developments in Nerve Stimulation

Percutaneous Electrode Guidance

The percutaneous electrode guidance (PEG) technique is a modification of transcutaneous NS: a percutaneous nerve electrode coupled to a nerve stimulator can be used to locate an underlying nerve by passing the superficial electrode over standard anatomic landmarks. Cutaneous stimulation of the underlying nerve occurs at nerve stimulator settings between 2 and 10 mA, with a 0.1-ms pulse duration (alternatively, 0–5 mA, pulse duration 0.2–1.0 ms). Cutaneous stimulation benefits from a longer pulse duration (0.2–1.0 ms), which enables an electrical motor response at a lower current. Since much of the initial stimulation is done by the probe, which indents the skin toward the nerve, the stimulating needle tip (inserted from within the outer PEG cannula) travels only a short distance in order to finally contact the nerve. Skin indentation during the performance of the PEG technique allows for a decrease in impedance as well as a maximal increase in electrical conductance. Thus, PEG has the net effect of eliciting a motor response with minimal discomfort to the patient [6, 13, 14].

Sequential Electrical Nerve Stimulation

Presently, current amplitude (amperage) is continuously varied, deliberately maintaining a constant frequency and pulse duration (one degree of freedom). Therefore, only one constant fixed pulse duration has been used (e.g., 0.1 or 0.2 ms). Some newer nerve stimulators allow the pulse duration to be preset at different fixed pulse widths (e.g., 0.05, 0.1, 0.3, 0.5, or 1.0 ms). However, this pulse duration cannot be easily varied during the actual block performance. Urmey and Grossi [15] evaluated a novel technique for nerve localization utilizing an electrical nerve stimulator programmed to deliver sequenced electrical nerve stimuli (SENS). The nerve stimulator generated alternating sequential electrical pulses of differing pulse durations at an overall set frequency of 3 Hz (3 cycles/s). Repeating pulse duration sequences of 0.1, 0.3, and 1.0 ms (shortest to longest) were generated, with 1/3-s period intervals separating each pulse.

Selective attenuation of the applied current resulted in the three pulses having more equivalent charges. In each case, the needle was advanced at an initial current amplitude of 1 mA until appropriate motor responses (MR) occurred. If 1 MR/s or 2 MR/s were noted, the needle was continually advanced until all 3 MR/s were visible. Current was then decreased until MR/s decreased to 1 or 2. At this point, the needle was again advanced slowly. When 3 MRs occurred at ≤0.5 mA, indicating that the 0.1-ms pulse was stimulating the nerve, final needle position was held constant. Prior to final injection, current was then slowly decreased with the needle held immobile.

Conventionally, increasing the current flow has been the only parameter used to increase stimulation range since it directly enables stimulation at a greater distance from the nerve. Additionally, with SENS, pulse durations of 0.3–1.0 ms were used almost simultaneously to increase the range, in distance, of successful stimulation at a given current amplitude. Therefore, higher pulse durations increase sensitivity for successful NS with the stimulator needle at a distance, whereas specificity is then enhanced by decreasing the pulse duration down to the standard 0.1 ms. By employing sequential long and short pulses, successful neurostimulation was able to occur at a much greater needle to nerve distance. Prior to SENS, these elicited motor responses did not occur with the standard 0.1-ms pulses. Thus, the near simultaneous variance of two separate parameters (applied current together with pulse width duration) enhanced successful PNS of the targeted motor nerve [6].

Ultrasound

As mentioned above, the use of ultrasound to locate peripheral nerves and their surrounding structures has become progressively more widespread in regional anesthetic practices. Ultrasound allows the operator to visualize their target nerve while seeing their needle tip in real time. It also allows the visualization of local anesthetic spread around the target nerve and allows us to avoid undesirable structures (i.e., intravascular or intraneural injections) [7]. Many of these benefits may not be provided by the anatomic and nerve stimulator-guided techniques of peripheral nerve block insertion. One study showed that in an appropriately imaged supraclavicular nerve block, a peripheral nerve stimulator adds no benefit [8]. This study demonstrated that ultrasound guidance may serve as a substitute for peripheral nerve stimulation (in patients with normal anatomy). Another study showed that for sciatic nerve block, ultrasound guidance resulted in higher success, a faster block onset, and faster progression of sensorimotor block while not increasing nerve block performance time or complications as compared to peripheral nerve stimulator-guided procedure [9]. According to the American Society of Regional Anesthesia and Pain Medicine, ultrasound guidance has improved the incidence of pneumothorax and local anesthetic systemic toxicity and the incidence and intensity of hemidiaphragmatic paralysis (unpredictable manner), but has no significant effect on the incidence of postoperative neurological symptoms [10]. While these benefits have been affirmed, one must always take into account the technical capabilities of both the ultrasound machine and the operator [11]. As ultrasonography is discussed elsewhere in this textbook, for a more in-depth discussion on ultrasound's involvement with regional anesthesia, please see Chap. 9.

Positioning

As with any aspect of clinical care, the positioning of the patient can decide the success or failure of the procedure at hand. Optimization of anatomy is essential to the success of any nerve block no matter what adjuvant techniques are available. This becomes even more important when taking into consideration patients of a different body habitus than average.

In some cases, pillows, towels, or a second practitioner may be used to assist in positioning a patient (supine, lateral, prone, sitting, etc.). In addition, specific positioning devices that assist practitioners when performing blocks are also available. One example includes a device which can maintain an elevated extremity; for example, a supine patient with a planned popliteal nerve block can be maintained with less need for counterpressure along the leg for visualization of the nerve. A table which can allow for adjustable height also can help the practitioner raise the leg instead of using stacks of blankets or pillows.

These examples allow the patient to remain supine while properly propping the lower extremity in position for the peripheral nerve block. This also allows access to the airway in the setting of sedation, allows for efficient nerve blocks, and requires no additional space, as it is placed directly on the patient's bed.

Regional Anesthesia Equipment Tray

When performing a regional anesthetic procedure, pre-made kits with needed supplies can be useful to perform the block. Not only does this provide organization and efficiency while performing the block but can also be added as a separate billable charge bundle, as the equipment used is not part of the typical general anesthetic protocol, leading to possible revenue [16]. Depending on the institution, regional anesthetic equipment kits can include, but are not limited to, nasal cannulae, EKG electrodes, pulse oximeter, needles, syringes, stopcock, sterile gloves, midazolam and fentanyl for sedation, and insulated nerve block needles. When placing a continuous nerve block catheter, the kit may be expanded to include a nerve block catheter, sterile drapes, sterile dressing, and a local anesthetic infusion device. Kits can also be custom-made to address the needs of the particular clinical setting and expected procedures to be performed.

Skin Preparation

Infection is a rare complication associated with regional anesthetic procedures but is a concern nonetheless. The concern has grown greater with the growing popularity of perineural catheters, as these can be indwelling devices. Two common antiseptics used to prepare the skin for the procedure are povidone-iodine and chlorhexidine. While both may kill organisms on the skin and some meta-analyses show similar results, there is a wealth of literature supporting the use of chlorhexidine over povidone-iodine. Chlorhexidine was demonstrated to have more rapid of onset and more efficacy at antisepsis with longer duration when being used for epidural or even central venous catheter or arterial line placement [17–21]. While this may be true and despite the increased effectiveness of chlorhexidine (chlorhexidine is bactericidal in nature) over povidone-iodine, chlorhexidine is not FDA approved for use during perineural administration due to concerns for neurotoxicity. There have been several case reports of chronic adhesive arachnoiditis associated with both epidurally and spinally injected chlorhexidine [22]. This concern may be secondary to the chlorhexidine itself or to the primary ingredient in the chlorhexidine skin preparation (alcohol) [23]. Alcohol has long been known to be used for neurolytic blocks and thus may be the cause of neurotoxicity, though it is unclear.

Ultrasound Transducer Covers

For single-shot and continuous peripheral nerve blocks in practice of the authors, the ultrasound transducer is typically covered in a clear, plastic, sterile sheath. This allows the practitioner to visualize ultrasound gel properly covering the transducer, permitting the ultrasound machine to have proper coupling between sound waves and tissue. In some practices, the ultrasound transducer is covered with a transparent film dressing only. The advantage to using the longer probe sheath is that the procedure is performed with higher sterility. The disadvantages, as identified by Tsui et al., consist of increased cost and the possibility of air tracking between the transducer and the inside of the sheath, producing a poorer image quality [24].

Injection Pressure Monitoring [25]

Another method that has been developed in order to improve safety and help avoid intraneural injection has been to monitor the injection pressure during perineural local anesthetic injection. One study performed in canines indicated that high injection pressures may indicate intraneural needle placement, leading to neurologic injury and deficits. It also found that injecting intrafascicularly with a pressure monitor required pressures >25 psi due to the low compliance of injecting into perineurium [26]. There are multiple techniques to monitor injection pressures. The compressed-air technique is when one draws up 10 mL of air with 10 mL of saline. If one holds the syringe upright and only compresses the air to half of its original volume when injecting, the practitioner cannot exceed 15 psi of pressure [27]. Another option that has been used is a disposable manometer. Placed between the syringe and tubing, the manometer can measure pressure directly from the syringe into the spring-loaded manometer of pressures <15, 15–20, or >20 psi.

All of the above being true, the cost of extra devices can be high, the compressed-air technique can be time-consuming to set up, and the risk of nerve injury is quite low; therefore, it is not commonplace to monitor injection pressures in all practices. In addition, it is a common belief that intraneural injection can be avoided by the sensation of resistance during injection and that smaller volume syringes enable the clinician to better feel this resistance, but in a recent animal study, the conclusion was that syringe feel was no better than chance at detecting intraneural injection when using a 20 mL syringe [28].

Needles

There are several different needles employed during regional anesthetic procedures. Each needle provides different advantages.

Stimulating Needles

Stimulating needles, also known as insulated needles, have a protective nonconducting sheath over the shaft of the needle, with the exception of the tip. By applying an electrical current to the needle using a nerve stimulator, it is possible to stimulate a nerve as the tip of the needle comes in proximity of the nerve.

When comparing nerve blocks using a nerve stimulator with stimulating needles versus ultrasound alone, studies have demonstrated quicker onset of sensory and motor blockade and longer duration with US guidance compared to peripheral nerve stimulation alone [29, 30].

Echogenic Block Needles

As there is an increasing prevalence in the use of ultrasound to guide the placement of peripheral nerve blocks and catheters, the development of an echogenic block needle was a logical next step. The primary purpose of these needles is to better visualize the needle tip during particularly difficult nerve block procedures, such as those requiring steeper insertion angles, though they may be used to improve visualization in novice anesthesiologists for blocks with shallow angles as well. Many of these needles exist in various forms and with different names (textured, reflector, cornerstone/corner cube reflector [CCR]). Textured reflecting surfaces are typically placed at the tip of the needles, which allow ultrasonic waves to reflect back to the ultrasound probe at any insertion angle. This technology is similar to bicycle reflectors [31]. Kamada et al. used gel phantoms to compare CCR needles with standard block needles and showed that a lower optical density (better echogenicity) and a better luminance occurred with the CCR needles than with standard block needles at an insertion angle of 30° [32]. Kilicaslan et al. used beef phantom models to demonstrate that inexperienced users of block needles were able to complete a block procedure more quickly with better visibility of the needle tip at insertion angles between 42 and 64° [33]. Finally, Brookes et al. demonstrated in vivo that patients receiving proximal sciatic nerve blocks for total knee arthroplasties had shorter procedure times, fewer needle redirections, and decreased patient discomfort with an echogenic needle versus a plain stimulating needle [34].

Needle Gauge

In general, a 21–22 G needle is used to place single-shot nerve blocks. Needles with smaller gauge improve patient comfort while placing the block; however, they are more difficult to inject through. These needles are usually used for local infiltration at the skin.

Larger bore needles can be useful when placing catheters. A 17–18 G Tuohy needle is commonly used to place perineural catheters as a larger needle is needed in order for a catheter to be able to pass through a port site.

Needle Bevel

There have been several studies concerning mechanical trauma in regard to the needle bevel. Short-beveled and <45° needles may have less incidence of nerve trauma: however, when nerve injury does occur, it may be more severe compared to long-beveled needles, >45° [35–38].

Catheters

Recently, perineural catheters have become popular to provide anesthesia and analgesia for surgical cases, especially orthopedic and vascular procedures. Brachial plexus catheters have been shown to have favorable outcomes [39]. Interscalene catheters have been shown to decrease pain and opioid usage after shoulder surgery [40]. Sciatic nerve catheters in both the popliteal fossa and the subgluteal crease improve analgesia in the postoperative period following foot surgery [41]. Finally, adductor canal catheters have also been used successfully with dilute local anesthetics to improve pain control following total knee replacement while minimizing the motor blockade associated with continuous femoral nerve blockade [42].

Infusion catheters have been useful for continuous infusion of perineural local anesthetic. Catheters usually come in a 19–22 G size. Smaller gauge catheters may increase resistance to infusing medication through. They also may be more difficult to thread and more likely to kink.

The catheters themselves have been constructed with several different properties and varieties. They can be single port or multiorifice. Single-port catheters have their opening at the distal tip of the catheter. With single-port catheters, test injectate is all expelled from the single orifice, allowing for a more reliable test dose to the same area, should the orifice of the catheter be intravascular or intrathecal. In contrast, multiorifice catheters may be less likely to plug given the multiple openings and may be more reliable for detection of intrathecal or intravascular placement via aspiration.

Newer catheters may be made of different materials, leading to differences in stiffness and flexibility. Metal reinforced catheters may be difficult to kink; however, they are not MRI compatible and should be noted when placed. In addition, those catheters known to be more stiff may have a greater likelihood to puncture a structure, such as a vessel.

In addition, stimulating catheters that are able to conduct an electrical current have been used. By applying an electrical current along the catheter and finding a subsequent muscle twitch along the expected nerve distribution, the catheter is theoretically in closer proximity to that nerve. Data comparing stimulating catheters to nonstimulating catheters has been conflicting. While some studies have demonstrated that stimulating catheters may lead to better analgesic quality [43] and a higher success rate following nerve block in combination with ultrasound guidance [44], other studies have demonstrated a similar quality of analgesia and increased time to proper catheter positioning [45].

Given the prevalent use of ultrasound in today's regional anesthetic practices, and the continued use of perineural catheters to prolong patient analgesia, echogenic nerve catheters are now an additional tool of our anesthetic practice. Data comparing stimulating catheter and needle versus echogenic needles showed a decrease in procedure time and patient discomfort with echogenic needle and catheter versus stimulating needle and catheter, with no difference in visibility during sciatic nerve block with a low-frequency ultrasound transducer [34]. In addition, ultrasound has been used in unique ways to identify the location of a perineural catheter. Using a catheter with a guidewire, the removal and reinsertion of the guidewire (pumping maneuver) produced a color Doppler effect along the track of the catheter and created an M-mode tracing to help identify its proper placement [46].

Conclusion

As we look back upon the history of regional anesthesia, it is clear that while peripheral nerve blockade was previously performed without adjuncts for nerve localization, the complication rates were higher, and the success rates were lower. With further technological advances (i.e., ultrasound, peripheral nerve stimulation, injection pressure monitors, positioning devices, echogenic needles and catheters), we are now able to perform peripheral nerve block more safely and successfully.

Review Questions

1. Identifying nerve location can be:
   (a) Anatomic
   (b) Ultrasonographic
   (c) Functional
   (d) All of the above
2. Electrical nerve stimulation is based on:
   (a) Conductive area
   (b) Resistance
   (c) Distance
   (d) All of the above
3. A nerve stimulator:
   (a) Applies a constant current impulse
   (b) Charge = (*I*) × (pulse duration)
   (c) Utilizes an oscillating current
   (d) (b) and (c)
4. Nerve stimulator current:
   (a) Is pulsed at 1–2 Hz (cycles/s)
   (b) Starts at 10 mA
   (c) Pulse duration of 0.1–0.2 ms
   (d) (a) and (c)
5. Motor contractions:
   (a) Occur at low current (0.2–0.5 mA)
   (b) Do not occur greater than 1 cm from needle tip to nerve
   (c) Start at a current of 1–2 mA
   (d) All of the above
6. Pure sensory nerves:
   (a) May be stimulated
   (b) Endpoint is a sensory paresthesia
   (c) Are not commonly stimulated clinically
   (d) All of the above
7. When using a high-intensity current (>1 mA):
   (a) Motor and sensory stimulation occurs
   (b) Painful C fiber activity occurs
   (c) More current is required with longer duration (>0.5 mA)
   (d) (a) and (b)
8. True statements regarding needle polarity and grounding are:
   (a) Needle is negative by default
   (b) The grounding electrode should be applied within 6 in. of the target nerve
   (c) A positive needle requires a higher stimulating current
   (d) (a) and (c)
9. Ultrasound-guided regional anesthesia provides all of the following benefits except:
   (a) Decreased incidence of pneumothorax
   (b) Decreased incidence of local anesthetic systemic toxicity
   (c) Decreased incidence of postoperative neurological symptoms
   (d) Decreased incidence of hemidiaphragmatic paralysis
10. Chlorhexidine is more advantageous over povidone-iodine in regard to antisepsis because it:
   (a) Is more rapid in onset
   (b) More efficacious
   (c) Has longer duration antimicrobial activity
   (d) All of the above
11. Short-beveled needles compared to long-beveled needles:
   (a) Have less incidence of nerve trauma
   (b) Have less severe nerve trauma when trauma occurs
   (c) Are >45°
   (d) Are more comfortable for the patient
12. Tuohy needles:
   (a) Have an orifice at the tip in line with the shaft of the needle
   (b) Are nonstimulating needles

   - (c) Traverse through tissue in a straight line
   - (d) Are larger bore needles that allow advancement of a catheter through its shaft
13. Single-port catheters compared to multiorifice catheters:
    - (a) Are more reliable when tested with test injectate
    - (b) Are more reliable when aspirated for return of fluid
    - (c) Are more likely to become obstructed by a plug
    - (d) (a) and (c)
14. Stimulating catheters compared to nonstimulating catheters:
    - (a) Are equivalent in analgesic quality
    - (b) Improve block success when used in conjunction with ultrasound when placing infraclavicular blocks
    - (c) Are only single orifice
    - (d) (a) and (c)

Answers:

1. d
2. d
3. d
4. d
5. d
6. d
7. d
8. d
9. c
10. d
11. a
12. d
13. a
14. b

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