PROCEDURE

32 Peripheral Nerve Stimulators

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PURPOSE: Peripheral nerve stimulators (PNSs) are used in association with the administration of neuromuscular-blocking medication agents to assess nerve-impulse transmission at the neuromuscular junction of select skeletal muscles.

PREREQUISITE NURSING KNOWLEDGE

- PNSs are used in association with the administration of neuromuscular-blocking drugs (NMBDs) to block skeletal muscle activity.
- NMBDs are given in the intensive care unit, along with sedatives and opioids, most commonly to coordinate contemporary modes of mechanical ventilation with breathing in patients with severe lung injury. Neuromuscular-blocking agents are also used to assist with the management of increased intracranial pressure after a head injury; for severe muscle spasms associated with seizures, tetanus, and drug overdose; to reduce intraabdominal hypertension[1]; in hypothermia protocols for cardiac arrest[6]; and for preservation of delicate reconstructive surgery.
- NMBDs do not affect sensation or level of consciousness. Because NMBDs lack amnesic, sedative, and analgesic properties, sedatives and analgesics should *always* be given concurrently to minimize the patient's awareness of blocked muscle activity and discomfort. Sedatives and analgesics should be initiated *before* NMBDs because neuromuscular blockade hinders the assessment of anxiety and pain.[5]
- Numerous medications, such as aminoglycosides and other antibiotics, beta blockers, calcium channel blockers, corticosteroids, and anesthetics, and conditions, such as acidosis and various electrolyte imbalances, potentiate the effects of neuromuscular-blocking agents. Thus the level of blockade is subject to variation, which necessitates vigilant monitoring with a PNS and titration of the NMBD.[6]
- The muscle twitch response to a small electrical stimulus delivered by the PNS corresponds to an estimated number of nerve receptors blocked by the NMBDs and assists the clinician in the assessment and titration of the medication dosage. The level of blockade is estimated by observing the muscle twitch after stimulating the appropriate nerve with a small electrical current delivered by the PNS.
- The train-of-four (TOF) method of stimulation is most commonly used for ongoing monitoring of NMBD use. After delivery of four successive stimulating currents to a select peripheral nerve with the PNS, in the absence of significant neuromuscular blockade, four muscle twitches follow. The four twitches signify that 70% or fewer of the receptors are blocked. Three twitches correspond to approximately 75% blockade, and two to one twitches in response to four stimulating currents correlate with approximately 80% to 90% blockade of the neuromuscular junction receptors.[9] One to two twitches is the recommended level of block, although the appropriate level has not yet been determined through research in the critically ill population.[5] Absence of twitches may indicate that 100% of receptors are blocked, which exceeds the desired level of blockade (Table 32-1).
- The stimulating current is measured in milliamperes (mA). The usual range of milliamperes required to stimulate a peripheral nerve and elicit a muscle twitch is 20 to 50 mA, although increasing the current to 70 or 80 mA may be necessary, especially in the obese patient.[9]
- Some stimulators do not indicate the milliamperes. Instead, digital or dialed numbers ranging from 1 to 10 represent the range of milliamperes from 20 to 80 mA. With use of these instruments, the usual setting is 2 to 5, although a setting of 10 is sometimes necessary. Other stimulators (with and without digital displays) automatically adjust the voltage output relative to resistance and deliver the current accordingly.[10]
- The ulnar nerve in the wrist is recommended for testing, although the facial and the posterior tibial nerves may also be used.
- Peripheral nerve monitoring is used in conjunction with the assessment of clinical goals, and *clinical decisions should never be made solely on the basis of the twitch response.*
- Titration of the drugs according to clinical assessment and muscle twitch response may help provide a sufficient level of blockade without overshooting the goal. Overshooting the level of blockade with use of excessive doses of NMBDs is of special concern in the critically ill patient because it may predispose the patient to prolonged paralysis and muscle weakness, reported in the literature.[6] Monitoring with a PNS during the administration of NMBDs results in the use of less medication, hastens recovery of spontaneous ventilation, and accelerates restoration of neuromuscular transmission (NMT),[2] which is necessary for resumption of muscle activity. Although some patients have severe muscle weakness after neuromuscular blockade, peripheral nerve monitoring during NMBD therapy facilitates prompt recovery of NMT when therapy is terminated.[2]

TABLE 32-1 Train-of-Four (TOF) Stimulation as a Correlation of Blocked Nerve Receptors

TOF (No. of Twitches)	Percent of Receptors Blocked (Approximately)[7]
0/4	100
1/4	90
2/4	80
3/4	75
4/4	<70

Adapted from Figure 4, p. e5, Train-of-four suppression in Wilson J, Collins AS, Rowan BO: Residual neuromuscular blockade in critical care, Crit Care Nurse *32(3):e1–e10, 2012.*

EQUIPMENT

- Peripheral nerve stimulator
- Two pregelled electrode pads (the same as is used for electrocardiography monitoring)
- Two lead wires packaged with the peripheral nerve stimulator
- Alcohol pads for skin degreasing and cleansing

Additional equipment, to have available as needed, includes the following:

- A bipolar touch stimulator probe may be substituted for the pregelled electrodes and lead wires
- Scissors or clippers if hair removal is necessary

PATIENT AND FAMILY EDUCATION

- If time permits, assess the patient's and family's level of understanding about the condition and rationale for the procedure. ***Rationale:*** This assessment identifies the patient's and family's knowledge deficits concerning the patient's condition, the procedure, the expected benefits, and the potential risks. It also allows time for questions to clarify information and voice concerns. Explanations decrease patient anxiety and enhance cooperation.
- Explain the procedure and the reason for the procedure, if the clinical situation permits. If not, explain the procedure and reason for the intubation after it is completed. ***Rationale:*** This explanation enhances patient and family understanding and decreases anxiety.
- Describe the equipment to be used. ***Rationale:*** This description may decrease anxiety.
- Reassure the patient and family that medications for sedation and analgesia are provided throughout this therapy so the patient is comfortable while paralyzed. ***Rationale:*** Reassurance that the patient's pain and anxiety will be treated during therapy is provided.
- Describe the experience of the stimuli as a slight prickly sensation. ***Rationale:*** The use of sensation descriptors may reduce anxiety.
- Explain that the electrodes require periodic changing, which feels like removing an adhesive-backed bandage. ***Rationale:*** This explanation may elicit decreased anxiety.

PATIENT ASSESSMENT AND PREPARATION

Patient Assessment

- Verify that the patient is the correct patient using two identifiers. ***Rationale:*** Before performing a procedure, the nurse should ensure the correct identification of the patient for the intended intervention.
- Assess the patient for the best location for electrode placement. Consider criteria such as edema, fat, hair, diaphoresis, wounds, dressings, and arterial and venous catheters. ***Rationale:*** This assessment improves conduction of stimulating current through dermal tissue.
- Assess the patient for history or presence of hemiplegia, hemiparesis, or peripheral neuropathy. ***Rationale:*** Motor response to nerve stimulation of the affected limb may be diminished; receptors may be resistant to NMBDs and lead to excess doses.[9]
- Assess whether burns are present or whether topical ointments are being used. ***Rationale:*** In patients with burns or topical ointments, for whom electrode adherence is difficult, a bipolar touch probe may be more effective than the electrode pads and lead wires. Poor electrode adherence interferes with the conduction of the stimulating current.

Patient Preparation

- Ensure that the patient and family understand preprocedural teachings. Answer questions as they arise and reinforce information as needed. ***Rationale:*** Evaluates and reinforces understanding of previously taught information.
- Clip hair at the electrode placement sites if necessary. ***Rationale:*** This action improves electrode contact, which facilitates current flow to the nerve.
- Cleanse skin and degrease with alcohol. ***Rationale:*** Cleansing improves electrode contact, which facilitates current flow to the nerve.
- Apply the electrodes and test the TOF response to determine the adequacy of the location before initiating administration of an NMBD. In an emergent situation, testing the TOF response before the administration of an NMBD may not be possible. ***Rationale:*** Testing improves the reliability of the interpretation of the TOF response.
- Whenever possible, determine the supramaximal stimulation (SMS) level before initiating NMBDs. The SMS is the level at which additional stimulating current elicits no further increase in the intensity of the four twitches. In an emergent situation, determination of the SMS level before the administration of an NMBD may not be possible. ***Rationale:*** This determination helps establish adequate stimulating current and improves reliability of testing.

Procedures for Peripheral Nerve Stimulators

Steps	Rationale	Special Considerations
Testing the Ulnar Nerve		
1. HH		
2. PE		
3. Extend the arm, palm up, in a relaxed position; cleanse with alcohol pad (Fig. 32-1).	The ulnar nerve is superficial and easy to locate; degreasing increases conduction.	
4. Apply two pregelled electrodes over the path of the ulnar nerve (see Fig. 32-1). Place the distal electrode on the skin at the flexor crease on the ulnar surface of the wrist, as close to the nerve as possible. Place the second electrode approximately 1–2 cm proximal to the first, parallel to the flexor carpi ulnaris tendon. **(Level E*)**	Enables stimulation of the ulnar nerve. Skin resistance causes the greatest impediment to current flow, which can be reduced through clean dry skin and secure electrodes. The electrode gel enhances conduction. Maintaining the electrodes as close as possible in alignment with the nerve minimizes artifact from direct muscle stimulation.[9]	Ensure that the patient's wrist is clean and dry.
5. Use caution in selecting the site of the electrode placement to avoid direct stimulation of the muscle rather than the nerve. **(Level E*)**	Direct muscle stimulation elicits a response similar to the TOF, which makes evaluation of blocked nerve-impulse transmission difficult.	In patients with hemiplegia, place the electrodes on the unaffected limb because resistance to NMBDs on the affected side may lead to excess doses.[9] In patients with limbs immobilized from orthopedic casts, use the unaffected limb because possible resistance to some NMBDs on the affected limb may lead to excess doses.[4]

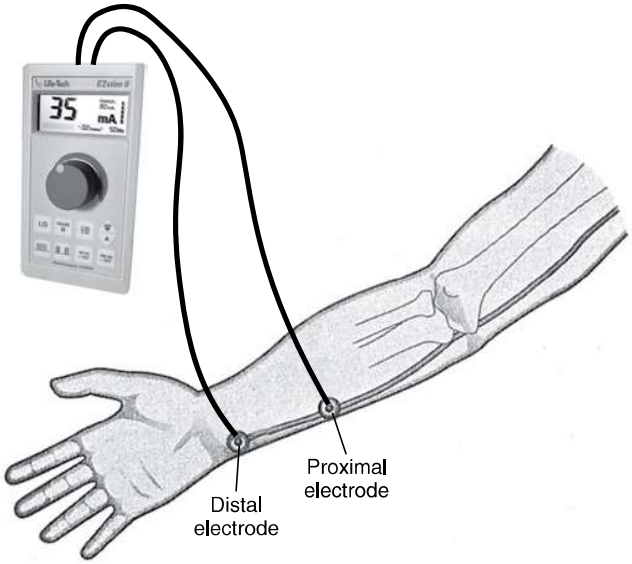

Figure 32-1 Placement of electrodes along the ulnar nerve.

*Level E: Multiple case reports, theory-based evidence from expert opinions, or peer-reviewed professional organizational standards without clinical studies to support recommendations.

Procedures for Peripheral Nerve Stimulators—*Continued*

Steps	Rationale	Special Considerations
6. Plug the lead wires into the nerve stimulator, matching the negative (black) and positive (red) leads to the black and red connection sites.	Necessary for the conduction of electrical current.	
7. Attach the lead wires to the electrodes. Connect the negative (black) lead to the distal electrode over the crease in the palmar aspect of the wrist. Connect the positive (red) lead to the proximal electrode.	Prepares the equipment.	
8. Turn on the PNS and select the current determined by the SMS or, if not performed, a low current (10–20 mA is typical).	Excessive current results in overstimulation and can cause repetitive nerve firing.	Patients with diabetes mellitus may need higher stimulating current than patients without diabetes because of impaired motor nerve fibers and nerve endings.[8]
9. Depress the TOF key; through tactile assessment, determine twitching of the thumb and count the number of twitches. Do not count finger movements, only the thumb.	Finger movements result from direct muscle stimulation. The quality of the twitches may be subtle and decrease in amplitude with increasing edema; detection with tactile methods increases sensitivity and accuracy.	Placing the operator's hand over the fingers helps reduce interpretation of artifactual movement. Use the dominant hand for tactile assessment because it may more accurately detect the TOF response.
10. Maintain a consistent current with each stimulation.	Increases reliability and validity in the quality of the twitch response.	
11. Discard used supplies and remove PE.		
12. HH		
Testing the Facial Nerve		
1. HH		
2. PE		
3. Place one electrode on the face at the outer canthus of the eye and the second electrode approximately 2 cm below, parallel with the tragus of the ear (Fig. 32-2).	Stimulates the facial nerve. Maintaining the electrodes as close as possible in alignment with the nerve minimizes artifact from direct muscle stimulation.[9]	Ensure that the patient's face is clean and dry. When wounds, edema, invasive lines, and other factors interfere with ulnar nerve testing, the facial or posterior tibial nerves may be substituted. The risk for direct muscle stimulation is greater, however, with resulting underestimation of blockade. Also, the alternate nerves correlate less well with blockade of the diaphragm.[7] **(Level C*)**

*Level C: Qualitative studies, descriptive or correlational studies, integrative reviews, systematic reviews, or randomized controlled trials with inconsistent results.

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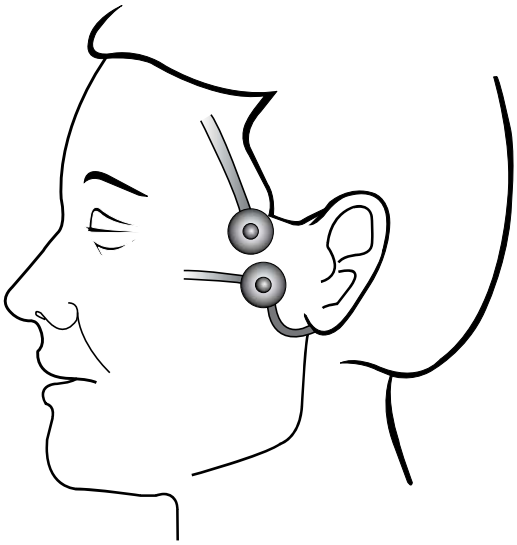
Procedures for Peripheral Nerve Stimulators—*Continued*

Steps	Rationale	Special Considerations
 **Figure 32-2** Placement of electrodes along the facial nerve.		
4. Plug the lead wires into the nerve stimulator, matching the black and red leads to the black and red connection sites.	Necessary for conduction of the electrical current.	
5. Attach the lead wires to the electrodes. Connect the negative (black) lead to the distal electrode at the tragus of the ear. Connect the positive (red) lead to the proximal electrode at the outer canthus of the eye.	Prepares the equipment.	
6. Turn on the PNS and select the current determined by the SMS or, if not performed, a low current (10–20 mA is typical).	Excessive current results in overstimulation and can cause repetitive nerve firing.	
7. Depress the TOF key; through tactile assessment, determine twitching of the muscle above the eyebrow and count the number of twitches.	Determines the neuromuscular blockade at the junction between a branch of the facial nerve and orbicularis muscle.	
8. Discard used supplies and remove PE.		
9. HH		
Testing the Posterior Tibial Nerve		
1. HH		
2. PE		
3. Place one electrode approximately 2 cm posterior to the medial malleolus (Fig. 32-3). **(Level E*)**	Stimulates the posterior tibial nerve. Maintaining the electrodes as close as possible in alignment with the nerve minimizes artifact from direct muscle stimulation.[9]	Ensure that the patient's skin is clean and dry.

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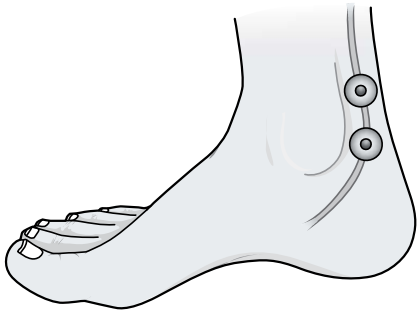
Procedures for Peripheral Nerve Stimulators—*Continued*

Steps	Rationale	Special Considerations
 **Figure 32-3** Placement of electrodes along the posterior tibial nerve.		
4. Place the second electrode approximately 2 cm above the first (see Fig. 32-3).	Maintaining the electrodes as close as possible in alignment with the nerve minimizes artifact from direct muscle stimulation.[9]	
5. Plug the lead wires into the nerve stimulator, matching the black and red leads to the black and red connection sites.	Necessary for conduction of the electrical current.	
6. Attach the lead wires to the electrodes. Connect the negative (black) lead to the distal electrode 2 cm posterior to the medial malleolus. Connect the positive (red) lead to the proximal electrode 2 cm above the medial malleolus.	Prepares the equipment.	
7. Turn on the PNS and select the current determined by the SMS or, if not performed, a low current (10–20 mA is typical).	Excessive current results in overstimulation and can cause repetitive nerve firing.	
8. Depress the TOF key; through tactile assessment of plantar flexion of the great toe, count the number of twitches.	Determines the neuromuscular blockade at the junction between the posterior tibial nerve and the flexor hallucis brevis muscle.	
9. Discard used supplies and remove PE.		
10. HH		
Determining the Supramaximal Stimulation		
1. HH		
2. PE		
3. Beginning at 5 mA, increase the milliamperes in increments of 5 mA until four twitches are observed.	Uses the lowest level necessary to elicit the twitches.	
4. Note the amount of current (in milliamperes) that corresponds to four vigorous twitches. Administer one to two more TOF stimuli to confirm the response. This current level is then used in TOF testing for that site.	If no increase in intensity of the muscle twitch is found when the milliamperes are increased, the SMS is the level at which four vigorous twitches were observed.	For example, if a strong response is observed at 30 mA, raise the current to 35 mA. If no increase is seen in intensity of the twitch, the SMS is 30 mA. If an increase is seen, raise the milliamperes to 40 mA. If an additional increase is seen in twitch intensity, raise it to 45 mA. If the intensity shows no further increase, the SMS is 40 mA.

Procedure continues on following page

Procedures for Peripheral Nerve Stimulators—*Continued*

Steps	Rationale	Special Considerations
Determining the Train-of-Four Response during Neuromuscular-Blocking Drug Infusion		
1. HH		
2. PE		
3. Retest the TOF 10–15 minutes after a bolus dose or when continuous infusion of NMBD is given/initiated/changed.	Evaluates the level of blockade provided.	Always assess electrode condition and placement before testing.
4. If more than one or two twitches occur and neuromuscular blockade is unsatisfactory for clinical goals, increase the infusion rate as prescribed or according to hospital protocol and retest in 10–15 minutes.	Signifies that less than 85–90% of receptors are blocked.	
5. Retest every 4–8 hours after a clinically stable and satisfactory level of blockade is achieved.	Evaluates the level of blockade and avoids underestimation and overestimation of blockade.	
6. Discard supplies and remove PE.		
7. HH		
Troubleshooting with Zero Twitches		
1. HH		
2. PE		
3. Change the electrodes and ensure that the patient's skin is clean and dry. **(Level E*)**	Drying of the gel or poor contact from moisture or soiling compromises conduction.[10]	
4. Check the lead connections and the PNS for mechanical failure and change the battery if needed. **(Level E*)**	One of the most common causes of PNS malfunction is low battery voltage.[9]	
5. Increase the stimulating current. **(Level E*)**	The current may be inadequate to stimulate the nerve, especially for increasingly edematous patients.[9]	
6. Retest another nerve (the other ulnar nerve or facial or posterior tibial nerves).	Avoids overestimating the level of blockade with false zero twitch responses.	
7. If no other explanations are found for a zero response, check the NMBD infusion for the rate, dose, and concentration. Reduce the infusion rate of the NMBD as prescribed or according to hospital protocol. **(Level E)**	Excessive neuromuscular blockade produces absence of a twitch response and, if allowed to persist, may contribute to prolonged paralysis or severe weakness.[6] Peripheral hypothermia causes a decrease in twitch response and may require a decrease in NMBD by 80%.[9]	
8. Discard supplies and remove PE.		
9. HH		

*Level E: Multiple case reports, theory-based evidence from expert opinions, or peer-reviewed professional organizational standards without clinical studies to support recommendations.

Expected Outcomes

- Slight discomfort during the TOF test
- The muscles of the thumb twitch, rather than the fingers, when the ulnar nerve is stimulated
- The twitch response approximates the number of blocked peripheral nerve receptors; for example, four twitches before initiating the NMBD infusion and one to two twitches when a desired level of blockade is achieved
- The NMBD dosage is titrated according to the TOF test and clinical goals
- Resumption of four twitches occurs within 2 hours when the NMBD is discontinued[7]

Unexpected Outcomes

- Moderate to severe discomfort from the TOF test
- Impaired skin integrity when the electrodes are removed
- The fingers twitch when the ulnar nerve is stimulated as a result of artifact; if the thumb does not twitch, this signifies direct muscle rather than ulnar nerve stimulation
- Resumption of four twitches does not occur within 2 hours of discontinuation of NMBD[7]

Patient Monitoring and Care

Steps	Rationale	Reportable Conditions
		These conditions should be reported if they persist despite nursing interventions.
1. Cleanse and thoroughly dry the skin before applying electrodes.	Improves the electrode adherence.	
2. Change the electrodes every 24 hours or whenever they are loose or when the gel becomes dry.	Optimizes conduction of the stimulating current. This action also assists with decreasing the risk for skin breakdown from the adhesive on the electrodes. Use caution when removing the old electrodes so as not to disrupt skin integrity.	• Skin breakdown
3. Select the most accessible site with the smallest degree of edema and hair and with no wounds, catheters, or dressings that impede accurate electrode placement over the selected nerve.	Facilitates ease in testing, electrode adherence, and the conduction of current.	
4. Never use the Single Twitch, Tetany, or Double Burst settings, if available on the PNS. **(Level E*)**	These methods are designed for profound neuromuscular blockade and may cause extreme discomfort.[10]	
5. Assess the patient's oxygenation and ventilation, neurological function, and tissue perfusion before increasing the rate of the NMBD infusion.	The patient may have subtle movement of the extremities with an acceptable TOF response. Clinical decisions should never be made solely on the TOF test results.	• Excessive patient movement despite acceptable TOF • Change in vital signs • Decreased oxygenation (e.g., measured via arterial blood gas or pulse oximetry) • Change in neurological function
6. Extreme caution must be exercised to prevent the PNS lead wires from contacting an external pacing catheter or pacing lead wires.	Direct electrical current can be conducted from the PNS through the pacing wires to the heart.	• Cardiac dysrhythmias or change in patient condition

*Level E: Multiple case reports, theory-based evidence from expert opinions, or peer-reviewed professional organizational standards without clinical studies to support recommendations.

Procedure continues on following page

Patient Monitoring and Care—*Continued*

Steps	Rationale	Reportable Conditions
7. Perform the TOF testing every 4–8 hours during NMBD infusion after the patient's condition is clinically stable and a satisfactory level of neuromuscular blockade is achieved, or per institution policy.	Determines an effective dose of NMBD.	• Abnormal TOF results
8. Consider objective methods of sedation monitoring, such as bispectral index monitoring (see Procedure 88) or evoked potentials, during NMBD therapy.[3] **(Level E*)**	Muscle paralysis during therapy with NMBDs hinders sedation assessment with subjective instruments.	
9. Remove the electrodes, lead wires, and PNS from the patient for magnetic resonance imaging or exposure to any magnetic field.	Metal objects are attracted to the magnetic field.	
10. Follow institution standard for assessing pain. Administer analgesia as prescribed.	Identifies need for pain interventions.	• Continued pain despite pain interventions

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Documentation

Documentation should include the following:

- Patient and family education
- The time, baseline SMS milliamperes, most recent milliamperes, TOF twitch response, and nerve site tested
- The TOF response as 0/4, 1/4, 2/4, 3/4, or 4/4
- Dosage of NMBD
- Assessment data (e.g., neurological, pulmonary, cardiovascular)
- Unexpected outcomes
- Troubleshooting attempts
- Additional interventions
- Pain assessment, interventions, and effectiveness

References and Additional Readings

For a complete list of references and additional readings for this procedure, scan this QR code with any freely available smartphone code reader app, or visit http://booksite.elsevier.com/9780323376624.

References

1. De Laet I, et al: The effect of neuromuscular blockers in patients with intra-abdominal hypertension. *Intensive Care Med* 33(10):1811–1814, 2007.
2. Foster J, Clark AP: Functional recovery after neuromuscular blockade in mechanically ventilated critically ill patients. *Heart Lung* 35(3):178–189, 2006.
3. Jacobi J, et al: Clinical practice guidelines for the sustained use of sedatives and analgesics in the critically ill adult. *Crit Care Med* 30:119–140, 2002.
4. Kim KS, et al: The duration of immobilization causes the changing pharmacodynamics of mivacurium and rocuronium in rabbits. *Anesth Analg* 96:438–442, 2003.
5. Murray M, et al: Clinical practice guidelines for sustained neuromuscular blockade in the adult critically ill patient. *Crit Care Med* 30:142–156, 2002.
6. Murray MJ, Brull SJ, Bolton CF: Brief review: Nondepolarizing neuromuscular blocking drugs and critical illness myopathy. *Can J Anaesth* 53(11): 1148–1156, 2006.
7. Nagelhout JJ, Naglaniczny KL: *Nurse anesthesia*, ed 3, Philadelphia, 2004, Saunders.
8. Saenz AD: *Peripheral nerve stimulator—Train of four monitoring*. Medscape. <http://emedicine.medscape.com/article/2009530-overview>. (Accessed 14.12.14.).
9. Saitoh Y, et al: Monitoring of neuromuscular block after administration of vecuronium in patients with diabetes mellitus. *Br J Anaesth* 90:480–486, 2003.
10. Thompson C: *Monitoring the neuromuscular junction*. <http://www.anaesthesia.med.usyd.edu.au/resources/lectures/nmj_monitoring_clt/nmjonitoring.html>. (Accessed 01.02.16.).