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Potential risks of nerve conduction studies and needle electromyography

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Electrodiagnostic studies such as nerve conduction studies (NCS) and needle electromyography (EMG) provide important and complementary information for evaluating patients with suspected neuromuscular disorders. NCS and needle EMG are reasonably safe diagnostic investigations and are generally associated with only mild transient discomfort when performed by experienced physicians. However, there is the risk of complications in some patients, because NCS involve the administration of electric current and EMG involves inserting a needle percutaneously into muscle tissue. This article reviews the potential risks of NCS and needle EMG.

Key words: Nerve conduction studies; Complications; Electrodiagnosis; Safety

INTRODUCTION

Nerve conduction studies (NCS) and needle electromyography (EMG) are generally well tolerated and are low-risk procedures in the hands of trained practitioners.¹ Mild procedural pain, discomfort, and bruising are very common during NCS and EMG, and while these undesired effects are fortunately usually transient and self-limiting, and will not aggravate preexisting symptoms, some patients with underlying medical conditions can present with unexpected symptoms. This article provides practical recommendations for handling potential issues that can occur during NCS and EMG examinations.^{2,3}

RISKS OF NCS

Patients sensitive to electricity

Patients with severe conditions may be injured by weak electrical stimulation due to them not having certain protective factors. A dry and undamaged skin has a high electrical resistance, but skin near venous or arterial catheters (especially if saline solution is applied to surrounding areas) has a low resistance, and electrical stimulation at these areas can be directly transmitted to other organs, including the heart. The heart is protected by a large amount of surrounding soft skin tissue, which prevents the heart from being directly stimulated by an externally applied electric current. However, electrical stimulation can be directly transmitted to the heart when a cardiac catheter is present. Therefore, electrical stimulation that can be negligible in normal situations may cause critical injuries in these patients.

Electrical stimulation should be avoided near catheters, especially if a saline solution has leaked. Two major sources of electricity that can affect hospitalized patients are the currents from attached electronic devices and electrodiagnostic tools. Side effects from stimulators can be prevented by avoiding stimulated areas with dermal catheters, especially in areas where the saline solution is being injected. Inappropriate grounding can result in a current leak and consequent excessive electricity being conducted to the patient. Permitted current leaks from devices attached to a patient are around 10 μ A, and appropriate grounding is needed to protect the patient from electrical damage to the heart. All elec-

tronic devices used to examine a patient require additional grounding to conduct any leaked current, and grounds and plugs also need to be checked regularly to ensure that no mechanical problem is present.

The safety of the patient requires particular attention if more than one piece of electrical equipment is attached. For example, if multiple devices receive power from different sources and at least one of the plugs is not functioning correctly, electric current can leak to the nonfunctional plug (s) and flow through the patient to the grounding plug. Therefore, all unnecessary electronic devices should be detached from the patient, and the remaining devices should be plugged into a single power source so that they use the same power plug and have a common ground.

When using electrodiagnostic tools, ground electrodes should be placed between the stimulation and recording electrodes and close to the needle electrode. This configuration will allow any leaked current to flow to the grounding electrode and thereby prevent it from spreading to other parts of the body.

Pacemaker and inserted cardioverter-defibrillator

Patients with pacemakers can undergo NCS and EMG without serious risks as long as the electrical grounding electrode is positioned appropriately. Positioning the stimulation electrode closer to the pacemaker and pacing lead will increase the risk of a voltage being generated that is sufficient to stop the pacemaker. Patients with an external pacemaker are at risk of serious electrical damage to the heart via conductive leads, and so NCS cannot be applied to them.

The risks related to inserted cardioverter-defibrillators are not well understood. Cautions required when performing NCS in these patients include examining the condition of the patient beforehand, considering the equipment attached to the patient, and deciding whether the equipment should be turned on or off throughout the examination (in consultation with a cardiac neurophysiologist). The examiner should not stimulate the nerve roots, plexus, or peripheral nerves near the cardioverter-defibrillator. For example, if a device is inserted into the chest wall, stimulation of cervical vertebrae, Erb's point, and the axilla should be avoided. Similarly, if a device is inserted into the abdomen, stimulation of the lumbar vertebrae and the inguinal region should be avoided. In any case, the stimulation should be applied at

least 15 cm away from any inserted device.

Before applying electrical stimulation, the examiner must confirm that the grounding electrode is safely positioned. Even if the maximum stimulation is not applied, the pulse duration should remain below 0.2 ms. The stimulation rate of the inserted cardioverter-defibrillator should not exceed 1 pulse/s. Despite these theoretic concerns, investigations of routine NCS in patients with implanted cardiac devices during continuous monitoring of the electrocardiogram and interrogation of the devices found that the electrical signals from NCS (with stimulations up to 100 mA for 0.5 ms) of the leg, arm, and, in some patients, at Erb's point, were not sensed by and also never affected the programming of the devices.^{4,5} If any limitations of the stimulation area, pulse time, or frequency are thought to affect the results and interpretation of NCS, the examiner must mention this in the final report.

Needle electrical stimulation

When supramaximal stimulation of a nerve located deep in a limb cannot be achieved with surface stimulation, near-nerve stimulation using a monopolar needle may be performed. This technique involves slowly advancing the needle electrode until it is in close proximity to the nerve, which allows the nerve to be stimulated using the minimum amount of current.⁶ It is unlikely that needle stimulation would be performed on a nerve near the heart, and so there is little if any, practical risk to the heart with this technique. However, there is a risk of hematoma formation or damage to structures along the route taken by the needle electrode. For example, the brachial plexus could be damaged or pneumothorax with puncture of the apex of the lung could occur when needle stimulation is applied to the brachial plexus at Erb's point, and so needle stimulation at Erb's point should be avoided.⁶

Implanted deep brain stimulators and vagal nerve stimulators

Implanted deep brain stimulators and vagal nerve stimulators rarely interfere with EMG recordings,^{7,8} and no known contraindications exist in such patients. Prior arrangement with patients and their specialist nurses is required to switch any such devices off during EMG studies.

RISKS OF NEEDLE EMG

Needle EMG is generally a safe procedure when performed by experienced physicians. However, because the technique involves inserting a needle through the skin and up to several centimeters into a muscle, potential complications may occur.⁹

Bleeding and hematoma

Inserting EMG needles into skeletal muscles is generally well tolerated with minimal or no bleeding. Needle EMG can be applied to patients taking antiplatelet agents or anticoagulants, and those with thrombocytopenia and coagulation factor deficiency. In such cases, the risks of intramuscular hematoma or other types of bleeding and the potential benefits of performing needle EMG should be considered carefully before deciding whether or not to perform needle EMG.

Hemorrhagic complications are more likely to occur after a needle-EMG examination in the following situations:

1. Platelet count of $< 50,000/\text{mm}^3$.
2. Prothrombin time of 1.5- to 2-fold (i.e., international normalized ratio $> 1.5\text{-}2.0$) greater than normal.
3. Activated partial thromboplastin time of 1.5- to 2-fold greater than normal.
4. Taking oral, intravenous, or subcutaneous anticoagulants.
5. Taking antiplatelet agents.
6. Other medical conditions (e.g., chronic renal failure, or acquired or inherited coagulopathies).

These patients have an increased risk of bleeding and need to be carefully monitored for possible hemorrhage with starting at small muscles. In order to ensure hemostasis, compression should be applied to the examination site for a longer time. There are a few cases reports in the literature representing a very small proportion of cases (probably $< 1/10,000$) of medically significant hematomas and resultant potentially severe compartment syndromes, which in most instances were due to known bleeding disorders (either medically induced or acquired).^{9,10} An ultrasound-based prospective investigation of more than 300 muscles in patients on warfarin, aspirin, or clopidogrel found that the incidence of hematoma after needle EMG did not differ significantly between patients taking and not taking antithrombotics,

although two subclinical hematomas were detected in the antithrombotic group.¹¹

The information in the literature indicates that the requirement of patients to discontinue warfarin or aspirin before performing needle EMG is somewhat controversial, given the risk of discontinuing antithrombotic medications causing thromboembolic complications. A subcommittee of the American Academy of Neurology reported that warfarin and aspirin “possibly do not increase the bleeding risk in needle EMG”.¹² Patients with hemophilia or other coagulation impairments that cannot be treated properly should not undergo EMG.

Infection

Infection control is crucial when performing any invasive test. Soft-tissue infections secondary to needle EMG have been reported in very rare cases (< 1/10,000).¹⁰ Reusable needles are now largely outmoded, and so the risk of infection is decreasing. A disposable needle electrode is typically used for multiple insertions in several muscles in the same patient during needle EMG testing, and there is no evidence that inserting the same needle electrode into the same patient multiple times increases the risk of infection. Alcohol is a convenient and fast-working sanitizer, and so alcohol sanitization should be performed before EMG, with contaminated or dirty skin washed with soap and water before sanitizing with alcohol. EMG should not be performed on infected skin or pressure ulcers.

Pathogens can travel via the blood between the patient and examiner, or via the needle from patient to patient, and the risk of such infections should be minimized. In cases of exposure to blood-borne pathogens, the regulations suggested by the Korea Occupational Safety and Health Agency (KOSHA) must be followed.¹³ The KOSHA regulations apply to all individuals with direct exposure to blood and other infectious materials. Protective gloves are mandatory, and masks and gowns should be worn. Moreover, examiners must be aware of risks from blood-borne pathogens, and the medical records of the patient should be stored.

Infection route

Infection with HIV, hepatitis B, and other blood-borne pathogens often occurs when blood or another infectious fluid comes into contact with wounds, damaged skin, or mucous membranes, or directly enters the body across the skin.

Blood is the most likely medium transferring HIV or hepatitis B in many types of invasive test.

General preventive measures

Personal protective equipment such as gloves and gowns reduce the risk of blood-borne or other infectious disease carriers coming in contact with the skin or mucous membranes of healthcare professionals. Personal protective equipment should be stored in a designated area before leaving the examination room or be placed in a sterilization/discard box. The type of protective equipment required varies between different clinical situations.

Gloves must be worn when performing tests that may involve touching blood or infectious materials, including needle EMG. While wearing the gloves, the examiner should not touch anything other than the patient or the examination tools. Gloves should be changed for each patient or if they are contaminated or torn. Gloves must be removed prior to leaving the examination room, and examiners must wash their hands after examinations are completed.

Needle electrodes and sterilization

Contaminated needle electrodes should not be bent, cut, or broken. The electrode should be capped using a machine or one hand (i.e., not both hands), and contaminated needle electrodes should be put into the appropriate waste container immediately after use. The safety rules that apply in each examination room must be followed, and the waste container should be near the area where the needle electrodes are being used. If reusable needle electrodes are contaminated, the examiner must not put his or her hands into the waste container or storage box to discard the electrode. Surface electrodes should be sterilized with bleach (diluted 1:10) or 70% isopropanol. Electrodes that have come into contact with blood or body fluids must be sterilized completely or discarded.

Prions that cause Creutzfeldt-Jakob disease

Prions such as those that cause Creutzfeldt-Jakob disease are extremely infectious and cannot be sterilized using regular methods, and so needles used for patients with suspected Creutzfeldt-Jakob disease must be discarded. In order to prevent infection, these must be sterilized using an autoclave (> 15 lb/in² and 121°C for 60-90 minutes) or incinerated.

ed before discarding.

Pneumothorax

There are cases where needle EMG or NCS are applied to the intercostal, diaphragm, serratus anterior, supraspinatus, rhomboid, and paraspinal muscles. These nerves and muscles are located close to the pleura and lungs, which results in a risk of pneumothorax.¹⁴ The examiner must consider the potential benefits of the tests and risks of pneumothorax before deciding whether to perform these tests. The risk has been found to be highest for the serratus anterior muscle (1/200 examinations) and lower for the diaphragm (< 1/500 examinations).

Peritonitis can occur when applying needle EMG to abdominal muscles. As for pneumothorax, the examiner must consider if the potential benefits of the tests at these locations outweigh the risks of peritonitis before deciding whether to perform them.

CONCLUSION

NCS and needle EMG provide useful diagnostic information with a low risk of complications. However, the examiner must still appreciate the known and theoretical complications associated with these procedures. Both NCS and needle EMG are very common causes of procedural discomfort and mild pain. Needle EMG commonly causes bruises, but significant hematoma and bleeding are rare. The most clinically significant complication of needle EMG is a pneumothorax, which can occur when examining particular muscles. It is fortunate that the complications are generally rare, minor, and self-limited.

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