

Guideline 11A: RECOMMENDED STANDARDS FOR NEUROPHYSIOLOGIC INTRAOPERATIVE MONITORING – PRINCIPLES

Neurophysiologic intraoperative monitoring (NIOM) provides information about the functional integrity of neural structures in anesthetized patients. **The goal of NIOM is to make surgery safer by detecting incipient neurological injury at a time when it can be avoided or minimized and by aiding in the identification of neural structures.** The following guidelines emphasize important aspects of NIOM while avoiding the temptation to promulgate rigid rules into a field in constant development. These guidelines should not be viewed as a “how-to manual” for NIOM, but rather as a summary of the general principles.

The first in this series of NIOM guidelines relates to basic principles. Issues regarding personnel interpreting and performing NIOM, the equipment being used, documentation during the procedure, and standards of safety that are discussed below apply to all types of monitoring. An overview of pharmacologic and physiologic influences and interpretation of NIOM data is also presented. These topics will be expanded upon in the subsequent guidelines where appropriate.

A. Personnel

The monitoring team should be under the direct supervision of a physician with training and experience in NIOM. The monitoring physician should be licensed in the state and privileged to interpret neurophysiologic testing in the hospital in which the surgery is being performed. He/she is responsible for real-time interpretation of NIOM data. The monitoring physician should be present in the operating room or have access to NIOM data in real-time from a remote location and be in communication with the staff in the operating room (Nuwer 2008). There are many methods of remote monitoring, however any method used must conform to local and national protected health information guidelines (Emerson 2008). The specifics of this availability (i.e. types of surgeries) should be decided by the hospital credentialing the committee. **In order to devote the needed attention, it is recommended that the monitoring physician interpret no more than three cases concurrently.**

NIOM should be performed by a technologist with appropriate skills, knowledge, abilities, training, experience, and credentials. **The technologist should be present in the operating room to hook-up, monitor, and disconnect the patient from monitoring equipment after surgery.** When NIOM data is being acquired, the technologist should be in the operating room (Nuwer 2002).

NIOM requires cooperation between the surgical, anesthesia, and NIOM teams. Pharmacologic, physiologic, and mechanical factors under the control of the surgeon and anesthesiologist must be considered when interpreting changes in NIOM data. The anesthesiologist is often able to select anesthetic techniques that can facilitate monitoring relevant signals, while affording maximal patient safety. **The NIOM team should**

immediately notify the surgical team and the anesthesiologist of significant changes in the signals (Nuwer 2002).

B. Equipment

The NIOM equipment must have sufficient channels to monitor all the modalities necessary for the type of surgery being performed. The monitoring system should have the capacity to display raw signals and continuous trends; store time/date of recorded waveforms; trigger the stimulation of certain potentials such as electromyographic, peripheral, or cranial nerve; record free run signals; record the technologist's notes with waveform data; and retrieve and review recorded data for post-hoc analysis. It should be noted that post-hoc analysis cannot replace real-time interpretation by the physician. The system should have automatic artifact rejection; a provision for rejection of artifact related to electrocautery is desirable. Additionally, the system should have the capacity for remote, real-time display of NIOM data (Niznik 2008).

C. Documentation

It is recommended that a complete record of averaged waveforms be stored. It is recognized that most systems do not permit storage of continuous, raw, unaveraged data, such as free-running electromyographic (EMG) signals. The NIOM record should contain the times of surgical events and procedures. Alerts that were issued to the surgeon or anesthesiologist should be noted. The anesthetics and drugs used should be recorded, and significant changes in dose of these medications should also be noted. Significant changes in physiological parameters, such as blood pressure and temperature, should be recorded. If the equipment allows, it may be desirable to maintain this documentation along with the stored waveforms. A final report summarizing the NIOM data should be filed in the patient's chart (Nuwer 2002). Long-term storage of the records should be provided, as required by law.

D. Standards of Safety

Electrical safety is of particular concern in the operating room. Anesthetized patients cannot report discomfort or pain; therefore, it is imperative to insure that NIOM equipment operates within safe limits. Malfunctioning equipment can lead to patient burns and other serious complications (Stecker, Patterson et al. 2006; Patterson, Stecker et al. 2007). Modern commercial NIOM systems intended for human use are required to comply with electrical safety standards (NFPA 2005). There should be a 100 μ A limit on total chassis leakage, and 10 μ A limit for isolated patient connections (Seaba 1980; NFPA 2005). The grounding system should ensure that no voltage greater than 20 mV rms can be measured across an impedance of 1,000 ohms, typically at 60 Hz, between any combination of exposed conductive surfaces or grounding conductors that may be in contact with the patient or personnel. A line isolation monitor should be in place to detect leakage or fault current to ground (NFPA 2005). Amplifier inputs must be isolated in the operating room. NIOM equipment must be mounted securely in appropriate housing with protection from spills of blood and other fluids.

All NIOM systems must be inspected before use and at least twice a year. The grounding and the chassis leakage current of all instruments connected to the patient or located in the same operating room as the patient must be tested. A more frequent test schedule is recommended for a system exposed to the high voltages of cautery and/or rough use because of transportation to different recording locations.

E. Pharmacologic and Physiologic Influences

It is desirable to maintain a relatively constant pharmacologic and physiologic state during critical monitoring periods. Interpretation of NIOM changes should be related to the pharmacologic, physiologic, and pathophysiologic influences. Blood pressure, temperature, and anesthetic parameters should be monitored simultaneously with the neurophysiologic data. The interpreter should be cognizant that changes in NIOM data may be just as marked with hypotension and cardiovascular collapse as with surgical manipulation or compression of neural pathways.

Most anesthetic agents have significant impact on neurophysiologic signals. An understanding of these effects is important for the interpretation of NIOM data changes during surgery (James 2008; Sloan and Jantti 2008). Further, it is often possible for the anesthesiologist to select anesthetic agents that facilitate monitoring. Nitrous oxide and halogenated inhalational agents, for example, may substantially attenuate transcranial electrical motor evoked potentials (TceMEPs) recorded over muscles. These agents also attenuate the cortical components of somatosensory evoked potentials (SEPs); this effect can be particularly prominent for lower extremity SEPs and in young children. Subcortical components are, on the other hand, much less affected by these agents. Other agents, such as propofol, attenuate cortical SEP and muscle TceMEP signals to a much lesser degree (Clapcich, Emerson et al. 2004). By suppressing EMG artifact, neuromuscular blocking agents can greatly facilitate SEP monitoring, in particular monitoring of subcortical components recorded with “scalp to non-cephalic” electrode derivations. In some cases, monitoring of subcortical signals may be possible only in the presence of neuromuscular blockade. Neuromuscular blocking agents, however, interfere with monitoring of spontaneous EMG, compound muscle action potentials (CMAPs), and muscle TceMEPs (James 2008).

To differentiate between systemic and local manipulation effects, it is often useful to record neurophysiologic data from surgically unaffected structures as controls (e.g. contralateral or rostral to the surgical site). During thoracic spinal cord surgery, for example, systemic effects would be expected to affect both upper and lower extremity muscle TceMEPs and SEPs, whereas local manipulation would only be expected to alter lower extremity muscle TceMEPs and SEPs (Burke, Nuwer et al. 1999).

F. Normative Data and Interpretation

Normative values for SEPs, brainstem auditory evoked potentials (BAEPs), and CMAPs, while useful for standard laboratory testing, are not relied upon to determine

abnormalities intraoperatively. Although often difficult for practical reasons to arrange, a preoperative neurophysiologic study in some patients depending on the surgery planned and clinical situation can be very useful for NIOM planning during surgery, troubleshooting purposes prior to the surgical case, and obtaining a preoperative baseline study. **Baseline values for NIOM data, however, are established following induction of anesthesia and positioning of the patient, but prior to surgical intervention.** These values are the most informative measure in a given patient, and significant changes provide clues to neural compromise. **Baseline values may need to be reestablished if changes in anesthetic medications or other physiological parameters occur during the case.**

NIOM should be performed continuously throughout the surgical procedure. In general, **monitoring should begin before any surgical manipulation of nervous system has occurred and continue until the surgical procedure is terminated.** In cases where it is determined that there is little or no risk to neural structures during a specific portion of a particular procedure, the interpreting physician may, in consultation with the surgeon, elect to suspend NIOM.

There are no NIOM-based criteria to predict absolutely untoward neurologic outcomes. For SEPs and BAEPs, there are two general approaches to interpreting intraoperative changes. One is to use predefined limits (commonly a **50% decrease in amplitude or 10% increase in latency**) and to warn the surgeon when those limits are exceeded. The other is to warn the surgeon of changes in waveform amplitude, latency, and morphology that exceed baseline variability, even in these changes are small or represent a change from prior consistent values (Moller 1995). In either case, it is important to note that, in general, **surgical injury more often produces waveform amplitude or morphology changes, than latency prolongation.** Criteria for significant change in muscle TceMEP are less clearly established. Once again, two general approaches have been used. The **first is to warn the surgeon when there is complete or near-complete loss of muscle TceMEPs.** The other alert criterion is an increase in the stimulation intensity needed to elicit the muscle TceMEP response. **In the case of peripheral nerve monitoring, runs of neurotonic discharges are used to warn the surgeon regarding injury to peripheral nerves.** Significant changes with electroencephalographic (EEG) monitoring depend on the surgical procedure; however, they often include loss of faster frequencies, focal slowing, and loss of amplitude (Lopez 2004; Minahan and Mandir 2008). These changes are described further in each individual guideline.

The NIOM guidelines for individual modalities that follow are intended to provide a blueprint for how NIOM can be performed. It is recognized that some laboratories may have alternative methods for performing these tests. However, a clear rationale for using such methods should exist. The reader is encouraged to consult the references for more details on performing various NIOM procedures.

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