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Excerpt
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1 Introduction, history, and staffing for intraoperative monitoring

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Neurophysiologic intraoperative monitoring (IOM) has grown over three decades into a method widely used to prevent neurologic injury during surgery. Common IOM techniques include electroencephalography (EEG), electromyography (EMG), evoked potentials (EPs), and nerve conduction velocity (NCV).

Intraoperative monitoring can warn the surgeon of changes in time to correct problems and prevent postoperative neurologic deficits. It may also identify some systemic problems. By using IOM to assess a patient's neurologic safety, a surgeon may provide a more thorough procedure or operate on a high-risk patient who might otherwise be turned away. Finally, patients and families can take comfort that neurologic risks are being evaluated during the case.

False alarms do occur, e.g., in 1% of scoliosis spinal-cord monitoring. False alarms are cases when the IOM warns of changes, but the patient awakens from surgery without a new deficit. Some may be false alarms caused by technical failures, difficulty obtaining good quality tracings, or anesthetic changes. In other cases, IOM sometimes raises an alarm, interventions are accomplished, and yet the patient awakens with a neurologic injury. Raising an alarm does not necessarily prevent deficits.

False-negative cases are those in which a patient suffers a postoperative neurologic injury that was not predicted by IOM. In spinal-cord SEP (somatosensory evoked potential) monitoring, the false-negative rate is around 0.1% of SEP-monitored scoliosis procedures (Nuwer *et al.*, 1995). Some false-negatives are due to deterioration soon after surgery. Some injuries are in pathways that were not monitored, e.g., some root lesions. Occasionally, false-negative cases are due to errors by the IOM team, who failed to recognize changes when they occurred. Finally, the existence of some otherwise unexplainable false-negative monitoring cases is a reminder that no technique is 100% accurate in predicting outcomes.

History of monitoring

Early uses of neurophysiologic monitoring during surgery date back to the first half of the twentieth century. Penfield (Penfield and Boldrey, 1937) used direct cortical stimulation in patients undergoing epilepsy surgery to define the locations of motor and sensory cortex. Direct recording of EEG from exposed cerebral cortex (electrocorticography, ECoG) guided the surgeon to resect regions of epileptic discharges, slowing, or lack of fast activity (Jasper, 1949; Marshall and Walker, 1949). Both techniques are still used.

More than a decade later, routine scalp EEG was used during carotid endarterectomy (CEA) (Thompson, 1968; Wylie and Ehrenfeld, 1970; Sharbrough *et al.*, 1973) to assess for cerebral ischemia during carotid clamping. Electroencephalography accurately measures degrees of cerebral ischemia during carotid endarterectomy (CEA) (Sundt *et al.*, 1974). It has provided an excellent substitute for keeping the patient awake during CEA or using other ischemia testing techniques and has become commonly used as a safeguard for CEA patients.

Spinal-cord IOM was first investigated in the early 1970s by Japanese investigators using epidural recordings of spinal potentials evoked by direct spinal stimulation (Shimoji *et al.*, 1971; Imai, 1976). These techniques were validated as accurate methods for monitoring spinal cases (Tamaki *et al.*, 1972, 1981).

Spinal IOM using somatosensory evoked potentials (SEPs) was developed in the mid-1970s. This involved using middle- and long-latency 50–200 ms cortical potentials during orthopedic procedures (Nash *et al.*, 1974, 1977; Nash and Brodkey, 1977), but the attempts were too prone to disruptive signal noise, variability, and sensitivity to anesthesia. Grundy (1982), an anesthesiologist working with Nash, described ways to reduce anesthetic effects and extended the techniques to neurosurgery. These early SEP cortical IOM techniques used filters at 1–100 Hz, and measured middle- and long-latency potentials (e.g., Engler *et al*., 1978; Speilholz *et al*., 1979).

Spinal-cord IOM with scalp SEPs remained problematic in the early days because of excessive noise and irreproducible background variability. By the late 1970s, Nuwer and Dawson (1984) studied the variability in these recordings and determined that short-latency SEP techniques improved monitoring, and recorded with restricted filters and other technical modifications, which substantially reduced variability and greatly improved SEP reliability. This SEP method was then widely adopted for spinal-cord IOM

In the UK, Jones (Jones *et al*., 1982) pioneered epidural spinal recordings with posterior tibial nerve stimulation. This technique was used in response to safety concerns about repeated spinal epidural electrical stimulation.

Spinal-cord IOM with these scalp or epidural SEP methods was the technique of choice for the next two decades. Occasional false-negative monitoring cases were reported. Clinicians noted that SEPs test sensory pathways, whereas the most feared postoperative problems were motor. Burke eventually popularized transcranial electrical stimulation as a practical corticospinal technique for use under anesthesia (Hicks *et al*., 1991, Burke *et al*., 1992). The technique has developed through changes in locations of electrodes and stimulus trains.

Methods using auditory EPs and EMG during surgery around cranial nerves were developed in the 1980s. These were used for posterior fossa procedures, initially microvascular decompression and acoustic neuroma resection (Møller and Møller, 1985).

Commercial IOM equipment became available by 1981. Before that, clinical neurophysiologists adapted and customized research or other kinds of clinical equipment for use in specific IOM procedures. Often the early, customized equipment was specific to a particular application. Particular surgeons directed early clinical services, often with a research or technical development purpose. Those techniques were not generally available to other surgeons across their institutions. The first general IOM clinical service, set up at UCLA in 1979, offered a variety of techniques to any surgeon in any surgical discipline. In the early 1980s, annual academic neurophysiology and surgery meetings included IOM research reports. By the mid-1980s, special dedicated symposia taught IOM to clinical neurophysiologists, surgeons, and technologists. Those meetings carried the message of IOM to a much wider audience. The first two IOM textbooks (Nuwer, 1986; Møller, 1988) provided more detail and references to this wider audience. By the late 1980s, IOM was an established technique in general use.

Initially, IOM included EEG, ECoG, EPs, EMG, and NCV techniques. These "first-wave" techniques were familiar to most clinical neurophysiologists. The subsequent "second-wave" techniques expanded the field to include motor EPs and pedicle screw testing, as well as advances in remote supervision, increase channel number, and greater flexibility of commercial equipment. There are now many types of monitoring and surgical neurophysiology testing. Table 1.1 shows a list of the various kinds of monitoring that are or have been used. Not all of these techniques can be recommended for clinical use. Visual EP monitoring has proven too difficult and unreliable so far. The future may bring better, more reliable techniques. Neurogenic EPs are those in which the rostral spinal cord is stimulated and recordings are made at the limb muscles. In theory, the neurogenic EPs are from corticospinal tract conduction, but in reality, they are primarily conducted along other pathways, such as antidromic posterior column transmission with reflex muscle innervation. The visual and neurogenic EPs are no longer used for monitoring at this time. Other techniques described in Table 1.1 are advanced beyond the level of this book. For further information, the reader is referred to Nuwer (2008).

Applications for intraoperative monitoring

There are now many disorders for which intraoperative neurophysiologic monitoring and testing are used. Table 1.2 lists the various clinical disorders for which monitoring and testing are used. Some of these are surgeries commonly encountered in neuromonitoring services. Others are more specialized and advanced surgical situations. This book presents typical neuromonitoring situations. For further discussion of the more advanced and less common techniques, see Nuwer (2008).

In cases involving the cerebral circulation or cardiothoracic cases, EEG and SEPs are often applied. Craniotomies may make use of electrocorticography, EEG, SEPs, and direct cortical stimulation. Deep brain electrode implantation uses microneurography. Posterior fossa cases may use cranial nerve EMG monitoring, SEPs, and BAEPs (brainstem auditory evoked

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Table 1.1 Techniques used for intraoperative neurophysiologic monitoring and testing

Electroencephalography (EEG)	
Electrocorticography (ECoG)	
Direct cortical stimulation to localize sensory, motor, and language function	
Deep brain stimulator electrode placement	
Somatosensory evoked potential (SEP)	SEP monitoring with scalp and cervical recording Monitoring spinal epidural potentials with peripheral nerve stimulation SEP for intraoperative mapping of motor cortex
Motor evoked potential (MEP)	Corticospinal tract monitoring with D and I waves from the spinal cord Transcranial electrical stimulation MEPs with recording from limb muscles Mapping the corticospinal tract Neurogenic EPs with rostral spinal cord stimulation and limb recording
Visual, brainstem, and auditory evoked potentials	Visual evoked potentials Brainstem auditory evoked potentials Mapping the brainstem and floor of the fourth ventricle
Electromyographic, reflex, and nerve conduction monitoring	Intraoperative peripheral nerve stimulation and recording Intraoperative facial nerve monitoring Oculomotor and lower cranial nerve monitoring Intraoperative monitoring with free-running EMG Intraoperative EMG during spinal pedicle screw instrumentation Selective dorsal rhizotomy Nerve root assessment with SEPs and MEPs

potentials). Spinal surgery often uses SEPs and MEPs (motor evoked potentials), and may use EMG monitoring for pedicle screw testing. Cauda equina surgery may use SEPs, EMG, and nerve conduction or reflex testing. Surgery in the periphery more often uses nerve conduction techniques, and may also use SEPs.

Table 1.2 Procedures in which intraoperative neurophysiologic monitoring and testing is used

Cerebral, head, and neck surgery	Epilepsy surgery Resection and debulking of cerebral tumors Movement disorders, electrode and ablation placement Resection and debulking of brainstem lesions Cranial base surgery Microvascular cranial nerve decompression Middle ear, mastoid, and parotid surgery Surgery at acoustic and vestibular nerves Surgery at glossopharyngeal, vagus, and laryngeal nerves at thyroid, larynx, carotid, and chest
Spine surgery	Correction and stabilization of scoliosis Spinal surgery for fractures and extramedullary tumors Surgery for intramedullary spinal-cord tumors Surgery for cervical diskectomy and fusion with decompression of myelopathy Lumbar stenosis and fusion surgery Surgery for tethered cord syndrome and other cauda equina lesions Dorsal root entry zone procedures and other surgeries for pain
Peripheral nerve surgery	Brachial plexus surgery Lumbosacral plexus surgery Total hip arthroplasty Pelvic surgery Peripheral nerve surgery
Vascular surgery	Carotid endarterectomy Clipping intracranial aneurysms Descending aortic procedures Cardiac surgery
Interventional radiology procedures	Intracranial endovascular procedures Spinal endovascular procedures Carotid balloon test occlusion

Effective monitoring teams will have many tools available for use as needed. This allows them to vary their techniques or bring in other tools where necessary.

Physician supervision and the monitoring team

Two kinds of IOM are used in surgery. They differ in their goals. *Monitoring* aims to identify any signs of injury and raise an alarm. *Testing* aims to identify neurologic structures. Monitoring occurs over hours, waiting to see if a change occurs from baseline. Testing is performed at a specific discrete time. The two are referred to together as *intraoperative monitoring* (*IOM*), although intraoperative neurophysiology might have been a better general term.

Testing requires personal involvement of a clinical neurophysiologist to identify a neurological structure, e.g., for ECoG or localization of language or motor cortex. Professional judgment is required to recommend what tissue to resect. That professional skill is at a level greater than that demanded of a technologist alone. The clinical neurophysiologist in the room interprets the recordings and discusses recommendations personally with the surgeon. This is referred to as *personal supervision*.

Monitoring does not require in-room personal physician supervision for routine cases. Monitoring requires a team with sufficient expertise and good communication. The IOM team members take on three functions: (a) the hands-on in-room technologist; (b) an expert in IOM technology and application; and (c) a neurophysiologist supervisor. Sometimes two of these functions are combined and performed by one person. For example, an expert monitoring specialist may perform both the in-room hands-on function and serve as the team's IOM technology and application expert. In that case, a physician supervisor relies on the expert for problem solving and related duties as well as hands-on monitoring. In a different scenario, a supervising clinical neurophysiologist is an expert in IOM technology and applications who remotely supervises a registered EEG technologist in the operating room. A third scenario could involve a clinical neurophysiology physician with modest IOM experience who works with an in-room registered EEG technologist, while both use the services of an expert (third person) to help them with monitoring questions, strategies, policies, and problem solving. In this case, the expert serves as a consultant, much like a physician taking advice from a consultant in other areas of practice. In any case, monitoring needs all three functions to be filled: in-room hands-on, clinical neurophysiology interpretation and supervision, and expertise in IOM techniques and problem solving. This team concept for IOM allows for the several kinds of necessary roles and expertise, and preserves the traditional role of the hospital and public agencies for overseeing the health care service.

The supervising physician often monitors in real time at a remote location and is able to intervene in the case as needed. Communication between the physician and in-room technologist may be by phone, paging, or instant messaging. In other situations, the physician enters the operating suite to communicate directly, supervise testing decisions, and resolve problems. The monitoring physician is on the medical staff of the hospital in which the surgery occurs and licensed to practice medicine in that state.

Routine brain or spinal-cord monitoring typically does not require the continuous personal in-room involvement of a clinical neurophysiologist (Nuwer and Nuwer, 1997). Technology now allows for remote on-line real-time monitoring from elsewhere in the building or even off-site. The supervising clinical neurophysiologist is nearby or on-line. The availability to intervene remains, as does the ability to become involved in postoperative care as needed. This is referred to as *direct supervision*.

Some clinical neurophysiologists directly supervise more than one case simultaneously. The literature showing good outcomes for IOM is based on cases in which one to three patients were supervised simultaneously (Nuwer *et al.*, 1995). The original concept of IOM services was based on this direct monitoring of one or two and occasionally three cases. At this time, there is insufficient literature to support monitoring of more than three simultaneous cases. It remains unclear whether the larger number of simultaneous cases could be monitored while still giving sufficient professional attention to each case. The supervising clinical neurophysiologist needs to be ready to be solely involved in a particular case if needed. To pay full attention to one case as needed, there must be a plan for transferring the supervision of any other simultaneous cases to another physician (American Academy of Neurology Professional Association, 2008).

Physician training and certification

Formal physician training in IOM is carried out in clinical neurophysiology fellowships. In the USA these require graduation from a neurology or child neurology residency program. The training in clinical neurophysiology is usually one to two years long. These programs include didactic training broadly in all areas of clinical neurophysiology plus clinical in-depth majors in two of four fields: EEG, EMG, sleep, or intraoperative monitoring. The traditional national Accreditation Council for Graduate Medical Education (ACGME) accredits these training programs.

Two examinations are given to show competence in this field. The American Board of Psychiatry and Neurology (ABPN) administers a clinical neurophysiology examination. The ABPN is a member board of the American Boards of Medical Specialties (ABMS), the national umbrella organization for traditional medical boards. The clinical neurophysiology examination is a written multiple choice examination. It covers broadly the whole discipline of clinical neurophysiology. One can successfully pass that examination without much knowledge about IOM in particular. The other of the two examinations in this field is given by the American Board of Clinical Neurophysiology (ABCN). The board has several examinations, one of which is the examination in intraoperative monitoring. The latter is a comprehensive examination that shows mastery of the IOM field. These two board examinations differ in that the ABCN examination expressly tests for mastery of IOM, whereas the ABPN examination does not.

Continuing medical education (CME) courses for physicians are given through three medical organizations: the American Clinical Neurophysiology Society (ACNS), the American Society of Neuromuscular and Electrodiagnostic Medicine (AANEM), and the American Academy of Neurology (AAN). These formal courses are offered as part of general clinical neurophysiology and neurology educational and scientific meetings for each society. The American Society of NeuroMonitoring (ASNM) is a group composed of IOM technologists, PhD non-physicians who are IOM experts, and some IOM physicians from several specialties. The ASNM annual meetings are another source of continuing education in IOM.

Physicians who do not have the opportunity to take a one–two-year fellowship, and yet still wish to begin providing IOM clinical services, should make use of an expert consultant in IOM who can help define protocols, screen technologist staff, and help with problem solving as needed. That consulting role may be filled by PhD diplomates of the American Board of NeuroMonitoring (DABNM) who are non-physician, or physicians who are experienced in IOM.

Some PhD or MD consultants are available to help with IOM services. Some run independent businesses that can supply traveling technologists as needed. Some provide local physicians with training and consulting. Some are DABNM. That examination is open to interested persons with a master's degree or higher with experience in intraoperative monitoring. It does not require a professional to be licensed. This group of individuals can help with IOM expertise, and are best suited to serve the IOM expert consultant role in an IOM team in which the clinical neurophysiology physician lacks sufficient personal IOM experience.

The standard in the medical community requires involvement of a clinical neurophysiology physician in IOM. The American Medical Association (AMA), in its policy statement on intraoperative neurophysiologic monitoring, states, "Our AMA policy is that supervision and interpretation of intraoperative neurophysiologic monitoring constitutes the practice of medicine . . ." The in-room non-physician personnel work is provided "under the direct or on-line real-time supervision of the . . . physician trained in, or who has demonstrated competence in, neurophysiologic techniques and is available to interpret the studies and advise the surgeon during the surgical procedures." (American Medical Association, 2008).

The AMA also has a policy on the role of unlicensed PhD personnel (American Medical Association, 2006):

> It is AMA policy that: (1) the diagnosis of disease and diagnostic interpretation of a study or studies for a specific patient constitutes the practice of medicine; (2) a PhD clinical lab scientist or other non-physician laboratory personnel work under the supervision of a physician under their applicable scopes of work to perform a study or studies that will be the basis of a diagnostic interpretation for a specific patient; and (3) the Medicare physician fee schedule compensates only authorized persons for the diagnostic interpretation of a specific patient and should not provide payments directly to non-physician lab personnel working under the supervision of a physician to perform a laboratory study or studies.

Intraoperative monitoring is dangerous when carried out without the team of IOM expert, clinical neurophysiologist, and trained technologist. The insufficiently prepared team is predisposed to giving overly optimistic or inaccurate information to the surgeon or anesthesiologist. This can promote a false sense of security that the case can proceed without neurologic impairment when the IOM does not show that this is the case.

The team also allows for routine screening by public safety systems in health care. Credentialing and privileging the clinical neurophysiologist by each hospital's neurology service and medical staff office allows for others with expertise in general clinical neurophysiology to evaluate the team's skills, knowledge, abilities, training, and experience in the testing and monitoring requested. Board certification and continuing education can be checked. It also enables the medical staff organization to review the physician's malpractice history, staff and patient complaints, documentation compliance, and other factors that should influence whether privileges and credentials should be granted. Licensing of the physician in that state allows an external review of many of those same items by an independent board less likely to be influenced by internal hospital needs, and answerable to the public for its decisions. Licensing also provides a method for restraining or removing practitioners who fail to meet criteria for safe and effective patient care within the current health care system. Licensing boards can act upon problem practitioners by investigating complaints, bad outcomes, and unprofessional behavior, and can issue public reprimands, demands for further education, restrictions on practice, suspensions and revocations of licenses.

Another point at which IOM falls under the domain of the practice of medicine is the statutory restriction of the practice of medicine to licensed physicians. Diagnosis is a professional opinion about the presence, absence, type, location, or severity of an illness or injury. A diagnostic interpretation is a professional opinion about a diagnosis based upon the findings in a test. Examples of diagnostic interpretations are:

- Normal SEPs,
- Abnormal SEPs due to a central delay in latencies,
- The drop in cortical peak amplitude could be due to the increase in inhalation anesthesia,
- The drop in cortical peak amplitude is severe,
- The most likely location of this impairment is in the spinal cord below the mid-cervical level.

A diagnostic test is one that produces findings suitable for a diagnostic interpretation. Examples of diagnostic tests are: magnetic resonance imaging, transcranial Doppler ultrasound, electrocardiography, and positron emission tomography. Further examples are electroencephalography, electromyography, evoked potentials, and nerve conduction studies. State business and professional statutes and regulations limit the diagnostic interpretation of these diagnostic tests to licensed physicians. The few exceptions are for limited license practitioners, such as the use of X-rays by dentists or podiatrists. These public health care policies are intended to protect the public.

In contrast, technologists and other non-physicians can generally report the findings of a test to a surgeon. Findings are the objective latencies and amplitudes that can be read from cursors, after consideration of where the cursors should be placed and whether tracings are suitable for measurement. Findings can be related to baseline values. Findings are also subject to the diagnostic interpretation of the supervising physician. Examples of test findings are:

- The cortical peaks are at their baseline latencies and amplitudes.
- The cortical peak amplitudes have dropped by 60%.
- The cortical peaks are now absent.

These public processes for the regulation of health care services are handled through the credentialing, privileging, and licensing of physicians. The IOM team needs to stay within the limits of these public health care processes so as to help assure that the public is provided with good quality care and that problem providers are restrained or removed as needed. The clinical neurophysiologist is the key to this, being the only member of the team who is subject to these public health care policy regulations (Nuwer, 2002).

The technologist's role and training

A technologist generally lacks suitable skills, knowledge, abilities, training, and experience to provide the IOM services without supervision by a clinical neurophysiologist. Technologists also lack the medical knowledge and statutory authority to advise a surgeon about clinical options when changes do occur. Most institutions require physician supervision of medical procedures including IOM, much in the same way as for interpretation of MRI (magnetic resonance imaging) or CT (computed tomography). In any case, the monitoring supervisor needs to have medical staff privileges for clinical neurophysiology at the hospital where the monitoring is conducted. The privileging should meet all local public policies to review and approve each individual's suitability to provide these clinical services.

Technologists, a key part of the IOM team, need sufficient experience in neurophysiologic testing, techniques, basic sciences, and relevant clinical sciences before being able to provide remote IOM supervision. Usually, this includes several years of regular inpatient and outpatient experience of conducting EEG and evoked potentials. That experience is an important basis for knowing what signals look like, identifying changes and abnormalities, and dealing with technical problems.

In the USA, formal technologist training programs are usually two years long. Students are trained in didactic fundamentals and clinical practical experience in routine EEG and evoked potentials. Many have additional didactic and clinical experience in IOM. Students are prepared to conduct routine testing, but need additional experience in IOM before being left alone as the in-room member of the IOM team. These training programs are supervised and accredited by a national organization, the Committee on Accreditation for Education in Electroneurodiagnostic Technology (CoA-END).

Each technologist should be proctored and given progressively reduced supervision when introduced to IOM. The technologist's privileging should be specific, i.e., a technologist who knows well how to monitor EEG during a carotid endarterectomy does not necessarily know how to monitor somatosensory EPs in a spinal-cord case. The technologist should also have mastered the outpatient and routine inpatient application of techniques before embarking on the IOM application of that modality. Of course, that cannot be applied to some techniques, such as transcranial electrical stimulation, where there is no outpatient application.

Technologists' competence and knowledge are tested with registration examinations. In the USA, the American Board of Registration of Electroencephalographic and Evoked Potential Technology (ABRET) sponsor these registration examinations. Basic competency examinations are given in EEG and evoked potentials. These require both a written and an oral examination. An additional examination is given in intraoperative monitoring, which grants the successful applicant the Certificate in Neurophysiologic Intraoperative Monitoring (CNIM). The CNIM is obtained by passing a written multiple choice examination without an oral examination component. Well trained IOM technologists have these several registration credentials. Technologists are required to maintain continuing education credits to keep their certificates active. Credits are given through educational offerings in the field, especially those given by the American Society of Electroneurodiagnostic Technologists (ASET).

An alternative track for obtaining the CNIM allows individuals with a bachelor's degree to take the examination despite a lack of skills, knowledge, ability, training, or experience in EEG and evoked potentials. Some have had a small number of cases of actual IOM experience. This leads to the observation that the CNIM credential is a mark of a degree of book knowledge but not necessarily a mark of sufficient practical experience or clinical knowledge. In this situation, the supervising clinical neurophysiologist should assess the actual ability of each technologist, and allow in-room monitoring privileges only to those who have demonstrated actual skills, knowledge, ability, training, or experience in particular IOM techniques. A certificate by itself is not sufficient.

Summary

Intraoperative monitoring applies many useful techniques to various surgical procedures. The monitoring teams encompass several specialists contributing their own expertise. Goals are to enhance patient care, avoid neurological deficits, allow for more complete procedures, allow procedures even on some high-risk patients, and provide feedback to the surgeon about actions that could injure the nervous system.

Questions

1. The false-negative rate for spinal-cord somatosensory evoked potential monitoring is approximately:
   (a) 5%
   (b) 1%
   (c) 0.5%
   (d) 0.1%
2. False-negative cases are those in which:
   (a) The IOM remains stable, but the patient awakens with a new deficit
   (b) The IOM changes, correctly predicting the new deficit
   (c) The IOM remains stable, and the patient awakens without a new deficit
   (d) The IOM changes, but the patient awakens with no new deficit
3. The first kind of intraoperative neurophysiology monitoring used in surgery was:
   (a) Somatosensory evoked potentials
   (b) Electrocorticography
   (c) Electromyography
   (d) Auditory evoked potentials

4. The use of EEG to monitor carotid endarterectomy was popularized around:
   (a) 1960
   (b) 1970
   (c) 1980
   (d) 1990
5. Health care public policy regulations restrict the interpretation of IOM results to:
   (a) Physicians, PhD DABNMs, and CNIM technologists
   (b) Physicians and PhD DABNMs
   (c) Physicians and CNIM technologists
   (d) Physicians
6. A professional opinion about the presence, absence, type, location, or severity of an illness or an injury is a:
   (a) Diagnostic interpretation
   (b) Diagnostic test
   (c) Diagnosis
   (d) Finding
7. Technologists are allowed to report:
   (a) The latency and amplitude values
   (b) That the results are normal
   (c) That the results are abnormal
   (d) That the changes are due to a new spinal-cord level impairment
8. Which organization allows unlicensed non-physicians to take its board examinations?
   (a) American Board of Psychiatry and Neurology (ABPN)
   (b) American Board of Clinical Neurophysiology (ABCN)
   (c) American Board of Electrodiagnostic Medicine (ABEM)
   (d) American Board of NeuroMonitoring (ABNM)
9. The intraoperative monitoring certificate given by the American Board of Registration in Electrodiagnostic Technology to technologists is abbreviated as:
   (a) DABNM
   (b) CNIM
   (c) REEGT
   (d) CLTM
10. Supervision by a physician who is near the operating room and available to enter the room at short notice is referred to as:
   (a) Personal supervision
   (b) Remote supervision
   (c) Direct supervision
   (d) General supervision

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2 The preoperative assessment

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It is extremely helpful for patients undergoing surgery with intraoperative monitoring to have a preoperative assessment by the neurophysiologic intraoperative monitoring (NIOM) team prior to the surgical case. A preoperative assessment is important to allow the monitoring team to gather additional information on the patient that is not always readily available in the surgical team's clinic notes (Table 2.1). This includes current medications, allergies, prior surgical and medical history and an understanding of what risks may be involved, given any prior anesthetic or surgical complication. It allows a discussion of expectations by the patients or their parents for the day and days leading up to the surgical procedure and those days needed for recovery after the procedure.

It has been well established that collaborative communication can reduce the number of communication failures and subsequent adverse events in surgical procedures (Lingard *et al.*, 2004). Surgical teams may follow preoperative team checklists to enhance communication and avoid mishaps. These anesthetic and surgical checklists typically focus on operative medications, anesthesia requirements, the use of special instruments, and a description of the operative plan, which includes the estimated duration of the surgery, description of procedure, and the use and choice of blood products (Lingard *et al.*, 2008). Similarly, it is important that the neurodiagnostic monitoring team be able to evaluate the patient prior to the day of surgery, since their focus will be different from what is evaluated for in most surgical and anesthetic preoperative checklists and evaluations.

The NIOM preassessment will include a history and in some cases possibly a focused physical examination as well. The history will be focused on key features, which will be pertinent in the results obtained by monitoring particularly neurological, orthopedic, and neurosurgical history and the existence of medical, anesthetic, and surgical complications. Studies have shown that perioperative complications affect patient outcome (Glassman *et al.*, 2007) and can significantly affect the results of NIOM (Albert *et al.* 1995).

This assessment by the NIOM group will help determine the choice of correct monitoring modalities and the exclusion of inappropriate ones. It will allow for a better understanding of abnormalities, including conduction delays that may be seen in the intraoperative baseline study, and correlate these with the patient's clinical scenario. The NIOM group preoperative assessment will also allow the acquisition of clinical information from the physical examination and history, in order to select appropriate muscle groups for recording. In addition, information that may exclude the patient from certain monitoring modalities, such as transcranial electric stimulation of motor tracts, will be obtained.

Much collaboration and communication occurs between the NIOM and anesthesia teams during the procedure and having the staff and equipment in close proximity can facilitate this communication. Figure 2.1 demonstrates a common set-up of equipment for NIOM and anesthesia monitoring. One can see from this picture that the proximity of the staff may enhance communication between them.

Figure 2.2 shows a preoperative SEP, obtained by recording from the ulnar nerve on a patient with a deformed left upper extremity. No responses could be obtained from the deformed side, eliminating the need to troubleshoot this in the OR case (Thuet *et al.*, 2005). Recording had also been attempted on the median nerve but without success in this patient.

Figure 2.3 shows additional equipment, which has been set out in the operation room for a complicated spine surgery. The stacks of additional trays of instrumentation equipment that are required can often impact the space available in the operation room for monitoring equipment and personnel. This limitation of space can make it difficult for the technical staff to get to the patient during times of troubleshooting and