
CHAPTER 11

Intraoperative Cranial Nerve Monitoring

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INTRODUCTION

The increasing availability and sophistication of intraoperative cranial nerve monitoring (IOM) within the last few decades has opened a new era in the pursuit of functional neural preservation during microsurgery. The use of intraoperative electromyographic (EMG) facial nerve monitoring has been a standard of care for the resection of acoustic neuromas and other cerebellopontine angle tumors for over a decade.¹ Parallel applications are now routinely being used to monitor cranial nerves during other otolaryngology procedures involving the parotid gland, thyroid, neck, middle ear, and mastoid. Although monitoring is becoming more commonly used for these procedures, polls suggest that there is currently no consensus on the role of IOM as being a standard of care in these settings. Nonetheless, it is interesting to note that, although litigation 20 years ago for iatrogenic facial palsy focused on whether or not monitoring was used, litigation today focuses on whether or not it was used *correctly*. Thus, a key objective of this chapter is to examine common pitfalls in intraoperative monitoring because “poor monitoring is worse than no monitoring.”

HISTORY

The concept of intraoperative nerve monitoring has been in existence for over a century. Early forms of intraoperative facial nerve monitoring consisted of visual confirmation of facial motion or tactile con-

firmation by an assistant’s hand. As early as 1898, Krauze described galvanic stimulation of the facial nerve during an acoustic neurectomy, with visual confirmation of the response.² In the 1940s, Olivecrona³ made a concerted attempt to routinely preserve the facial nerve during acoustic tumor resections using a facial nerve stimulator and a nurse whose responsibility was to observe the patient for facial contractions. At times, the surgery was performed under a local anesthetic to allow the patient to move their face upon demand. During the mid-1960s, Parsons, Jako, and Hilger independently reported on dedicated facial nerve monitors that were intended for use during otologic and parotid surgery.⁴⁻⁶ Jako’s device was distinguished by a mechanical transducer placed along the patient’s cheek that detected facial contractions. Delgado et al⁷ were the first to report on intraoperative electromyographic (EMG) facial nerve monitoring during cerebellopontine angle (CPA) surgery. Using surface electrodes, they reviewed a printout of the EMG tracings. Sugita and Kobayashi⁸ modified this technique by using accelerometers to transduce facial motion into electrical energy, but commented on one false-positive error due to inadvertent stimulation of the motor portion of the trigeminal nerve. More importantly, they used a loudspeaker to provide acoustic feedback that allows the surgeon to interpret the evoked responses in context to ongoing surgical events. Prass and Luders⁹ subsequently correlated specific patterns of EMG activity to surgical manipulations. Silverstein et al¹⁰ enhanced Jako’s motion-detector device (WR Electronics, St Paul, MN) and recommended its use for many otologic procedures. Kartush and Prass¹¹ developed the “Nerve Integrity Monitor” (NIM)

with Nicolet Company (Madison, WI) in 1984 that was subsequently purchased by Xomed (Medtronic) and has become the most commonly used device in the United States.¹¹ Many other companies now produce “multimodality” monitoring devices that can monitor up to 32 channels of responses not only of EMG but also EEG making them ideal for complex spine and brain monitoring. Their sophisticated multimodality features, however, add a high degree of complexity and, therefore, are typically only used by specially trained technologists. Many devices are available that are acceptable for cranial nerve monitoring. This chapter uses the NIM for many examples simply because of the senior author’s 25 years of experience with it: including its strengths and weaknesses. A few other dedicated devices for cranial EMG monitoring include the Magstim Neurosign, the WR Electronics Silverstein, WR Electronics Brackmann and the IOM Solutions Nerveana (Figure 11–1).

NEUROMONITORING BASICS

Goals of Monitoring

The goals of intraoperative neural monitoring have been well established. First and foremost is to assist in identifying the nerve of interest. Second, information gleaned from responses during monitoring assists in the detection of injury to the nerve during dissection. Third, stimulation proximal to the manipulated nerve post dissection can provide a predictive assessment of nerve function.

Responsibility of Monitoring

There are two aspects of monitoring. One is the technical component, which consists of using and setting up the monitoring equipment correctly and



Figure 11–1. Numerous dedicated EMG nerve monitors are commercially available. (Reprinted with permission, courtesy of Jack M. Kartush, MD)

understanding the inherent properties of the system to avoid an erroneous setup (eg, no muscle relaxation, correct electrode placement, low impedance, etc). The other aspect is the interpretive component. Is the person performing the monitoring able to distinguish between a true response versus an artifactual one? When problems occur, can they perform appropriate troubleshooting to identify and correct the issue at hand? With something relatively simple, such as facial nerve monitoring, it is often possible for the surgeon to perform both components, assuming that he or she has undergone the proper training to do so. Many features of the NIM were specifically designed to allow for surgeon interpretation such as auditory representation of the EMG through both raw EMG and intelligently designed alarms that alert the surgeon to significant responses as well as potential problems such as electrode displacement or high impedance. Another important feature is confirming current flow during stimulation with both visual and auditory displays. In fact, a surgeon trained in monitoring is unequivocally the ideal person to interpret the responses as he or she can immediately correlate them to the surgical events. Even the best trained technologist, neurophysiologist, or neurologist will have difficulty separating true responses from artifact without the benefit of seeing and understanding the surgical events in real time.

In contrast, complex types of monitoring that require the averaging of small potentials such as auditory brainstem recording (ABR) and somatosensory evoked potentials (SSEP) typically require too much time and effort for the surgeon, which could distract from the operation. Furthermore, many surgeons simply are not trained in performing the technical or interpretive aspects of these more complex monitoring. Thus, either the surgeon has undergone sufficient training to manage both the technical and interpretive aspects of nerve monitoring or a well-trained technician, neurophysiologist, or neurologist should assist in monitoring. Unfortunately, poor reimbursement in this country has made it prohibitive for neurologists to spend hours or an entire day in one operating room. Thus, with a trained technologist in the operating room, professional interpretation is increasingly being performed by remotely located neurophysiologists and neurologists, who

receive real-time information through the internet. While there is little need for such remote monitoring for basic EMG modalities if the surgeon is well trained, complex procedures (EEG for carotidectomy, transcranial motor evoked potentials [MEP] for scoliosis surgery) benefit greatly from a well-trained team of local technologist and remote neurologist/neurophysiologist. Today, most hospitals seek monitoring service companies who specialize in these complex procedures and have the requisite information technology (IT) resources to ensure appropriate hardware, software, and systems management to optimize connectivity from the OR to the remote monitoring professional.

Monitoring Pitfalls

Monitoring is an adjunct, not a replacement for anatomical knowledge and surgical skill. When neurophysiologic responses appear to conflict with anatomy and surgical findings, one must either troubleshoot for a solution or disregard the monitor. As the senior author (JMK) has stated for decades, "Poor monitoring is worse than no monitoring." Monitoring can be likened to going into a minefield with a minesweeper that is malfunctioning. Under this circumstance, it is better to disregard the minesweeper rather than to depend on something that is unreliable. There are many possible pitfalls even for relatively simple monitoring modalities such as facial nerve recording. Just as physicians learn to generate a differential diagnosis for medical disorders, so must the well-trained surgeon develop consistent protocols and a differential diagnosis for intraoperative monitoring problems if they are to perform both technical and interpretive components without a technologist or neurophysiologist. As the use of monitoring has become increasingly routine in otolaryngology, neurosurgery, and spine surgery, surgical residency programs should begin to include monitoring courses in their core curriculum, and test for competency in this area just as they do in other critical areas. General surgeons are just beginning to adopt monitoring for thyroidectomy and, without any prior experience in monitoring, it is critical that they actively pursue IOM training. A great deal of

effort has gone into the training of IOM technologists and reading professionals over the last 20 years. Organizations such as the American Society of Neurophysiologic Monitoring (ASNM) provide training courses for surgeon, technologists, neurophysiologists, and neurologists as well as a means to certify levels of monitoring interpretative competence (eg, American Board of Neurophysiologic Monitoring [ABNM]). In contrast, the American Board of Registration of Electroencephalographic and Evoked Potential Technologists (ABRET) has focused on a certification exam for technologists, Certification for Intraoperative Monitoring (CNIM). Thus, surgeons who choose to perform technical and/or interpretive aspects of monitoring should take advantage of these educational resources.

There are numerous technical and interpretive pitfalls that can lead to false-positive and false-negative errors. A false-positive error occurs when a signal is interpreted as being a true response from the nerve of interest when in fact it was generated by artifact or another neuromuscular generator. Examples include (a) mistaking a response from a pharyngeal constrictor while seeking a vocal fold response during thyroidectomy, or (b) mistaking a response from masseter and temporalis muscles while seeking a facial nerve response during acoustic tumor surgery adjacent to the root entry zone of the trigeminal nerve.

A false-negative error occurs when a response from the nerve of interest is missed. There are multiple causes of such an error. Long-lasting neuromuscular blockade and topical anesthetics can abolish or impair EMG responses. Not understanding that monitoring is disabled during electrocautery can result in the nerve being burned and yet no response will be detected during cautery. The experienced surgeon learns that when cautery must occur in close proximity to a nerve, it should be done at the lowest possible setting and then the *nerve should be electrically stimulated immediately following cautery (or other risky maneuver) to confirm that it has not been injured.*

Incorrect setup of electrodes or monitoring parameters can result in both false negative and false-positive errors. Errors with multimodality devices can occur in numerous additional ways that may be difficult to detect because electrodes cannot only be placed in the wrong input of an interface

box that may have scores of different input sockets, but software allocation of stimulus and recording pathways can lead to misallocation of the signals. For example, in SEP monitoring, we have seen stimulation of the left leg when the right arm was the intended target. Similarly, during ABR recording, software misallocation may inadvertently lead to the sound signal being conveyed to the right ear transducer, when the left ear is the intended side. These and other details are addressed later in the chapter.

FACIAL NERVE MONITORING

Clinical Application

Although the indications for facial nerve monitoring are expanding, its benefit has been most apparent during resection of acoustic neuromas given the high incidence of postoperative facial palsy prior to the use of monitoring. These benign tumors typically originate from the superior vestibular nerve in the internal auditory canal. The proximity of the adjacent facial nerve accounts for its routine involvement by tumor displacement or microscopic infiltration. Most clinicians prefer an EMG-based system using intramuscular needle electrodes to maximize recording sensitivity and specificity. The high sensitivity of electromyographic facial nerve monitoring allows electrical stimulation of the nerve to be supplemented by identifying low amplitude mechanical-evoked potentials caused by blunt surgical trauma. The specificity of EMG monitoring reduces the chance for false-positive errors that can occur with a motion detector-based system. Sugita and Kobayashi⁸ reported on one case in which the facial nerve was inadvertently cut because stimulation of the trigeminal nerve resulted in contraction of the muscles of mastication. The motion detector was not able to differentiate between this movement versus contraction of the facial musculature.

Retrospective studies indicate improved facial nerve outcome with intraoperative monitoring particularly with large acoustic tumors.¹²⁻¹⁵ Although a controlled, prospectively randomized study would be most convincing, such a study is unlikely to take place because most of today's surgeons who

have adopted monitoring believe that there is an unequivocal benefit and are reluctant to withhold this modality from their patients. It is surprising that after years of reluctant acceptance, some now refer to the analogy that there has never been a controlled study for skydiving with and without parachutes . . .

Because the incidence of nerve injury in chronic ear surgery is markedly less than that seen in acoustic neuroma surgery, it is more difficult to show if injury could have been avoided with monitoring due to the need for an extremely large sample size. In a recent survey conducted to identify facial nerve IOM practice in the United States in this setting, the authors found that although 75% of the 223 respondents had access to monitoring, only 32% thought that it was a requirement.¹⁶ The standard of care is often defined as what the average provider would have done under similar circumstances. Those who performed more otologic surgeries than other types of surgeries were more likely to use the monitoring for chronic ears.

The use of monitoring in middle ear and mastoid disease, especially in the setting of revision surgery, is justified anatomically. Noss et al¹⁷ retrospectively reviewed 262 cases and found that while a dehiscence facial nerve was visualized during 10% of the primary surgeries and in 20% of the revision surgeries, an electrophysiological dehiscence was detected through the use of stimulation in 53% of the primary surgeries and in 96% of the revision cases. A stimulation threshold of <1 volt was concluded to be a more useful criterion of dehiscence than clinical observation under an operating microscope. The cost-effectiveness of intraoperative facial nerve monitoring in both primary and revision surgeries for middle ear and mastoid disease was demonstrated by Wilson et al.¹⁸ The estimated additional cost of \$222.73 to \$528.00 to the otologic surgery for monitoring and an audiologist/technician was offset by the avoidance of the high management costs of facial nerve paralysis.

Lowry et al¹⁹ surveyed US otolaryngologists to determine the patterns of use of facial nerve monitoring during parotid gland surgery. Of the 1,548 respondents, the more parotidectomies performed per year (>10 and >20), the more likely monitoring was used (79% and 60%, respectively). Four hundred and ninety-two of the 627 (78.5%) surgeons

who responded to a query on the type of monitoring used, reported using intraoperative monitoring without the use of nerve stimulators, whereas 21.5% used nerve stimulators only without EMG monitoring. There was no statistically significant association between the use of monitoring in current practice and a history of inadvertent permanent facial nerve injury. The authors concluded that there was a growing trend of facial nerve monitoring during parotid surgery despite the lack of any published prospective, randomized clinical studies to examine the efficacy of its use in this setting.

An interesting corollary is the gradual acceptance of pulse oximetry in anesthesia. At first many anesthesiologists and nurse anesthetists were reluctant to accept “yet another gimmick” that would take away from the “art” of anesthesiology. Many took pains to vocally indicate that it was not a standard of care. However, as pulse oximetry has become less expensive, widely available and a useful real-time measure to assess oxygenation, it has indeed become a standard of care, even though no controlled study has shown a statistical difference in outcomes. Like pulse oximetry, we predict that the use of intraoperative neuromonitoring will increase simply because it provides “critical information of key structures at risk in the operative field.” Neuromonitoring has become accepted in many surgical fields including brain, spine and thyroid. One of the last remaining fields that we predict will finally adopt monitoring is in pelvic surgery where the risks of impotence and incontinence during prostatectomy, hysterectomy and colorectal oncologic surgery remain problematic.

Setup and Recording Technique

Long-acting muscle relaxants should be avoided. Although low doses may not have a significant effect on the response to electrical stimulation, they diminish the ability to monitor small amplitude responses associated with mechanical evoked potentials of the facial nerve. Therefore, judging depth of paralysis using a “Train of Four” peripheral nerve stimulator at a relatively high current setting is not an accurate measure of the facial nerve’s ability to respond to minor surgical trauma.