INTRAOPERATIVE NEUROPHYSIOLOGICAL MONITORING TECHNIQUES:

An Overview of Applications & Techniques

Neuro Alert

Intraoperative Neurophysiological Monitoring Techniques: An Overview of Applications & Techniques

Intraoperative neurophysiological monitoring (IONM) is a monitoring technique aimed at reducing the risk of neurological deficits after operations that involve the nervous system. The goal of such monitoring is to identify changes in the spinal cord, brain, and peripheral nerve function to minimize risk or irreversible damage. The technique is also effective in localizing anatomical structures, including sensorimotor cortex and peripheral nerves, which help in guiding surgeons during an operation.

Evoked potential monitoring includes motor evoked potentials (MEP), somatosensory evoked potentials (SSEP), visual evoked potentials (VEP), and brainstem auditory evoked potentials (BAEP). Electromyography (EMG) is also commonly used during operation. Data for analysis in SSEP, BAEP, and VEP is obtained from scalp recordings. Electroencephalography (EEG) is a technique used to monitor cerebral function during vascular surgeries such as carotid endarterecromy (CEA) among other cases where brain perfusion may be compromised. Additionally, EEG, if recorded directly from the pial surface, can help in determining resection margins for epilepsy surgery and to monitor seizures.

This eBook provides a simplified overview of the various IONM techniques, highlighting the purpose, methodology, and clinical applications of each. But first, a brief history of IONM.

WHERE IT ALL BEGAN

The action potential of nerves was first reported in 1848 by Du Bois-Reymond who is also credited with describing the first EMG. Electrical activity in the brain was then reported by Caton in 1875, and Han Berger was the first to report EEG tracings from the human brain in 1928/29.

Intraoperative EEG was first used in 1935 by Foerster and Alternberger and further developed by Herbert Jasper and Wilder Penfield between late 1930s and the 1950s. Jasper and Penfield used ECoG for localization and surgical treatment of epilepsy and performed careful mapping of cortical function through direct stimulation.

The first SSEP was recorded in 1947, which led to understanding of evoked potentials including those produced by auditory and visual stimulation. In 1978, the first BAEP was reported. Between then and now, several breakthroughs have been reported. Today, IONM activities utilize computerized equipment with microprocessors to allow channel recordings and various filtering capabilities as well as spectral analysis.

ELECTROMYOGRAPHY (EMG)

PURPOSE

EMG refers to the recording of electrical activity in the muscles. Changes in EMG recording indicate function of the innervating nerve.

TECHNIQUE

Multiple EMG needles are placed into the muscles being examined and EMG changes are recorded using a low noise amplifier. The recordings can be displayed visually and even sent to a speaker for audio monitoring. Any muscle, including the tongue, face, and sphincter musculature can be monitored.

CLINICAL USES

Electromyography is used in cranial nerve monitoring during surgical procedures in which facial nerves are at risk, such as in posterior fossa surgery and surgery in the temporal bone. It can also be used in selective dorsal rhizotomy, tethered spinal cord release, and pedicle screw placement.

EVOKED POTENTIALS

SOMATOSENSORY EVOKED POTENTIALS (SSEP)

PURPOSE

SSEP is used to monitor amplitude, shape, and latency responses to nerve stimulation, which are then compared to the patient's own normative data prior to start of surgery, and extremely rarely to laboratory norms more as a generalized view. First, a reproducible baseline recording is established, and then changes from the baseline responses used to determine neuropsychological dysfunction.

TECHNIQUE

SSEPs are recorded by electrically stimulating peripheral afferent nerves and recorded using scalp electrodes. Recording electrodes are placed on the scalp and on the cervical spine. The electrodes can also be placed at the Erb's point for upper extremity recording and over the lumbosacral for lower extremity SSEP recording. Needle electrodes are used to minimize artificial signal.

Given the presence of nonspecific EEG activity in the background, the evoked potentials are averaged to improve signal-to-noise ratio.

CLINICAL USES

SSEP is used in spinal surgery, localization of sensorimotor cortex, and cranial/vascular surgery. In cranial/vascular surgery, it is used in carotid surgery including endarterectomy, cerebral aneurysm surgery, and aortic cross-clamping.

EVOKED POTENTIALS

MOTOR EVOKED POTENTIALS (MEP)

PURPOSE

While SSEP is the standard means of intraoperative monitoring, significant motor deficits have been reported in patients undergoing spinal surgery. MEP was developed to improve the motor neurophysiological pathways.

TECHNIQUE

MEP responses are elicited using either magnetic or electrical stimulation of the motor cortex of the brain which activates the corticospinal pathway down to the spinal cord. Recordings are obtained as myogenic potentials from the innervated muscle or as neurogenic potentials in the distal spinal cord.

Transcortical magnetic stimulation delivers a pulsed magnetic field over the scalp around the primary motor cortex. Unfortunately, generating good results with this method in the operating room is difficult.

The more popular alternative, transcortical electrical stimulation, involves stimulation of electrodes of the scalp. In open brain surgeries, stimulation of electrodes placed directly on the brain surface is also possible. Electrical stimulation can also be applied directly over the spinal cord and distal neurogenic potentials recorded.

CLINICAL USES

MEP is primarily used in spinal surgery. A special type of MEP known as Transcranial Electrical Motor Evoked Potentials (TceMEP), if combined with SSEP, can significantly improve accuracy of monitoring in spinal cord function.

EVOKED POTENTIALS

BRAINSTEM AUDITORY EVOKED POTENTIALS (BAEP)

PURPOSE

BAEP is used to record cortical responses to auditory stimuli for purposes of monitoring the function of the entire auditory pathway including the acoustic nerve, brain stem, and cerebral cortex. It is sometimes also called Brainstem Auditory Evoked Responses (BAER), Auditory Brainstem Responses (ABR), or just Auditory Evoked Potentials (AEP).

TECHNIQUE

BAEP recordings are obtained by stimulating with auditory clicks in the patient's ear. Scalp electrodes placed near the ear at (A1, A2) are referenced to vertex (Cz) for best results. The clicks are delivered in a repetitive pattern at 11Hz with frequencies that don't coincide with the 60 Hz noise of AC current.

CLINICAL USES

The procedure is often used in cerebellopontine angle surgery, including surgery for acoustic neuroma or meningioma. It is also used for microvascular decomposition for tic douloureux or hemifacial spasm. Parameters usually measured include Latency of wave I-III, latency of wave I-V, latency of wave V, and peak amplitude of wave III.

EVOKED POTENTIALS

VISUAL EVOKED POTENTIALS (VEP)

PURPOSE

Monitoring visual pathways is helpful in surgeries involving areas such as the parasellar region which may be in proximity to the visual apparatus. VEP is therefore commonly used in tumors such as caraniopharyngioma, suprasellar meningioma, and pituitary adenomas. It is also used in surgery to assess the integrity of visual pathway structures such as optic nerves, although it cannot detect visual field defects.

TECHNIQUE

Visual stimulation is achieved by flashing strobe lights or light emitting diodes (LEDs) and potentials recorded with scalp electrodes. Typically, three negative peaks (N1, N2, N3) and three positive peaks (P1, P2, P3) are seen and latency and amplitude changes recorded. To obtain best results, noise reduction and signal averaging techniques are applied.

CLINICAL USES

There have been conflicting reports on the application of intraoperative VEP. While the technique has been used in monitoring tumor resections that require manipulation of the optic apparatus, its use is yet to become standard practice.

ELECTROENCEPHALOGRAPHY

ELECTROENCEPHALOGRAPHY (EEG)

TECHNIQUE

Intraoperative scalp EEG is mostly performed using digital EEG machines, although standard electrodes and paper can also be used. In the latter approach, 10-20 electrode placement is typically used and the signals recorded in 8-32 channels of bipolar with or without referential variations. Computerized techniques offer more visually transparent display but standard recordings show changes more quickly.

CLINICAL USES

Scalp EEG is mainly applied during carotid endarterectomy. EEG recordings have proved reliable when determining acute changes in cerebral blood flow that occur during operations such as carotid cross-clamping. Additionally, EEG is used during hypothermic circulatory arrest for cardiac surgery and during aneurysm clipping when carotid clamping is required.

ELECTROCORTICOGRAPHY

ELECTROCORTICOGRAPHY (ECOG)

TECHNIQUE

In intraoperative ECoG, saline-soaked cotton or carbon ball electrodes are attached by flexible wires to a frame fixed to the skull and used to record signals. Alternatively, stainless steel or platinum disc electrodes embedded in silastic can be used. Epileptiform spikes which are the main parameters measured are sharper at the cortical surface and have shorter durations of only 10-20 milliseconds.

CLINICAL USES

ECoG is used in a variety of situations where surgery is being applied to ameliorate seizures. In lesional cases, removing the surrounding areas that show frequent spiking can improve outcome. This is particularly helpful if the lesion cannot be removed.

IN SUMMARY

Multiple studies show that intraoperative neurophysiological monitoring is quite effective in improving surgical outcome. In particular, combining SSEP and MEP can significantly improve detection of intraoperative changes.

Neuro Alert

Together, we can put patient safety first

CLICK HERE TO RECEIVE A FREE CONSULTATION