Introduction to Intraoperative Neuromonitoring

An intro to “those squiggly lines…”

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Disclosures

• None

Learning Objectives

• History of Intraoperative Monitoring
• What is Intraoperative Monitoring
• Why is Intraoperative monitoring important
• What comprises a team
• What are typical monitoring modalities
• Conclusion
**Intraoperative Monitoring**

The most primitive method of monitoring the patient 50 years ago were continuous palpation of the radial pulsations throughout the operation or wake up test.

![Monitoring in the Past](image)

**History**

- **1921**, Dr. Penfield, intraoperative neurophysiology research
- **1950s**, Dr. Penfield, electrical stimulation to find epileptic foci
- **1970s**, Dr. Brown used Somatosensory Evoked Potentials (SSEP) for scoliosis operation
- **1974**, among 7,800 operations conducted with Harrington instrumentation, 87 patients had subsequently developed significant spinal cord problems
- **Early 1980s**, IOM in operations for large skull base tumors
- **1980**, the formation of American Society of Neurophysiological Monitoring (ASNM)

**Basis of Intraoperative Monitoring**

- “Do not harm” - the spirit of the Hippocratic Oath
- We may not be able to relieve the suffering from illness, but we should at least not harm the patient in our attempts to relieve the patient from illness

1. Intraoperative Neurophysiological Monitoring, A.R. Muller
Introduction - What is IOM?

- Use of intraoperative neurophysiological monitoring for detecting iatrogenic (during surgery) injury to nervous tissue that is being manipulated through changes in recordings
- Means of assessing the function of the brain, brainstem, spinal cord and peripheral nerves during surgery
- It is also becoming part of standard medical practice

Purpose of IOM

1. Reduce the risk of postoperative neurological deficits
2. It is also useful as a means of localization of function or of neural tissue in general that cannot be easily recognized
3. Research purposes in basic science, pathophysiology and therapeutic management

What are the most common types of recording modalities?

- Spontaneous activity
  - Electrocencephalography (EEG)
  - Electromyography (EMG)
- Evoked responses (through external stimulation of neural pathway)
  - Somatosensory Evoked Potentials (SSEPs)
  - Brainstem auditory Evoked Potentials (BAEPs)
  - Visual Evoked Potentials (VEPs)
  - Motor Evoked Potentials (MEPs)
- The type of test to be used and the sites of recording and stimulation are chosen on case per case basis
Complications during surgery

- Ischemia
- Mechanical insult

Here's The Cast

The Nurse  The Neurophysiologist
The Surgeon  The Anesthesiologist

Role of Neuromonitoring clinician in the O.R

- Participate in establishing before surgery communication protocols with the surgical team to report monitoring activity.
- Accurately apply all the recording and stimulating electrodes
- Perform monitoring procedures and documentation according to established protocols
- Have an understanding of anesthesia techniques and physiologic changes that can affect the wave forms being monitored
- Be competent in the operation of monitoring equipment including troubleshooting and electrical safety
- The neuromonitoring clinician should be under direct supervision of a trained clinical neurophysiologist
Role of IOM supervising physician

- Ensures that data essential for evaluation of the patient is available and that all equipment to be used for IOM is in proper condition
- Advocates for anesthetic conditions that optimize the likelihood of obtaining high quality data
- Evaluates and interprets all baseline signals and requests changes in monitoring procedures, if required
- Interprets all significant changes from baseline recordings in real time
- Evaluates context appropriate data and recommends therapeutic interventions as recommended

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Electroencephalography (EEG)

Recording of brain’s spontaneous electrical activity over a period of time, as recorded from multiple electrodes placed on the scalp

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I've seen you sitting in the corner of the OR for years... can you tell me what exactly you're looking at?

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Sentient Medical Services
EEG

- EEGs monitor electrical activity from outer brain
- Anesthesia can slow down brain activity — changes in EEG pattern
- Lower blood flow can slow down brain activity — changes in EEG pattern

Anesthesia or Ischemia?

OK, you’re looking at the brain’s electrical activity. How does that help prevent injury?
EEG changes associated with blood flow

Zones of ISCHEMIA

- No change: <20 ml/100g/min
- Minor changes: 20-30 ml/100g/min
- Major changes: >30 ml/100g/min or <20%

Alarm Criteria for EEG

The alarm criteria for significant changes in EEG is greater than 50% reduction in amplitude and frequency of the analogue EEG or a significant slowing in the alpha and beta frequencies. However, any persistent changes in amplitude or frequency is also reported.  

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Monitoring EEG

- For carotid endarterectomies, studies in human suggests that the risk of stroke can be reduced 10-fold in selective vascular shunting based on major EEG changes compared to not shunting (Nuwer, 1993)
- Multimodality monitoring in cardiac surgery (CABG) found a 2.7 day reduction in length of stay (Laschinger, 2003), 11% reduction in hospital expenses, significant reduction in neurological damage (0% vs 6.2%) and possible benefits to other vital organ systems (Edmonds, 2002 and 2005)
Somatosensory Evoked Potential Monitoring (SSEPs)

- Earliest used method in Intraoperative monitoring
- 1970s in operation of scolios
- Stimulation of peripheral nerve and recording from scalp
- Only monitor dorsal (sensory) spinal cord
- Patient sensory examination is recommended prior to surgery

SSEP

- By electrical stimulation of peripheral nerves
- Median nerve at wrist for injury above C8
- Posterior tibial nerve at ankle for injury below C8

SSEP

- Spinal cord through the dorsal roots, ascending pathways, thalamus and finally into primary sensory cortex
**Recording of SSEP**

- N9  brachial plexus
- N11 dorsal horn
- N13-17 dorsal column nuclei
- N20 Primary sensory cortex (contralateral)- upper limb
- N37 Primary sensory cortex (contralateral)- lower limb

**Alarm criteria for SSEP**

The alarm criteria for significant changes in SSEPs is greater than 50% reduction in amplitude and/or 10% increase in latency. However, any persistent changes in amplitude or latency is also reported.

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Motor Evoked Potentials (MEPs)

- Electromyography (muscle) responses of the peripheral muscles to electrical stimulation of the motor cortex.
- Stimulation through skull (over the motor strip of the frontal lobe).
- Travels through the spinal cord, plexus and nerves, descending pathway.
- Recording at the level of:
  - muscle (CMAP)
  - nerves (neurogenic MEP)
  - spinal cord (D-waves)

MEP
Alarm criteria for MEPs

The alarm criteria for significant changes in MEPs is the presence of absence of (i.e. all or none responses) CMAPs. However, any persistent changes in amplitude is also reported.

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Combined SSEP and MEP monitoring

Since SSEP and MEP monitor different areas of the spinal cord and brain, using them in tandem improves outcomes even greater.

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Brainstem Auditory Evoked Potentials (BAEPs)

- Produced by sending sound into the ear and recording from the scalp
- GOAL
  - Acoustic nerve preservation & subsequent hearing preservation
  - Brainstem and posterior circular preservation
- Eight nerve integrity (Wave I)
- Brainstem integrity (Wave V)
• Surgeries involving VIII nerve
  - Acoustic neuromas
  - Resection of vestibular schwannomas
  - Vestibular nerve section
  - Microvascular decompression of Cranial nerve (CN) V, VII, VIII & IV
  - Resection of other CPA or 4th ventricle tumor

Wave generator for BAEPs
• Wave I Distal portion of Acoustic Nerve
• Wave II Proximal portion of Acoustic Nerve
• Wave III Superior Olivary Complex (lower brainstem)
• Wave IV Lateral Lemniscus
• Wave V Inferior Colliculus (upper brainstem)
Criteria for abnormality for BAEP

- 10% increase in latency for Wave V
- 50% drop/decrease in amplitude for Wave V

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Spontaneous Electromyography (EMG)

- Monitor nerve roots
- Recording electrodes placed over the muscles
- No stimulation is performed
- No paralytic agents administered during the procedure

Abnormal EMG

- Spikes
- Bursts
- Trains

- Trains are continuous, repetitive EMG firing caused by continuous force applied to the nerve
EMG irritation

• Baseline recordings (note the low amplitude background noise)
• High amplitude spikes

Artifacts mistaken for Spikes or Trains

- A neurostimulator
- The surgical table
- The surgeon’s headlight
- Bipolar electrocautery device

Structures at risk

• In cervical and thoracic, the spinal cord is of greater importance.
• Conversely, in lumbar and sacral procedures, the nerve roots are at greater risk of injury.
Conclusion

- Multimodality intraoperative monitoring is extremely valuable in the prevention of neurological injury
- Knowledge of benefits and limitations of each modality monitored helps maximize the diagnostic value of Intraoperative Monitoring during procedures