Intraoperative Neural Monitoring in Pediatrics

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University of Colorado School of Medicine
1970’s Nash&Brown Monitoring Scoliosis
Distraction leads to paresis (SSEP < 50%) and paralysis (SSEP very small)

Nordwall Spine 4:486, 1979
The SSEP measures all but:

A. Transmission in the peripheral nerve stimulated
B. Transmission through the anterior spinal cord
C. Transmission through the brainstem medial lemniscal pathway
D. Transmission through the thalamus
E. Response of the sensory cortex
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A. Transmission in the peripheral nerve stimulated

*B. Transmission through the anterior spinal cord

C. Transmission through the brainstem medial lemniscal pathway

D. Transmission through the thalamus

E. Response of the sensory cortex
Posterior Tibial N. SSEP

- Primary Sensory Cortex
- Cervical Spine
- Epidural
- Lumbar
- Popliteal

stimulus

Med. Lemniscus

Cervico-Medullary Junction

Spinal Cord
SRS: SSEP Analysis 1995

- 173 surgeons, 51,263 surgeries
  - 88% used SSEP monitoring
- Overall injury 0.55%
  down from 1-4% expected
- Missed motor injury
  (1 in 787 cases)
- Cost analysis:
  monitor cost less than
  that to prevent 1 paralysis

Nuwer EEG J Clin Neurophysiol 96:6, 1995
Spine Surgery

- Spine positioning
- Brachial plexus injury
- Spine change with ligament release
- Cord manipulation
- Cord distraction, mechanical traction
- Instrumentation
- Hematoma
- Deliberate hypotension

Also useful in brain and brainstem procedures
Monitoring has become more utilized as the methods for spinal stabilization have evolved.
Age and SSEP

- SSEP evolves with maturation until adult values at age 3-4 years.
- Under age 3 the nervous system is more effected by temperature and physiological effects.
- Under age 3 anesthesia effects are marked and ketamine may be helpful. At adolescence the responses are better than adults.
SSEP v. MEP: Vascularity and topography
The MEP measures all but:

A. Direct stimulation of the corticospinal tract
B. Synaptic transmission in the spinal cord grey matter
C. Transmission in a peripheral nerve
D. Transmission through the neuromuscular junction
E. Response of the muscle motor units
The MEP measures all but:

A. Direct stimulation of the corticospinal tract motor cortex
B. Synaptic transmission in the spinal cord grey matter (corticospinal tract)
C. Transmission in a peripheral nerve
D. Transmission through the neuromuscular junction
E. Response of the muscle motor units
Motor Evoked Potentials

- **D** - Direct Stimulation
- **I** - Indirect Stimulation

**Motor Cortex**
- Pyramidal Cell
- Internuncial N

**Spinal Cord**
- Axon
- Ant Horn Cell
- Peripheral N
- NMJ
- Muscle

**Muscle - CMAP**
Motor Evoked Potentials

Uses

• **Cortical vascular surgery**
• “Map” motor cortex in asleep patients
  (reduced incidence of seizures 9.5% v. 1.2%
  Sala Childs Nerv Syst 295, 2009)
• Identify ischemia with vascular surgery
• Brainstem integrity (collision studies)
• **Spinal Cord integrity** (spine and intramedullary surgery)
• Peripheral nerve integrity
MEP very sensitive to spinal cord ischemia

- **Cortex**
  - 20-30 sec.

- **Spinal Cord**
  - Grey Matter: 2-3 min
  - Loss Anterior Spinal Artery: 7-10 min
  - White Matter: 10-15 min

- **Peripheral Nerve**
  - Conduction: > 15 min

- **Muscle CMAP**: 20 min
Age and MEP

- Concern electrodes on head < 18 months
- **Central and peripheral myelination continues to adolescence**
- Higher stimulation threshold up to 3 months
- Double train and spatial facilitation used
- D wave not recordable < 21 months

A challenge but doable in infants

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**TABLE 3. Motor Evoked Potential Success Rates as Influenced by Age, Lesion Location, or Preoperative Deficit**

<table>
<thead>
<tr>
<th></th>
<th>Upper Extremity</th>
<th>Lower Extremity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (y)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;7</td>
<td>90.5</td>
<td>55.0*</td>
</tr>
<tr>
<td>7 to 64</td>
<td>94.7</td>
<td>70.2*</td>
</tr>
<tr>
<td>&gt;64</td>
<td>95.7</td>
<td>55.6*</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain</td>
<td>97.8*</td>
<td>78.7*</td>
</tr>
<tr>
<td>Posterior fossa</td>
<td>100.0*</td>
<td>60.9*</td>
</tr>
<tr>
<td>Spine</td>
<td>89.8*</td>
<td>51.0*</td>
</tr>
<tr>
<td><strong>Motor deficit</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With weakness</td>
<td>90.4*</td>
<td>39.1*</td>
</tr>
<tr>
<td>Without weakness</td>
<td>98.2*</td>
<td>78.9*</td>
</tr>
</tbody>
</table>

The comparisons of upper extremity or lower extremity MEP were performed between different age groups, between different lesion location, and between groups with or without weakness. *P < 0.01 when the groups were compared with the chi-square test.
Auditory Brainstem Response

1. Auditory Radiation
2. Inferior Colliculus
3. Lateral Geniculate Body
4. Lateral Lemniscus
5. Cochlear Nucleus
6. Acoustic Nerve
7. Superior Olivary Complex
8. Organ of Corti

With respect to vertex time (ms): I, II, III, IV, V, VI

Areas:
- Auditory Cortex
- Thalamus
- Midbrain
- Pons
- Medulla
Auditory Brainstem Responses

Uses

- Integrity cochlea, c.n. VIII
- Hearing preservation with surgery
- General brainstem viability
Age and ABR

- Useful to **assess hearing** in infants
- Auditory nerve myelinated by birth – wave I normal
- Brainstem myelination proceeds caudal to rostral (waves 1 to V) – **progressive improvement** later waves to adult values at age 3

Useful in infants and adult values by age 3
Electromyography (EMG)

- Simple recording technology to assess nerve roots and reflex pathways
- Spontaneous activity to assess nerve injury
- Anesthesia: sensitive to muscle relaxants

Which is true of EMG recording?:

A. EMG in the very young may resemble a myopathy
B. In infants and newborns, neuromuscular transmission may suggest a transmission defect
C. Peripheral nerve myelination proceeds until age 3-5 with near adult conduction velocity by age 3
D. All of the above
Which is true of EMG recording?:

A. EMG in the very young **may resemble** a myopathy

B. In infants and newborns neuromuscular transmission may **suggest a transmission defect**

C. Peripheral nerve **myelination proceeds until age 3-5** with near adult conduction velocity by age 3

D. All of the above
Cranial Nerve Monitoring

- CN 3, 4, 6
- CN 9, 10, 11, 12
- CN 10
- CN 9, 12
- CN 3, 4, 6
- CN 9, 10, 11, 12

References for III, IV, V

Vertex electrode for BAEP and VEP

Contact lens for flash stimulation

BAEP

V (motor)
Intraoperative Facial Nerve Stimulation

1. Warn nerve nearby
2. Locate nerve
3. Confirm intact
4. Identify conduction blockade

NIH Consensus Statement December 11-13, 1991
Daube in Schramm in neurosurgery, p246, 1991
Yingling CD Otolaryngol Clin NA 25:413, 1992
Mapping the cranial nuclei to find the “safe entry zone” pathway in a brainstem distorted by a tumor beneath the surface.
EMG – Assessing Pedicle Screws

- Low threshold suggests breech of pedicle wall
  - Pedicle screws (15-25% misplaced)
  - Threshold of chronically depressed nerve for stimulation may be high
  - Unclear in cervical spine where pedicles small
  - Less useful in thoracic screws

Toleikis, in Deletis, Neurophysiol in Neurosurg, 231, 2002
Cauda Equina Monitoring

Tethered cord: Stimulation of cauda equina elements to identify non-functional tissue for sacrifice and sparing of functional nerve roots and bowel and bladder control.
In general:

A. Maturation of the nervous system evolves after birth until adolescence with the majority of changes under age 3
B. SSEP recordings are challenging under age 3 and superb in adolescence
C. MEP stimulation may be risky under 18 months due to open fontanelle
D. Facilitation methods may be needed for MEP under age 3
E. ABR is not recordable until age 5 years
In general:

A. Maturation of the nervous system evolves after birth until adolescence with the majority of changes under age 3
B. SSEP recordings are challenging under age 3 and superb in adolescence
C. MEP stimulation may be risky under 18 months due to open fontanelle
D. Facilitation methods may be needed for MEP under age 3 as is supportive anesthesia
E. ABR is not recordable until age 5 years (and useful) in infants
Intraoperative Monitoring

Standard of Care
• Scoliosis correction / complex spine
• Acoustic neuroma (facial nerve preservation)

Indispensable
• EEG – corticography in epilepsy surgery
• Cortical mapping of sensory-motor sulcus
• Brainstem mapping cranial nuclei and “safe entry zones” to deeper structures
• Mapping in dorsal rhizotomy for spasticity and tethered cord
• Peripheral nerve procedures
Goal: reduce nerve rootlets that contribute to spasticity but allow adequate antigravity function and bowel and bladder control.

EMG used to identify nerve rootlets to be sectioned that result in activity in adjacent muscles or contralateral. Rootlets are spared which contribute to anal and bladder control.
CHILDREN’S ORTHOPAEDICS

Somatosensory evoked potential monitoring of peripheral nerves during external fixation for limb lengthening and correction of deformity in children

M. R. Makarov,
M. L. Samchukov,
J. G. Birch,
A. M. Cherkashin,
S. P. Sparagana,
M. R. Delgado