MULTIMODALITY NEUROPHYSIOLOGICAL MONITORING IN SPINE SURGERIES

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What is Neurophysiological Monitoring?

• IONM (Intraoperative Neurophysiological monitoring) offers protection of neural tissues and organs (brain, spinal cord and peripheral nerves) during surgery.

• Early irritation or impending injury can often be detected by measuring spontaneous or elicited (evoked) electrical signals produced by the nervous system or attached muscle groups during surgery.

• IONM has been shown to be effective in reducing operative neurological complications in several types of surgery.
The Benefits of Monitoring

- **Increased safety of the surgical procedure.**
  IONM has been shown to play a significant role in reducing patient morbidity and mortality.

- **Increased ability to accommodate more complex cases.**
  IONM helps to identify new neurological impairment early enough to allow prompt correction of the cause. This "early warning" system provides surgeons with the comfort necessary to perform complex cases.

- **Decreased risk of adverse surgical outcomes.**
  IONM guides the degree of surgical intervention and provides a means for assessing the likelihood of post-operative complications.
Surgery and IONM

SPINAL CORD

BRAIN

PERIPHERAL NERVES
Types of Surgeries

- **Neurosurgery**
  - Spinal Fusion
  - Spinal Tumor (Intra-medullary/ Extra-medullary)
  - Tethered Cord
  - Cauda equina lesion
  - Dorsal Root Rhizotomy
  - Brachial plexus tumors
  - Spinal Stimulator Implant

- **Orthopedic Surgery**
  - Spinal corrections
  - Scoliosis
  - Hip replacement
  - Sacro Iliac Joint Fusion
  - DLIF / XLIF

- **Interventional Neuro Radiological Procedures**
  - Spinal AVM embolization
Multi-modality Monitoring in Spinal Surgeries

- Multi-modality intraoperative neurophysiologic monitoring (IONM), in general, can prevent or lower the risk of devastating neurologic deficit in a wide variety of cases which place neural structures at risk.

- And although they all have advantages and disadvantages, they are, in combination, an effective means for providing patient protection.
Modalities in Spinal Surgeries

- **What are Modalities:**
  
  Modalities are specific types of electrophysiological tests that can be used for testing specific neurological / functional pathways during different types of surgeries.

- **What is protected:**
  
  - Ascending somatosensory pathways functions like proprioception, stereognosis, weight discrimination, touch, vibration
  
  - Descending motor pathways function like primary voluntary body movements
Modalities for Spine

- Somatosensory Evoked Potential (SSEP)
- Spontaneous Electromyography (S-EMG)
- Triggered Electromyography (T-EMG)
- Trans Cranial Electrical Motor Evoked Potentials (TCeMEP)
- Direct waves (D-waves)
- Bulbocavernous Reflex (BCR)
- Train of Four (TOF)
- H-Reflex
- F-Response
Modalities

Somatosensory Evoked Potentials (SSEP)
• Somatosensory Evoked Potentials:
  – This test stimulates the patient distally and records along the pathway as the nerve pulse travels to the brain
  – Optimal for protection of the patients ascending sensory spinal pathways
  – Useful in detection of mechanical and ischemic changes in the peripheral nerves, spinal cord and cortex. Particularly in posterior spinal cord.
  – 95 to 98% specificity to sensory neurological events
SSEP

• Used when Peripheral Nerve, Spinal Cord (Dorsal Column), Brainstem or Cortex is at risk
• Stimulate Distal Nerves
  • Posterior Tibial/Peroneal/Femoral Nerves
  • Median/Ulnar Nerves
• Record Distal and Proximal Responses
• Measure Significant Changes in Responses
  • Latency
  • Amplitude
SSEP

Peripheral Potential
Brachial Plexus – Upper Popliteal Fossa – Lower (Sensory Nerve Action Potential)

Root Entry Zone
Dorsal Column and Medial Lemniscus
Thalamocortical
Primary Somatosensory Cortex

SSEP Recordings

- These are responses recorded after hands and feet stimulation. By recording at multiple locations we can determine the anatomic and functional integrity at different locations along the somatosensory pathway as the pulse travel from periphery to the cortex.
# SSEP Setup

## Stimulus Parameters: AEEG Guidelines

- **Pulse:** Electric Monopolar rectangular
- **Duration:** 100-300 µsec
- **Intensity:** 30-40 mA
- **Stim Rate:** Median (2-8/sec) Tibial (2-10/sec)
- **Sweep:** Median (40 ms) / Tibial (60 ms)
- **Averages:** 500-2000
- **Band-pass:** Cortical: 1-30 to 250-3000 Hz
- **Spinal:** 100-200 to 1000-3000 Hz

## Recording Parameters: AEEG Guidelines

<table>
<thead>
<tr>
<th>Median</th>
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<td>Ref</td>
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<td>PFd</td>
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</table>

[Image of EEG equipment]
SSEP assesses the sensory pathways from distal nerves through to the cortex. Electrodes are placed on the distal limbs and scalp. A small electrical current is given distally and recording along the pathway and at the scalp.

**Criteria**

- **Latency**: 10% increase from baseline
- **Amplitude**: 50% decrease from baseline
ISCHEMIC CHANGES IN SSEP

Amplitude Reduction
CHANGES IN SSEP

Anesthesia Event

Surgical Event
Effect of Hypotension on SSEP

Case: Drop in MAP from 103 to 76
Effect of Positioning on SSEP

NEUROSURGICAL ANESTHESIA

Section Editor:
Adnan W. Gelb

The Use of Somatosensory Evoked Potentials to Determine the Relationship Between Patient Positioning and Impending Upper Extremity Nerve Injury During Spine Surgery: A Retrospective Analysis

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Effect of Positioning on SSEP

Neurophysiological Identification of Position-Induced Neurologic Injury During Anterior Cervical Spine Surgery

Authors: Schwartz, Daniel; Sestokas, Anthony; Hilibrand, Alan; Vaccaro, Alexander; Bose, Bikash; Li, Mark; Albert, Todd
Publisher: Springer

Abstract:
This study was a retrospective review of 3,806 patients who underwent anterior cervical spine surgery with multi-modality neurophysiological monitoring consisting of transcranial electric motor evoked potentials, somatosensory evoked potentials and spontaneous electromyography between 1999-2003. The objectives of this study were twofold: (1) to evaluate the role of transcranial electric motor evoked potential tceMEP and ulnar nerve somatosensory evoked potential (SSEP) monitoring for identifying impending position-related stretch brachial plexopathy, peripheral nerve entrapment/compression or spinal cord compression and (2) to estimate the point-prevalence of impending neurologic injury secondary to surgical positioning effects. Sixty-nine of 3,806 patients (1.8% showed intraoperative evidence of impending neurologic injury secondary to positioning, prompting interventional repositioning of the patient. The brachial plexus was the site of evolving injury in 65% of these 69 cases. Impending brachial plexopathy was most commonly noted immediately following shoulder taping and the application of counter-traction. Brachial plexus stretch upon neck extension for optimal surgical access and visualization was second in frequency-of-occurrence. Evolving traction injury to the ulnar nerve attributed to tightly-wrapped or malpositioned arms was observed in 16% of alerted cases, whereas evolving spinal cord injury following neck extension accounted for an additional 19%. This study highlights the role of tceMEP and ulnar nerve SSEP monitoring for detecting emerging peripheral nerve injury secondary to positioning in preparation for and during anterior cervical spine surgery.

Keywords: intraoperative neurophysiological monitoring; anterior cervical spine surgery; surgical; positioning; transcranial electric motor evoked potentials; somatosensory evoked potentials; brachial plexopathy; positional peripheral nerve injury
Effect of Positioning on SSEP

Case

- 64 years old Female Patient
- Back pain with bilateral foot drop
- Procedure: Posterior Lumbar Laminectomy and Fusion, L3-L5

Changes in Left Ulnar
Effect of Positioning on SSEP

Case # 3: Changes on Left side
Effect of Positioning on SSEP

Case # 4: Changes on Left side
Advantages of SSEP

• SSEPs allows us to evaluate the functional integrity of dorsal column during high risk portions of the procedure.
• Help prevent brachial plexus injuries during surgery which can sometime occur due to patient positioning.
• Help assess peripheral blood flow
• Help differentiate between Evoked Potential loss caused by spinal cord injury, versus peripheral ischemia, versus stroke.
• SSEPs are still a valuable adjunct to monitoring when used alongside MEP and EEG monitoring.
Disadvantages of SSEP

– SSEPs do not assess motor pathways.
– SSEPs are highly susceptible to anesthetic agents and changes in hemodynamic variables.
– The blood supply to pathways monitored by SSEP is different than the blood supply to pathways involving motor function.
– Therefore SSEP changes do no correlate well with post-operative motor function.

Because of these factors, SSEPs are best utilized in conjunction with other modalities of monitoring.
SSEP: Anesthesia

- **Preferred**
  - N2O – 0%
  - Minimal volatile anesthetic ≤ 1 MAC%
  - Narcotic medication - Yes
  - Muscle relaxants - Yes

- **Alternative**
  - N2O – 60%
  - Minimal volatile anesthetic ≤ 0.5 MAC
  - Narcotic medication - Yes
  - Muscle relaxants - Yes
Hypotension can affect SSEP and TCeMEP signals globally. Ischemia will result in delayed time course.

Within the spinal cord the grey matter is most sensitive to ischemia with loss of synaptic activity at 1-2 minutes while conduction in sensory and motor white matter shows alteration in different time.
Effect of Hypotension on EPs

Abstract

3:41 Transcranial electric motor-evoked potential monitoring as an early indicator of emerging thoracic spinal cord ischemic injury

Daniel Schwartz¹, Mingwei Li MD¹, Alexander Vaccaro MD², Alan Hilibrand MD², M. Nancy Mirarchi DC¹, Craig Matsumoto PA, MS¹, Anthony Sestokos PhD¹, Samuel Strantzis BS¹ and Todd Albert MD²
¹ Surgical Monitoring Associates, Bala Cynwyd, PA, USA
² Rothman Institute, Philadelphia, PA, USA
Available online 26 November 2002.

Abstract

Purpose of study: Somatosensory evoked potential (SSEP) monitoring has enjoyed widespread application for assessing global spinal cord function during corrective thoracic spine surgery for scoliosis and trauma. Because the SSEP is dorsal column mediated, however, it can be insufficiently sensitive to identifying inadequate perfusion or impending ischemia to the anterior spinal cord. Transcranial electric motor-evoked potentials (TCEMEPs), on the other hand, permit real-time monitoring of the corticospinal tracts and, as such, provide instantaneous assessment of changes in spinal cord function secondary either to surgical insult or inadequate spinal cord blood flow from hypotension. The purpose of this study was to determine the sensitivity of TCEMEP monitoring as an early indicator of impending spinal cord injury during corrective thoracic spine surgery.
Modalities

Trans Cranial Electrical Motor Evoked Potentials (TCeMEP)
SPINAL TCeMEP

- Used when Spinal Cord (Ventral Column), Brainstem or Cortex is at risk
- Stimulate Motor Cortex
  ~ 100-500 V
- Record Distal Responses
- Measure Significant Changes in Responses
  - Presence/Absence
SPINAL TCeMEP
SPINAL TCeMEP

- Cortical Stimulation
  - Transcranial Electrical Stimulation (TES)
  - Direct Cortical Stimulation (DCS)
- “Spinal” MEP’s
- Muscle MEP’s
• Stimulating electrodes are typically placed at **C3 and C4**
• Allows for activation of both upper and lower extremity muscle groups
• Alternative stimulation sites used are C1 and C2
Spinal TCeMEP

Surgical Application

• Special consideration
  – Bite block
  – Anesthesia cortical suppression of motor, EEG monitoring anesthesia load
  – Intermittent runs

• Contra indication
  – History of seizures
  – Pace makers
  – Cochlear Implants
Spinal TCeMEP

Set Up Criteria

• Specific set up and coverage
  – Upper and lower motor pathways
  – Myelopathy suppression of motor function
  – Additional coverage of C5
  – Additional coverage of bowel/bladder
  – Additional coverage L4, L5 and S1

TceMEP Criteria

• Increases protection from SSEP only
  – SSEP only 85 to 90% and sensory specific
  – TceMEP is 90 to 100% and motor specific
• All or nothing CMAP MEP, presents/absents of muscle contraction
• 50% decrease in amplitude MMEP
### TCeMEP Setup

**Stimulus Parameters: FDA Guidelines**

- **Pulse:** Electric Monopolar rectangular
  - **Duration:** 50 µsec
  - **Intensity:** 100-800 V
  - **Inter Stimulus Interval (ISI):** 1.1-9.0
  - **Trains:** 1-9
  - **Averages:** 1

**Recording Parameters:**

- **Low Cut:** 10 Hz
- **High Cut:** 3000-10000 Hz
- **Sweep:** 10 ms/Div
- **Gain:** 100 µV/Div
- **Reject:** Off
- **Upper Ext:** Delt, FCU, BR, APB & ADM,
- **Lower Ext:** Quads, TA, MG, AH & EHB
Spinal TCeMEP
Spinal TCeMEP

Outcome Studies

MOTOR EVOKED POTENTIAL MONITORING DURING SPINAL CORD SURGERY;

Karl Kothbauer, MD, Pediatric Neurosurgery, Hyman-Newman Institute for Neurology and Neurosurgery Beth Israel Medical Center, New York City

- Intraoperative loss of muscle MEPs indicates some postoperative impairment of voluntary motor control with a specific of about 90% and sensitivity of 100%
- For instance muscle MEPs lost in one leg during the resection means that the patient will postoperatively be unable to move this particular extremity
Spinal TCeMEP

Outcome Studies

THRESHOLD-LEVEL REPETITIVE TRANSCRANIAL ELECTRICAL STIMULATION FOR INTRAOPERATIVE MONITORING OF CENTRAL MOTOR CONDUCTION;
Blair Calancie, Ph.D., William Harris, M.Sc., G. Fred Brindle, MD., Barth A. Green, MD and Howard J. Landy, MD

- Study of postoperative clinical outcome in 83 spinal surgery patient using SSEP and TES (TceMEP)
- Based on this data, the results of sensitivity and specificity calculations were 0.87 and 0.90, respectively, for SSEP monitoring relative to postoperative deficit and 1 and 1 respectively for TES monitoring relative to postoperative motor deficit.
Spinal TCeMEP: Case Study

Threshold-level repetitive transcranial electrical stimulation for intraoperative monitoring of central motor conduction

BLAIR CALANCIE, PH.D., WILLIAM HARRIS, M.SC., G. FRED BRINDLE, M.D., BARTH A. GREEN, M.D., AND HOWARD J. LANDY, M.D.

• C6 tumor
• 44 year old male, history of cervical meningioma
• Posterior resection, to be followed by an anterior resection
Spinal TCeMEP: Case Study

09:45

13:50

SSEPs

TcMEPs
Spinal TCeMEP: Case Study

SSEPs – no change

TcMEPs
- Left/Right TA – gone
- Right APB – gone
- Drop in left APB
Spinal TCeMEP: Case Study

SSEPs – no change

TcMEPs
• increase in threshold for all muscles
Post-Operative:

• Based on TcMEPs, anterior resection was cancelled

• Patient awoke with profound right-side weakness, moderate left-side weakness

• Profound proprioceptive loss in right lower limb

• Stayed in hospital for 3 weeks and was discharged to rehab and was ambulating at 3 months, with a cane
Effect of Hypotension on MEP

Case: Drop in MAP from 94 to 62
Effect of Neck Positioning on MEP

- 23 years old Female Patient.
  Presents with severe muscular dystrophy
- Procedure: ACDF
- Changes is SSEP and MEP during Halo placement.
  Responses returned after repositioning.
TCeMEP: Anesthesia

• **TIVA – Total Intra Venous Anesthesia (Preferred)**
  - N2O – 0%
  - Minimal volatile anesthetic – 0%
  - Narcotic medication - Yes
  - Fentanyl bolus, and a Propofol infusion (100-200 ug/kg/min)
  - No muscle relaxants

• **Alternative**
  - N2O – 60%
  - Minimal volatile anesthetic ≤ 0.5 MAC
  - Narcotic medication - Yes
  - Fentanyl bolus, and a Propofol infusion (25-200 ug/kg/min)
  - No muscle relaxants
Advantages of TCeMEP

– MEPs record corticospinal tract information allowing us to evaluate the functional integrity of motor tracts during high risk portions of the procedure.
– MEPs are stable waveforms recorded easily with strict TIVA technique.
– MEP assess the real-time function of voluntary motor pathways in the spinal cord, and reduce the risk of paraplegia.
– MEPs help detect ischemic changes in the motor cortex, spinal cord, and peripheral motor nerves.
Disadvantages of TCeMEP

– TCeMEPs have identified risk factors such as tongue lacerations, and in some populations, risk for seizures.

– TCeMEPs requires no muscle relaxant during the surgical procedures.
Modalities

Epidural Recordings
(D-Waves)
D-Wave Setup

**Stimulus Parameters: FDA Guidelines**

- **Pulse:** Electric Monopolar rectangular
  - **Duration:** 50 µsec
  - **Intensity:** 100-400 V
  - **Inter Stimulus Interval (ISI):** 1.1-9.0
    - **Trains:** 1
    - **Averages:** 1

**Recording Parameters:**

- **Low Cut:** 10 Hz
- **High Cut:** 3000-10000 Hz
- **Sweep:** 1-3 ms/Div
- **Gain:** 100 µV/Div
- **Reject:** Off

**Epidural Electodes**
Epidural (D-Waves)
Epidural (D-Waves)
### Epidural (D-Waves)

#### Alarm Criteria:

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<th>D-wave</th>
<th>Muscle Response</th>
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<td>unchanged</td>
<td>lost on one or both sides</td>
<td>temporary motor deficit</td>
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<tr>
<td>&gt;50% decrease</td>
<td>lost</td>
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Modalities

Electromyography (EMG)
Spinal S-EMG and T-EMG

- Used when Spinal Roots or Cranial Nerves are at risk
- Passive recording of activity in muscle
  (Free-Run EMG / S-EMG)
  - Subdermal electrodes
- Active triggering of activity (CMAP/T-EMG)
  - Prass probe
Spinal S-EMG and T-EMG

• The lower motor neuron consists of the anterior horn cell, its axon and all the muscle fibers innervated by that axon.

• Segmental nerve root monitoring involves monitoring the function of the motor unit axon by recording free-run and triggered EMG activity from the muscle fibers of the motor units.

• The number of nerve fibers innervating a muscle and the number of muscle fibers per motor unit varies from one muscle to another.
Spinal EMG

• Detection of:
  – Stretch
  – Compression
  – Heat
  – Ischemia
  – NOT resection

• Trauma makes nerves more sensitive
• Chronic compression leads to demyelination of nerve fibers
Spinal S-EMG

• Abnormal EMG Types:
  – Spikes
  – Bursts
  – Train
  – Neurotonic discharges
  – Irregular

Surface Vs Needle Electrodes:
  • Surface pads electrodes are not good for detecting MUP
  • Sub dermal EMG needles are better
  • EMG needles are too selective

(Skinner et al. 2008)
Spinal S-EMG
Spinal T-EMG

T-EMG
Triggered electromyography are recorded from the distal muscles. Activity recorded is associated with nerve, nerve root and pedicle screw electrical stimulation.

T-EMG is used for:
- Direct nerve stimulation
- Pedicle Screw stimulation

6 mA triggered pedicle stimulation response. Indicating probably pedicle wall breach.
Spinal T-EMG

What is Happening During Pedicle Screw Stimulation?

CURRENT FLOW

Current Leak Error
fluid, soft tissue, etc

Pedicle Screw

Reference

<table>
<thead>
<tr>
<th>REFERENCE</th>
<th>BAD</th>
<th>GOOD</th>
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<td>Calancie et al. 1994</td>
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<td>Maguire et al. 1995</td>
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<td>Clements et al. 1996</td>
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Spinal T-EMG
Outcome Studies

Monitored and non-monitored outcome studies

Separated into 2 groups

- Group I (n=185) without monitoring
- Group II (n=205) with monitoring

- Group I: Incidence of surgically induced radiculopathies was 9.6%
- Group II: Incidence of surgically induced radiculopathies was <1.0%
Modalities

Train Of Four
(TOF)
## D-Wave Setup

<table>
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<th>Stimulus Parameters:</th>
<th>Recording Parameters:</th>
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<tr>
<td>Setup Mode: TOF</td>
<td>Low Cut: 10 Hz</td>
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<tr>
<td>Pulse: Electric Monopolar rectangular</td>
<td>High Cut: 3000-10000 Hz</td>
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<tr>
<td>Duration: 100 µsec</td>
<td>Sweep: 20 ms/Div</td>
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<td>Intensity: 10-50 mA</td>
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<tr>
<td>Nerves: Median or Posterior Tibial</td>
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</table>

Train of Four: TOF 4/4
Modalities

Bulbo Cavernous Reflex (BCR)
Bulbocavernous Reflex (BCR)

• For patients at risk for low sacral neural injury.

• Patients are maintained with propofol, opiate infusion, and low inhalant anesthesia without muscle relaxant.

• Cutaneous sensory nerves of the penis (or clitoris) are stimulated

• For BCR recording, needle electrodes were placed into the external anal sphincter (EAS) bilaterally.
• Bulbacavernosa Reflex useful in determine functional status of the Pudendal sensory motor reflex and conus medullaris during surgical intervention.
Modalities

Selective Dorsal Root Rhizotomy (SDR)
Selective Dorsal Root Rhizotomy (SDR)

• Selective dorsal rhizotomy (SDR) is a procedure for the treatment of spasticity in some children with cerebral palsy. The incidence of cerebral palsy ranges from 2-2.5 per thousand school-age children. Of these children about 75% will have a spastic variety. Some of these children may benefit by reducing their spasticity through selective dorsal rhizotomy.

• Utilizing t-EMG has been reported as an effective tool for selection of abnormal rootlets.
### Selective Dorsal Root Rhizotomy (SDR)

#### Schematic Diagram of Intraoperative EMG Responses

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<tr>
<td>Stimulus: 1s Electrical Train</td>
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Selective Dorsal Root Rhizotomy (SDR)
Selective Dorsal Root Rhizotomy (SDR)

Incremental
Spinal Cord: Cervical/Thoracic

- **Anatomical Structures at Risk:**
  - Brainstem somatosensory pathways
  - Spinal cord
  - Spinal cord motor pathways

- **Monitoring Modalities Used During Surgery:**
  - Somatosensory Evoked Potentials (SSEP)
  - Transcranial Motor Evoked Potentials (TCoMEP)
  - Epidural Evoked Potentials (D-waves)
  - Spontaneous Electromyography (s-EMG) for cervical nerve root monitoring
Spinal Cord: Lumbar / Sacral

- **Anatomical Structures at Risk:**
  - Lumbar and Sacral nerve roots
  - Spinal cord

- **Monitoring Modalities Used During Surgery:**
  - Somatosensory Evoked Potentials (SSEP)
  - Transcranial Motor Evoked Potentials (TCE MEP)
  - Spontaneous Electromyography (s-EMG) for nerve root monitoring
  - Triggered Electromyography (t-EMG) for Pedicle Screw testing
  - Bulbocavernosus Reflex
Tethered Cord/Cauda Equina Tumor

• Anatomical Structures at Risk:
  – Lumbar and Sacral nerve roots
  – Spinal cord
  – Spinal cord motor pathways

• Monitoring Modalities Used During Surgery:
  – Somatosensory Evoked Potentials (SSEP)
  – Transcranial Motor Evoked Potentials (TCeMEP)
  – Spontaneous Electromyography (s-EMG) for nerve root monitoring
  – Triggered Electromyography (t-EMG) for Pedicle Screw testing
  – Bulbocavernosus Reflex
Spinal Intramedullary Tumor

• Anatomical Structures at Risk:
  – Spinal cord
  – Spinal cord sensory pathways
  – Spinal cord sensory pathways

• Monitoring Modalities Used During Surgery:
  – Somatosensory Evoked Potentials (SSEP)
  – Transcranial Motor Evoked Potentials (TCEMEP)
  – Epidural Evoked Potentials (D-waves)
  – Spontaneous Electromyography (s-EMG) for cervical nerve root monitoring
Spinal Arteriovenous Malformation (AVM)

- **Anatomical Structures at Risk:**
  - Arteries
  - Spinal cord
  - Spinal cord sensory pathways
  - Spinal cord sensory pathways

- **Monitoring Modalities Used During Surgery:**
  - Somatosensory Evoked Potentials (SSEP)
  - Transcranial Motor Evoked Potentials (TCE MEP)
Selective Dorsal Rhizotomy

• Anatomical Structures at Risk:
  – Peripheral sensory (dorsal) roots
  – Peripheral motor (ventral) roots

• Monitoring Modalities Used During Surgery:
  – Spontaneous Electromyography (s-EMG) for nerve root monitoring
  – Triggered Electromyography (t-EMG) for nerve root monitoring
  – Train of Four (TOF)
Spinal Cord Stimulator Implant

• **Anatomical Structures at Risk:**
  - Spinal Cord

• **Monitoring Modalities Used During Surgery:**
  - Spontaneous Electromyography (s-EMG) for localization
  - Triggered Electromyography (t-EMG) for localization of stimulator
  - Train of Four (TOF)
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Challenges in Neurophysiological monitoring
Challenges in Neuromonitoring

• Unfortunately, we all too often encounter technical and physiological challenges that we must overcome in order to adequately protect our patients.

• Becoming familiar with potential technical and physiological challenges can facilitate more positive intraoperative experience for the entire surgical team.
Changes

- **Technical**
  - Stimulation problems
  - Recording problems
- **Physiological**
  - Anesthesia
  - Temperature
  - Mean Arterial Pressure
  - Positioning effects
- **Surgical**
Challenges in Neuromonitoring

- **Physiological / Technical Challenges:**
  - Compromised blood flow to the extremities (peripheral ischemia, blood clots, BP cuff occlusion)
  - Positioning of extremities
  - I.V. Infiltration
  - Hypothermia / Hyperthermia
  - Scalp Edema-impeded stimulus delivery
  - Failure of stimulus delivery (multiple etiologies)
  - Failure of recording electrodes /equipment/ systems
  - Extraneous Artifact
Multi-Modality Neurophysiological Monitoring

- Employing a multi-disciplinary surgical approach including:

  - TCeMEP, SSEP, EMG, EEG and maintaining mean arterial pressure of at least 70 mmHg all contribute collectively to the significant reduction of post-operative paraplegia in the cervical, thoracic, lumbar spine and brain surgeries.
Benefits

• Improved patient care.
  • Reduce patient neurological deficits.
  • Reduce surgical morbidity and mortality.
Goals

- Identify significant changes in spinal function.
- Intervene and prevent permanent neurological damage.
THANK YOU

Success