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Intraoperative Neurophysiologic Monitoring: Multi-modal Monitoring for Complex cases

Presenter: Sarah Chandler, AuD

Moderator: Carolyn Smaka, AuD, Editor in Chief, AudiologyOnline

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Intraoperative Neurophysiologic Monitoring: Multi-modal Monitoring for Complex cases

Sarah Chandler, AuD

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Multi-modal Monitoring for Complex Cases

- Diclosures
  - Audiology Online provides an honorarium for presenting
  - Employed by OR Monitoring Consultants, Inc., a private practice, since 2004
  - No other conflicts of interest or financial disclosures

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Multi-modal Monitoring for Complex Cases

- An overview of multi-modal monitoring applications in the operating room, focusing on EMG, SSEP, and TcMEP. Techniques for recording, interpreting, and optimizing recordings in the operating room.

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Multi-modal Monitoring for Complex Cases

- As a result of this course, participants will be able to:
  - Describe three of the most commonly combined methods of intraoperative neurophysiologic monitoring
  - Explain how to choose an appropriate combination of techniques for monitoring
  - Define three or more challenges to obtaining good data for multi-modal recordings

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Disclaimer

- Intermediate/Advanced
  - Assuming familiarity with at least clinical ABR and the basic concepts of collecting a biological signal and using computer software to analyze it
  - Excellent ABR courses available on AudiologyOnline.com for a review of the basics of electrophysiology, including Analog/Digital conversion of signals
  - For further Anesthesia recommendations for IOM, Tod Sloan, M.D. has numerous articles and presentations available on the web

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Multi-modal Monitoring for Complex Cases

- Purpose of Intraoperative Neurophysiological Monitoring (IOM/IONM)
- Definition of Terms/Concepts
- Methods of Monitoring
  - Evoked Potentials (ABR, SSEP, VEP)
  - EMG
  - TcMEP
- Matching Methods to Surgical Risks
- Challenges to Obtaining Good Data
- Documentation

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Purpose of IONM

- To preserve function of the nervous system during surgical procedures
- Advisory role
  - Consistency
  - Trust
- Be the voice of the patient in a complex situation

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Definition of Terms/Concepts

- Sensory vs. Motor
- Central vs. Peripheral
- Electrophysiology Terms
  - Averaging
  - Triggered Stimulation
  - Free Run

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Definition of Terms/Concepts: Sensory vs. Motor

- Sensory
  - Vision, Hearing, Smell, Taste, Touch
  - Signal is created by an outside stimulation of a sensory organ and transmitted toward the brain
  - Dorsal Root
- Motor
  - Receives motor impulse from the brain or reflexive systems and send that signal to muscles
  - Ventral Root

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Definition of Terms/Concepts: Central vs. Peripheral

Central Nervous System

- Brain
- Spine
- Encased in dura
- Sends signals both ways
- Soft, less resilient*

Peripheral Nervous System

- 43 pairs of motor and sensory nerves connecting the rest of the body to the brain and spinal cord
  - Cranial Nerves
  - Spinal Nerves
  - Peripheral Nerves
  - Neuromuscular Junctions
- Stronger and more resilient*

*Tubbs, R. S., Rizk, E., Shoja, M. M., Loukas, M., Barbaro, N. M., & Spinner, R. J. (2015). Nerves and nerve injuries (Vol. 1). London, UK: Academic Press.

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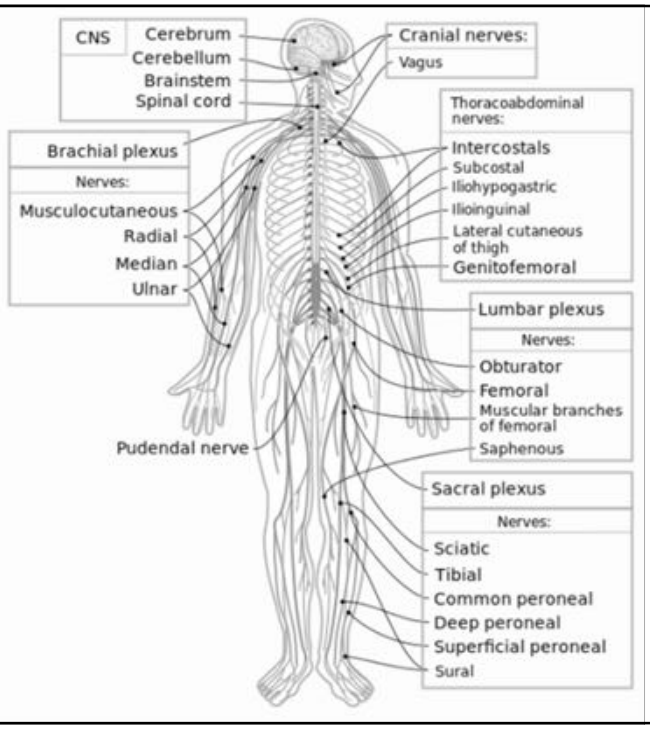

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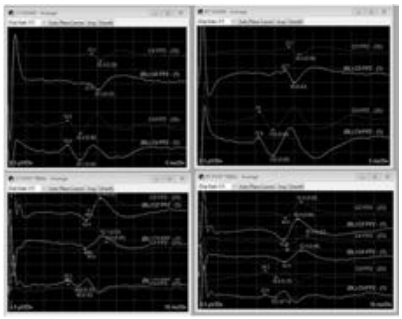
Definition of Terms/Concepts: Electrophysiology Terms

- Signal Averaging
  - Repeated, regular stimulation of the nervous system, converted to digital signal, average of a certain number of responses displayed as a single average
  - SSEP, ABR, VEP



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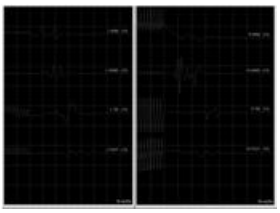
Definition of Terms/Concepts: Electrophysiology Terms

- Single Triggered Response
  - A single stimulation (may have multiple bursts of electrical energy), with response collected in one timeframe over a single, set period of time, beginning at or near to stimulation.
  - When collection period is over, a new recording begins without any averaging
  - TcMEP, Pedicle Screw Stimulation
  - Fast



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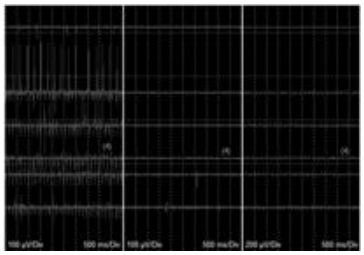
Definition of Terms/Concepts: Electrophysiology Terms

- Free Run
  - Continuous, real-time display of visual and acoustic EMG signals
  - Watching for activity, similar to input channel on an ABR



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Methods of Monitoring

- Sensory Evoked Potentials
  - Auditory Brainstem Response (ABR)
  - Somatosensory Evoked Response (SSEP)
  - Visual Evoked Potentials (VEP)
- Electromyography (EMG)
- Motor Evoked Potentials (MEP)
  - Direct Nerve Stimulation
  - Transcranial Motor Evoked Potentials (TcMEP)
  - Transcranial Magnetic Evoked Potentials

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Methods of Monitoring

- Sensory Evoked Potentials
  - Auditory Brainstem Response (ABR)
  - *Somatosensory Evoked Response (SSEP)*
  - Visual Evoked Potentials (VEP)
- *Electromyography (EMG)*
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  - *Direct Nerve Stimulation*
  - *Transcranial Motor Evoked Potentials (TcMEP)*
  - Transcranial Magnetic Evoked Potentials

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Methods of Monitoring: ABR

- Under appropriate anesthesia and without electrical interference, only need 50 to 350 sweeps.
- Cervical and Sub-cortical responses most resistant EPs to anesthesia factors

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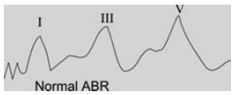
Methods of Monitoring: ABR

- Parameters
  - Masked Click at 80 to 100dBHL, insert earphones
  - Filters at 150 to 1500 Hz
  - Sensitivity ~5µV
  - Alternating Polarity
- Optimization
  - Noise Notch for 60Hz
  - Check during positioning and prep/drape
  - Switch Polarity to verify Wave I if needed



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Methods of Monitoring: Somatosensory Evoked Potentials

- Responses recorded over the limbs, spine, and scalp following the stimulation of peripheral nerves, trunks, or cutaneous nerves*

*Nabil J. Azar, M.D. Vanderbilt University Medical Center

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Somatosensory Evoked Potentials

- General Principles
  - Primarily Posterior Spine
  - Vascular supply separate
  - Recorded over *opposite* side somatosensory Cortex
- Upper Extremities:
  - Median or Ulnar Nerves
- Lower Extremities:
  - Tibial Nerves

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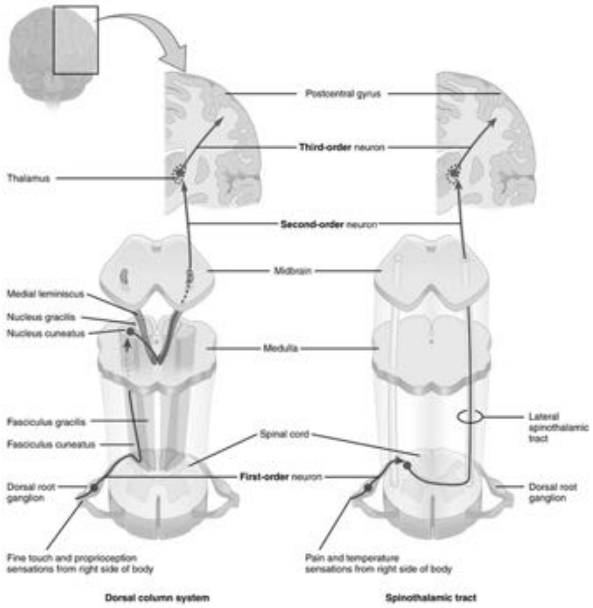
Somatosensory Evoked Potentials



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Somatosensory Evoked Potentials: Choose your spots

- Upper Extremity
  - Purposes
    - Brachial Plexus
    - Cervical sites and above
  - Median Preferred
    - Most robust response
    - Sites C-6 and above
  - Ulnar option
    - Sites C6-8 and above
- Lower Extremity
  - Purposes
    - Spinal sites at/above Sciatic Nerve
    - Blood flow to lower extremities
  - Tibial Nerve

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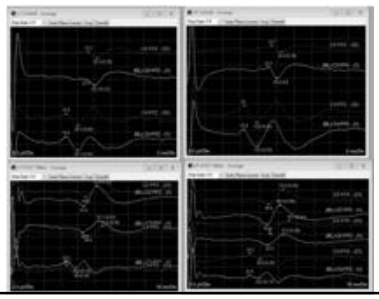
Somatosensory Evoked Potentials: Recording Sites

- Cortical Recordings
  - Cz
    - Sacrifice on Uppers if channels scarce
  - C3 (Rt. Stim)
  - C4 (Lt. stim)
- Subcortical Recordings
  - Place anywhere from Inion through Cervical Spine
    - Access determines placement
    - Chin or earlobe if necessary
  - Less affected by anesthesia
- Peripheral
  - Erb's Point Uppers
  - Peroneal Nerve Lowers
  - Verify stim is working
  - Sacrifice if channels scarce
  - Same side as stim



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Somatosensory Evoked Potentials: Parameters

- Filters
  - Cervical, Popliteal Fossa: 30-1500Hz
  - Cortical: 30-250Hz
- Sensitivity
  - 0.5-10µV
- Sweeps needed for signal averaging may vary
  - 200 Upper Extremities
  - 350 Lower Extremities
- Ground at non-operative side shoulder

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Somatosensory Evoked Potentials: Parameters

- Stimulation
  - Needles
    - May enter nerve and increase risk of injury
    - Start at 10mA and go up to find minimum level required
      - Adult Upper extremities often 16-26mA
      - Adult Lower extremities often 20-35mA
  - Sticky pad electrodes
    - Less chance of burn injury
    - At high end of stim range
    - Start at 15mA, expect to go up

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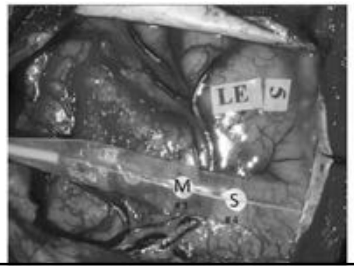
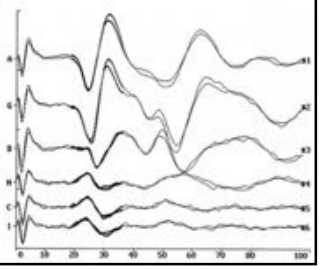
Somatosensory Evoked Potentials: Cortical Mapping

- Record SSEP prior to incision to verify it is recordable
- Record SSEP in 4 or more sites on a cortical strip placed by the surgeon.
- Polarity "flips" at border of Motor and Sensory cortex





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Somatosensory Evoked Potentials: Criteria For Alert

- 50% decrease in amplitude re: baseline
- 10% increase in latency re: baseline
- Non Surgically-induced changes can mimic
  - Hypothermia
  - Hypotension
  - Anesthetic agent changes
  - Electrical interference

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Methods of Monitoring: Electromyography (EMG)

- Diagnostic procedure to assess the health of muscles and the nerve cells that control them
- Detection of the electrical potential generated by muscle cells when the cells are activated

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Methods of Monitoring: Electromyography (EMG)

- General principles
  - No news is good news
  - Anesthetized patient should not be moving
- A pair of subdermal needle electrodes is placed in a single muscle, creating a circuit.
- Await a polarity change (action potential)
- Polarity change (action potential) is created by:
  - Thermal changes
  - Mechanical stimulation
  - Electrical stimulation
    - Direct or nearby cautery

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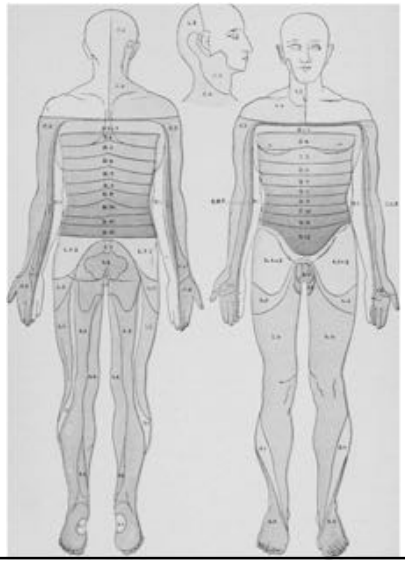
Electromyography (EMG): Choose your spots

- Based on nerves at risk
- At least 2-3 muscles to prepare for anatomic differences



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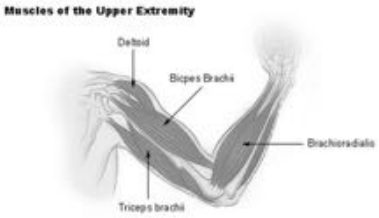
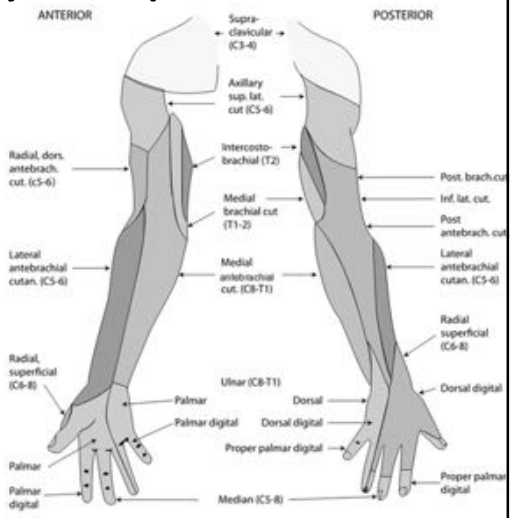
Electromyography (EMG): Choose your spots

- Upper Extremity EMG
- Most common:
  - Deltoid
  - Biceps
  - Triceps





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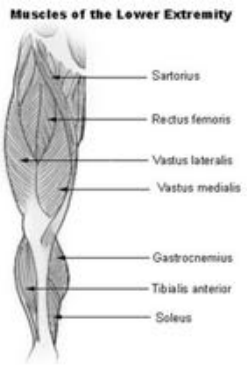
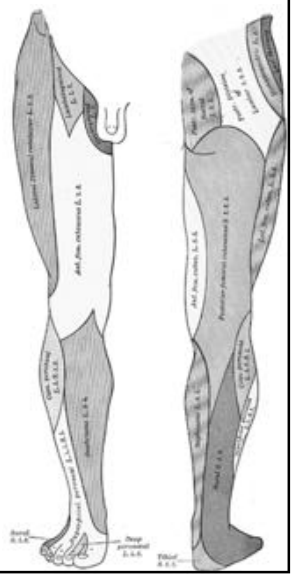
Electromyography (EMG): Choose your spots

- Upper Extremity EMG
- Most common:
  - Adductor
  - Quadriceps
  - Tibialis Anterior
  - Gastrocnemius





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Electromyography (EMG): Parameters

- Spinal
  - Filters 5-2000Hz
  - Time Base 400ms
  - Sensitivity 50µV
- Cranial
  - Filters 150-1500Hz
  - Time Base 400ms
  - Sensitivity 5µV

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Electromyography (EMG): Parameters

- Direct stimulation Levels
  - Intracranial
    - 0.05-0.3mA 0.05ms
  - Extracranial
    - Facial 0.3-1.0mA 0.1ms
      - Surgeons may request higher, document and don't go above 2.0mA
    - Vagus (thyroidectomies) 0.3-0.7mA 0.1ms
      - Up to 1.5 with documentation
  - Spinal
    - Direct 3.0-5.0mA 0.2ms 4.7Hz
      - Start low, go up to find threshold. No need to go further.
      - Up to 6.0 with documentation that surgeon was advised this is higher than typical
    - Pedicle 6.0-30mA 0.2ms 4.7Hz
      - Start low, go up to find threshold. No need to go further.
      - Up to 50mA when searching for threshold and with documentation that surgeon was advised this is higher than typical

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Electromyography (EMG): Pedicle Screw Stim

- Principle:
  - Bone should insulate stimulation
- Steps
  - Stimulation probe in pilot hole/tap
  - Stimulate screws with alligator clip or proprietary device
    - <6 poor placement, breach likely
    - Criteria for "adequate" ranges from 8mA to 12mA
    - >20mA is good

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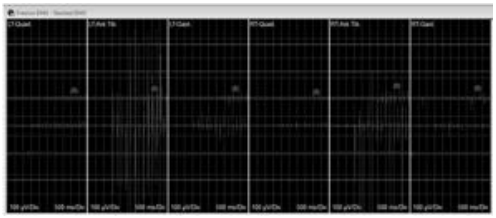
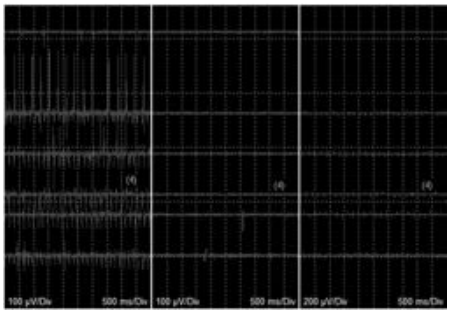
Electromyography (EMG): Criteria for Alarm

- Bursting
  - Deep Pop Sound
  - Complex, biphasic action potentials, not sustained
- Training
  - Sounds like popcorn popping
  - Sustained bursting for tens of seconds
  - Amplitude often lower than bursting





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Methods of Monitoring: Transcranial Motor Evoked Potentials (TcMEP)

- Transcranial electrical stimulation of the brain and recording of evoked neural or myogenic activity caudal to the area that is at risk during surgery

American Clinical Neurophysiology Society (2015) Guideline on Transcranial Electrical Stimulation Motor Evoked Potential (TES-MEP) Monitoring . Retrieved from http://www.acns.org/UserFiles/file/MEP_Guideline_Draft4Comment_3.2.15.pdf

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TCMEP: General Principles

- Direct measurement of integrity of corticospinal tract
  - No differentiation of which site is compromised
- Instant, no averaging
- More sensitive to ischemia due to metabolic needs
- Contraindications
  - Implanted electrical device (VNS, CI, Pacemaker)
  - Seizure History
- ***BITE GUARD!***

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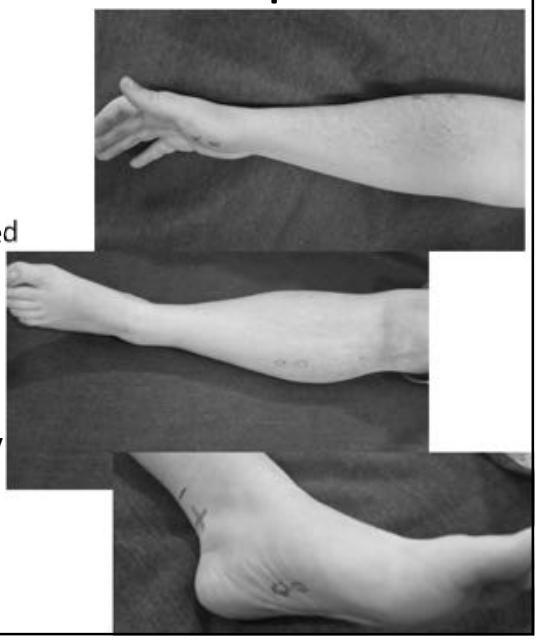
TcMEP: Choose Your Spots

- Upper Extremities
  - Arm
  - Thenar
  - Any arm site already used for EMG
- Lower Extremities
  - Tibialis Anterior
  - Abductor hallucis
  - Any leg/foot site already used for EMG



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TcMEP: Parameters

- EMG Filters
- Thenar often has to be reduced in gain to 200-500µV at same stim level that Tibialis Anterior is 30-50µV

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TcMEP: Parameters

- 3-7 pulses of 100-400V
  - some reports of up to 1000 V
- Stimulation from electrodes placed a few centimeters anterior to somatosensory electrodes at C3' and C4'
- 0.2-0.5ms
- Interstimulus interval (ISI) 2-4ms
- 100 ms window to view
- Thenar often has to be reduced in gain to 200-500µV at same stim level that Tibialis Anterior is 30-50µV

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TcMEP: Criterion for Alert

- Standardized criterion not fully agreed on
  - All or nothing
    - Most widely cited given variability of MEP signals
  - Amplitude criterion
    - 50% drop?
  - Threshold criterion
    - Where to start, what kind of drop?
  - Morphology criterion
    - Whose judgement?

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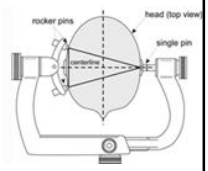
TcMEP: cautions and concerns



- Risk of injury
  - Mayfield head holder ≠ patient bucking
  - Bite Block! 
  - Seizure risk
- Nonstandard criteria
- Sensitive to anesthetic effects
- Technically challenging
- Watch for site bleeding

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Matching Method to Surgical Risk

- Which Pathways
  - Sensory, Motor, Mixed
- Which Levels
  - Cranial, Cervical, Thoracic, Lumbar, Sacral
- Which Risks
  - Compression, vascular deprivation, cutting

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Matching Method to Surgical Risk

- Keep some anatomy references on equipment or on your person. Do not depend on your cell phone.
- If surgeon thinks you don't know WHY you are monitoring, assumes you don't know WHAT you are doing
- On the other hand, if you are unclear, ASK the surgeon!
  - Better to have a delay than a disaster

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Matching Method to Surgical Risk: CPA Tumors

Acoustic Neuroma/Vestibular Schwannoma

- CN VII – Facial Nerve
  - EMG in 4 channel montage
- CN VIII – Auditory/Vestibulocochlear
  - ABR

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Matching Method to Surgical Risk: Arnold Chiari Malformation

Make room for dropped cerebellum and pad the area at C1 spine

- Ischemia and cord compression
  - TcMEP 2 upper and 2 lower extremity sites bilaterally
- Cord compression and direct dorsal injury during decompression
  - SSEP upper and lower extremities
- Brainstem function
  - ABR

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Matching Method to Surgical Risk: Occiput to Posterior Cervical

- Dorsal approach, Brachial Plexus (positioning)
  - SSEP upper and lower extremities
- Decompression concerns at Surgeon's request (rare)
  - EMG of upper extremities at muscles corresponding to sites of concern

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Matching Method to Surgical Risk: Anterior Cervical

Not commonly monitored, choose based on the risk that concerns the surgeon

- Cord Compression
  - SSEP
- Ischemia risk to cord
  - TcMEP
- Specific nerve roots
  - Upper extremity EMG
- Recurrent Laryngeal Nerve
  - Endotracheal tube EMG

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Matching Method to Surgical Risk: Thoracic Spinal Procedures

- Dorsal Column, Compression, Brachial Plexus
  - SSEP upper and lower
- Ischemia risk to cord, Fracture
  - TcMEP
- Specific nerve roots
  - EMG of those dermatomes if necessary, more common with Thoracic-lumbar
  - Reliability?

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Matching Method to Surgical Risk: Anterior Lumbar Procedures

- Vascular disruption from retractors
  - SSEP of lower extremities
  - Pulse oximetry of Left greater or second toe
- Root injury from discectomy, implanting cage, or cage/plate combo
  - Lower extremity EMG

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Matching Method to Surgical Risk: Lateral Lumbar Procedures

- Ischemia risk to cord, Fracture
  - TcMEP
- Dorsal column, compression, brachial plexus
  - SSEP Upper and Lower
- Nerve root
  - Blind approach in XLIF
  - Less likely if general surgeon moves iliacus for approach
  - Lower Extremity EMG, including iliacus
    - Difficult in obese patients for whom XLIF is designed

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Matching Method to Surgical Risk: Posterior Lumbar

- Nerve Root Injury
  - Lower EMG
- Pedicle Screw or Direct Nerve Stimulation
  - Lower EMG
- Brachial Plexus
  - Upper SSEP
- Dorsal column
  - Add Lower SSEP

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Matching Method to Surgical Risk: Tethered Cord

- Differentiate phylum causing stretching of cord from the nerve tissue surrounding it
  - Lower EMG
  - Consider genitourinary monitoring
    - Bladder electrode very difficult to obtain
- Direct Nerve Stimulation
  - Lower EMG
- Brachial Plexus if anticipating a long procedure
  - Upper SSEP

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Challenges to Obtaining Good Data

- Logistical
- Electrical
- Biological
- Anesthesia

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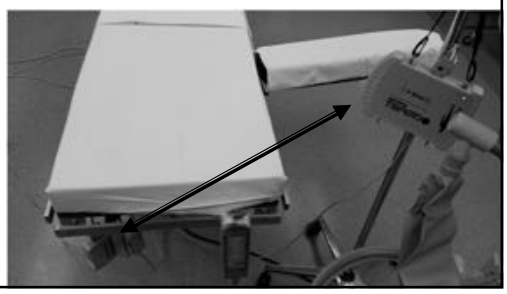
Challenges to Obtaining Good Data: Logistics

- OR table is valuable real estate
- Space in the room shrinks with people and equipment
- "Red Outlet" may be far from bed
- Separating stimulation and recording cords may be unworkable



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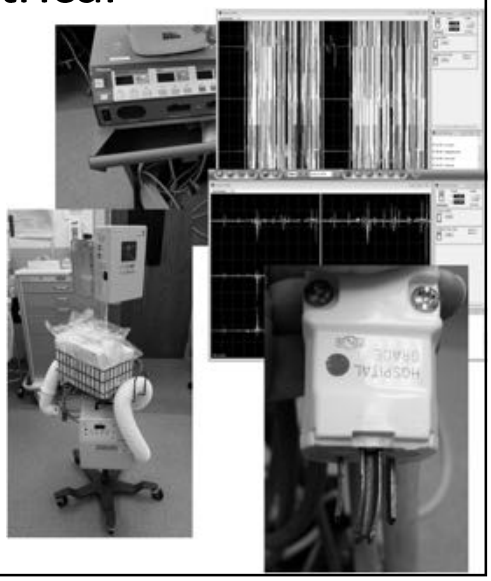
Challenges to Obtaining Good Data: Electrical

- Electrocautery
  - Bovie 10^{10} bigger larger than ABR signal
  - Bipolar less of a problem, but variable
- "Leaky" equipment
  - Beds and bed controls
  - Fluid warmers
  - Bis Monitor
  - Extension cords



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Challenges to Obtaining Good Data: Biological

- Hypothermia
  - Slows evoked responses
  - Decreases sensitivity of nerves
  - Room is 55-68ºF
  - Irrigation
- Blood pressure
  - Sensory response rises and falls with cortical blood pressure

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Challenges to Obtaining Good Data: Anesthesia

Disclaimer:

- The following summary is not exhaustive and deals with only those anesthetic agents typically seen in the midwestern, suburban, private hospitals and surgery centers our practice serves.
- For a more complete exploration of Anesthesia and it's effects on neuromonitoring, see Todd Sloan's papers.

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Challenges to Obtaining Good Data: Anesthesia

- Anesthesia Team Goal
  - Unconscious State
  - Analgesia
  - Muscle Relaxation

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Challenges to Obtaining Good Data: Anesthesia

- Anesthesia Team Arsenal
  - Intravenous Drugs
  - Inhaled Drugs
  - Topical Drugs

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Anesthesia: SSEP

- Volatile Inhalational Agents
  - Isoflurane, Sevoflurane, Desflurane
  - At >1/2 MAC level, cortical responses may disappear altogether
  - More of an issue for cervical and above, can use sub-cortical responses for thoracic and lumbar
- Nitrous Oxide up to 50% of mix
- Paralytic
  - May reduce myogenic interference in sensory evoked responses
- Blood Pressure has to be stable for SSEP to be stable
- Precedex sedative reduces need for agent

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Anesthesia: EMG

- Volatile Inhalational Agents
  - Not an issue
- Paralytic
  - Completely wipes out response
    - Even 4 twitches is not a guarantee
    - Topical anesthetic lidocaine for intubation reduces need for paralytic
    - Short acting paralytic like succinylcholine is fine
    - Rocuronium may linger
    - Reversal agents
      - Neostigmine paired with glycopyrrolate
      - Sugammadex expensive, new, may not be available
  - May be fine for shorter periods to allow for extensive exposures

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Anesthesia: TcMEP

- Worst of both worlds
  - Cannot suppress cortex with inhalational agents
  - Cannot paralyze
- "If I can't use gas and I can't use relaxant, what do you want me to use, a hammer?"

Total Intravenous Anesthesia

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Anesthesia: TcMEP

- Total Intravenous Anesthesia
  - Propofol
    - First line, but has to be used with another drug
  - Narcotics
    - Blocks pain without affecting IOM, so other drugs can be used at lower levels
    - Morphine, Demerol, Fentanyl, Sufentanil, Remifentanil (also known as liquid-gold, may not be on formulary due to price)
    - Can be reversed with NARCAN
  - Precedex reduces need to use narcotic, expensive
  - Ketamine
    - inexpensive, hallucinatory effects, including on waking

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Anesthesia: TcMEP

- Total Intravenous Anesthesia
  - Know who you're asking
  - Be courteous to your Anesthesia provider and tell them the moment you take your last TcMEP.

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A Word About Documentation

- Quality Care
- Financial Consequences
- Legal Consequences

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A Word About Documentation: Quality Care

- Store data often
- "Could someone take over this case in an emergency?" Does the data make sense?
- Preference Cards
  - Consider dating and updating yearly
- Document your discussion with Anesthesia
- Patient signature ensures a chance to
  - Ask about seizures, tape allergy, unexplained muscle movements, etc.
  - Eyeball if you need longer electrodes

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A Word About Documentation: Fianancial Consequences

- Proof that you were there
  - Insurances ask
  - 95940 in on-site, 15 minute intervals
- Proof the surgeon felt it was medically necessary
- Matching diagnosis codes ensures payment

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A Word About Documentation: Legal Consequences

- Contemporaneous Record
- Alterations in protocol need justification
  - "Per Dr. S., absent baseline is not unexpected, as pt. not ambulatory"
  - "Reference electrode inadvertently removed by anesthesia provider, Surgeon request IOM provider wait to replace until after imaging."
- "SIA" or Surgeon Informed and Acknowledged
  - Make sure they really do acknowledge
- Document when standard things happen
  - Time out, incision, scope in, switching sides, etc.
  - Gives a timeline if you and/or the surgeon testify

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Summary

- Multi-mode monitoring is a balancing act of risk-benefit.

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Multi-modal Monitoring for Complex cases

Questions?

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AAB-IOM

- **What is the Value of Specialty Board Certification in IOM for an Audiologist?**
- *Surgeons, patients, credentialing bodies, health care facilities and employers can be assured that the audiologist who has achieved AABIOM board certification in IOM possesses specialized education, training and experience beyond that required for entry into the general profession (e.g., Ph.D., Au.D.) as well as the Certificate of Clinical Competence in Audiology [CCC-A]. Board certified audiologists in IOM possess an advanced understanding in this sub-specialty in audiology. They have met rigorous educational, practice and examination requirements and are required to maintain their board certification by demonstration of ongoing continuing education, ethical professional standing and valid licensure to practice.*

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