SNACC Annual Meeting
Neuromonitoring Clinical Science Symposium:
Cranial Nerve Monitoring

Laura B. Hemmer, M.D.
Associate Professor of Anesthesiology and Neurological Surgery
Northwestern University Feinberg School of Medicine

l-hemmer@northwestern.edu

No Conflicts of Interest
+ Off label Drug Uses
Cranial Nerve Monitoring
Electromyography (EMG)

• Intraoperative cranial nerve monitoring is a form of EMG.
• EMG monitors intracranial or spinal cord nerves or nerve roots at risk during surgery.
  – Monitors spontaneous or evoked compound muscle action potentials (CMAPs) in muscles innervated by at-risk nerves.
  – “Spontaneous EMG” can identify blunt mechanical trauma to roots and motor nerves by evoking high-frequency bursts of CMAPs (=neurotonic discharges)
  – “Triggered EMG” can help identify intact nerves.
Cranial Nerve Monitoring
Electromyography (EMG)

• Intraop CN monitoring provides immediate feedback
  • that the nerve being manipulated is at risk of injury
  • and/or to trace the course of a nerve in patients with distorted anatomy (e.g. by tumor).
Cranial Nerve Monitoring
Electromyography (EMG)

- Monitoring of spontaneous EMG activity based on principle that thermal, mechanical, or metabolic irritation of a nerve => activity in innervated musculature.
  - EMG quiet = intact & functioning nerve OR severed/disrupted nerve
  - EMG bursts = usu from direct nerve manipulation
    - Unlikely significant permanent postop dysfunction
  - EMG train = suggest ↑ irritation of nerve fibers
    - Possible permanent nerve injury (stop precipitating surgical maneuver)
Cranial Nerve Monitoring

Electromyography (EMG)

• Manipulation of normal healthy nerves => little or no activation
• Manipulation of nerves that are slightly injured will tend to react more strongly
  • may act as impulse generators of spontaneous EMG activity (even if no current manipulation occurring.)¹

  – Absence of EMG activity does not ensure healthy nerve!
    • Electrically stimulate to ensure nerve intact.
    • Prolonged latency /decreased amplitude indicate nerve injury.²
Cranial Nerve Monitoring

Nerves

- Cranial nerves with a motor component can be monitored.

<table>
<thead>
<tr>
<th>Cranial nerve</th>
<th>Muscle group</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>Medial rectus</td>
</tr>
<tr>
<td>IV</td>
<td>Superior oblique</td>
</tr>
<tr>
<td>V</td>
<td>Masseter, temporalis</td>
</tr>
<tr>
<td>VI</td>
<td>Lateral rectus</td>
</tr>
<tr>
<td>VII</td>
<td>Orbicularis oris, orbicularis oculi</td>
</tr>
<tr>
<td>IX</td>
<td>Soft palate</td>
</tr>
<tr>
<td>X</td>
<td>Vocal cords</td>
</tr>
<tr>
<td>XI</td>
<td>Trapezius</td>
</tr>
<tr>
<td>XII</td>
<td>Tongue</td>
</tr>
</tbody>
</table>
Cranial Nerve Monitoring

Technique: Stimulation

• Intraop CN monitoring involves use of handheld electrical stimulating electrode to probe the surgical field and single or pairs of needle electrodes that are used to record EMG activity from muscle groups innervated by cranial nerves at risk.
  – Stimulus pulse durations ≈ 50–100 μs
  – Stimulation rate ≈ 3–5 pulses per second
  – Stimulus intensity ↑ at first to prevent nerve damage; once response obtained => stimulus intensity↓ to determine exact nerve location.
Cranial Nerve Monitoring

Technique: Stimulation

• Bipolar stimulation is more effective focal stimulus compared to monopolar.
  – (So current spread to nearby neural structures is decreased with bipolar stimulation.)

• However, submaximal stimulation can occur due to current shunting and placement of both the cathode and anode directly on the nerve can be cumbersome.

• Although possibility of stimulating other neural structures via current spread increased with monopolar, it is less cumbersome to only place one electrode within tight surgical space.
Cranial Nerve Monitoring

Technique: Electrode Placement

Cranial Nerve Monitoring

Electrode Placement

Typical Case: Acoustic Neuroma Resection

- CN VIII + CN VII + lower CNs at risk of surgical injury
- Intra-oral placement of recording electrodes is necessary for monitoring glossopharyngeal & hypoglossal nerves.
- Practical “routine” for anesthesiologist with planned CN IX, X, XII monitoring: ETT with embedded electrodes, temp probe, ± OG tube, intra-oral recording electrodes for CN IX and then XII, then careful bite block placement. Remember to time emergence to allow removal of electrodes (include in sign-out if handing over case!)

Glossopharyngeal Monitoring

- Efferent portion of CN IX innervates stylopharyngeus muscle
- Place needle electrode pair in soft palate halfway between the uvula and the posterior tonsillar pillar. (Skull Base Surgery 1995;5(4):245-50.)

Cranial Nerve Monitoring

Electrode Placement

• Vagal nerve and its branches at risk with numerous procedures, including surgery of skull base, neck, and chest.

• Most easily and commonly placed monitor for recurrent laryngeal nerve is neural integrity monitor (NIM) electromyogram (EMG) tracheal tube.
  – Non-invasive and placed by anesthesiologist.
  – Prior to electrodes integrated onto ETT, gold-foil surface electrodes positioned around ETT.

Cranial Nerve Monitoring
Electrode Placement

<table>
<thead>
<tr>
<th>Technique</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xomed NIM-2 EMG endotracheal tube</td>
<td>Quickly placed by anesthesiologist; Does not require DL or further procedure by surgeon; Lowest incidence of spontaneous false positive EMG activity; Least invasive technique</td>
<td>Highest relative cost (~$475 to the patient); Medium reliability (response rate 76.9%); Lowest sensitivity with highest mean stimulus current required (0.120 mA); Lowest average response magnitude; Potential for loss of electrode-vocal cord contact due to tube rotation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technique</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endolaryngeal thyroarytenoid electrodes</td>
<td>Reliably placed by experienced otorhinolaryngologist with visual confirmation of proper placement; Highest reliability (response rate 100%); Highest sensitivity with lowest mean stimulus current required (0.073 mA); Highest average response magnitude; Exhibited most frequent singular response to surgical dissection producing mechanical stimulation of vagal nerve</td>
<td>Requires DL skills for electrode placement; Requires extra procedure and time from surgeon for electrode placement; Although electrodes are inexpensive, cost increased by need for placement by DL (~$335 to the patient); Placement technique invasive with potential for vocal cord trauma, hemorrhage, abscess formation, and loss of foreign body; Highest incidence of spontaneous false positive EMG activity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technique</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percutaneous cricothyroid electrodes</td>
<td>High sensitivity with low mean stimulus current required (0.089 mA) when response obtained; High average response magnitude; Low cost of electrodes and low cost of placement (~$30 + possible placement cost to the patient)</td>
<td>Requires extra procedure and time from surgeon for electrode placement; Placement technique invasive with potential for vocal cord trauma, hemorrhage, abscess formation, and loss of foreign body; “Blind” electrode placement with lowest reliability (response rate 69.2%); High incidence of spontaneous false positive EMG activity</td>
</tr>
</tbody>
</table>

DL, direct laryngoscopy; EMG, electromyographic.

The American Journal of Otolaryngology, Vol. 20, No. 5, 1999
Intraoperative neuromonitoring of oculomotor function is not often performed, but there are multiple reports of its use in skull base surgery (and some non-skull base intracranial surgery) in the literature where it has influenced surgical strategy, with a summary reported by Lopez...
Cranial Nerve Monitoring

Indications

- The benefits of intraop CN VII are clear.
- Rate of facial nerve injury in skull base surgeries has decreased.
- Studies regarding CN monitoring of lower cranial nerves (CN 9–12) is more limited.

Neurosurg Rev (2008) 31:45–53
• Acoustic Neuroma Resection
  – Facial nerve obscured by tumor growth & facial nerve palsy one of most common postop complications.
  – Monitoring of facial nerve helps keep nerve intact during surgery and shown to improve postop outcome.
  – NIH consensus panel concluded, “...benefits of routine intraoperative monitoring of the facial nerve have been clearly established. This technique should be included in surgical therapy for vestibular schwannoma.”

Brainstem Mapping

- Brainstem mapping is a neurophysiologic technique for locating the cranial nerve motor nuclei (CMN) on the floor of the fourth ventricle.
- “Safe Entry Zone”
Anesthesia for EMG/Cranial Nerve Monitoring

- EMG resistant to anesthetics.
- EMG sensitive to neuromuscular blockade.
  ➔ avoid NMB during EMG monitoring.
Anesthesia for EMG/Cranial Nerve Monitoring

• If neural integrity monitor (NIM) electromyogram (EMG) tracheal tube:
  • Airway topicalization, such as with nebulized or trans-tracheal lidocaine or superior LN blocks, may interfere with monitoring.

Neuroanesthesia and EMG: Lateral Spread

• Lateral spread response (=EMG activity)
• Occurs when stimulation of one branch of CN VII => activation of other branches of CN VII.
  – Abnormal response
    • Normally stimulation in one branch would not cause a response in another branch.
    • Result of irritation of the nerve.
  – Not affected by intravenous or inhalation anesthetics; very sensitive to muscle relaxant.

Neuroanesthesia and EMG: Lateral Spread

- Used in microvascular decompression surgery for hemifacial spasm.
  - LSR disappearance may help predict success in alleviating the hemifacial spasm.\(^1\)-\(^3\)
  - Initial presence must be verified early in surgery.
    - Non-depolarizing muscle blockade is usually avoided for intubation & throughout surgery.
    - Long term predictive value of the lateral spread response questioned.\(^3\)-\(^4\)

Cranial Nerve Monitoring

Safety

• CN Monitoring is associated with some risks.
  – Risk of bleeding & hematoma.
  – Stimulation of CN IX at high thresholds can trigger reflex hypotension & bradycardia.
    • Increase stimulation stepwise until peripheral response.
  – Stimulation of CN XI at high intensity can cause brisk contraction of the trapezius and sternocleidomastoid muscles, => head movement.
  – Stimulation of CN X at high intensity can cause tachycardia. (Skull Base 1995)

• Autonomic disturbances from nerve manipulation too! (Skull Base 1995)
Neuroanesthesia and IONM

Patient care facilitated and improved when all intraop teams have a basic understanding of what the other teams are doing and when teams communicate.

Anesthesiologists can (and should) play an active role in neuromonitoring to help ensure the best outcome for our patients.
Thank you!

l-hemmer@northwestern.edu