Intra-Operative Electrophysiology in Neuro-Otological Surgical Procedures

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- Intra-operative monitoring (IOM)
  - Definition
  - Rationale
- Anatomy
  - Auditory system
  - Facial nerve
- Early literature
- Surgical procedures
- Test protocol
  - ECochG
  - ABR
- Recent literature
- Factors influencing outcome
- Examples of waveform changes

INTRAOPERATIVE MONITORING: Definition

- The application of continuous evoked response recording during a surgery that puts a cranial nerve and/or the CNS at risk with:
  - online data analysis
  - immediate interpretation
  - periodic reporting to the surgeon (s)
- The objective is the detection of surgery-related neuropathophysiology as soon as possible, with appropriate modification of surgery, to prevent postoperative auditory or neurologic deficit.

INTRAOPERATIVE MONITORING: Rationale

"There is consensus that intraoperative real-time neurologic monitoring improves the surgical management of vestibular schwannoma, including preservation of facial nerve function and possibly improved hearing preservation by the use of ABR monitoring."

Acoustic Neuroma. NIH Consensus Development Conference Statement. 1991

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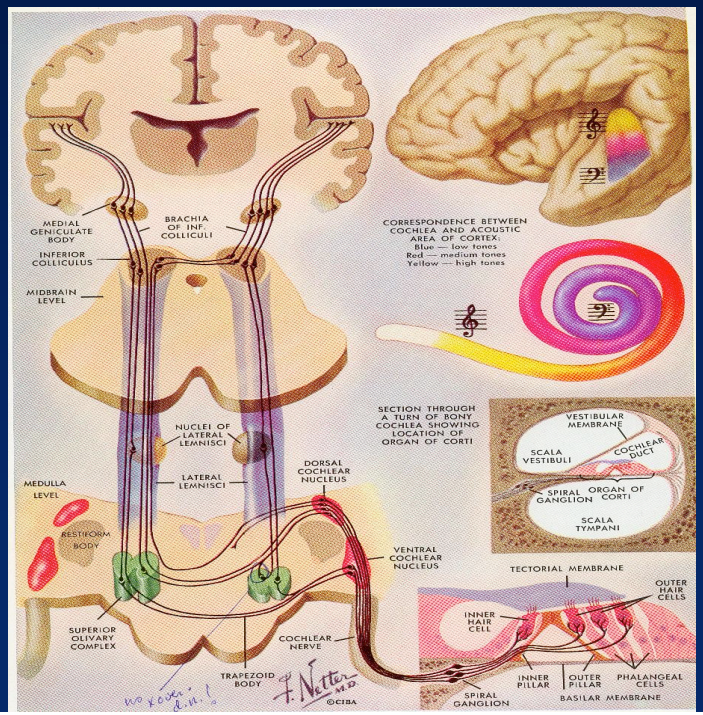
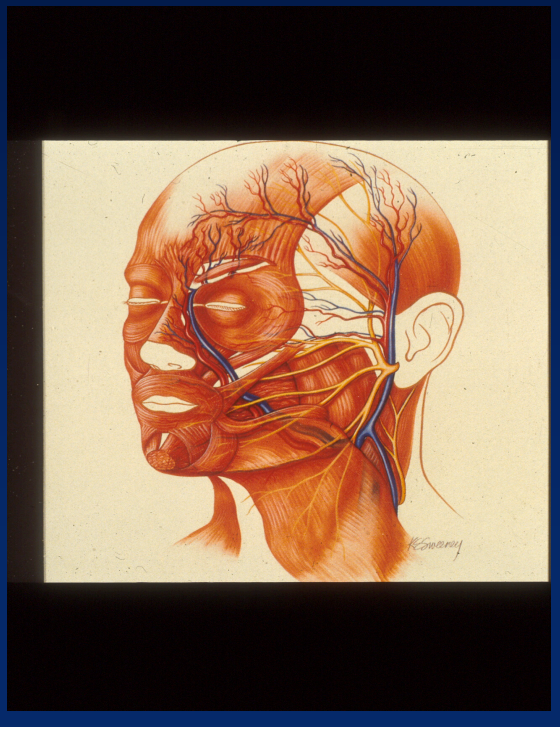
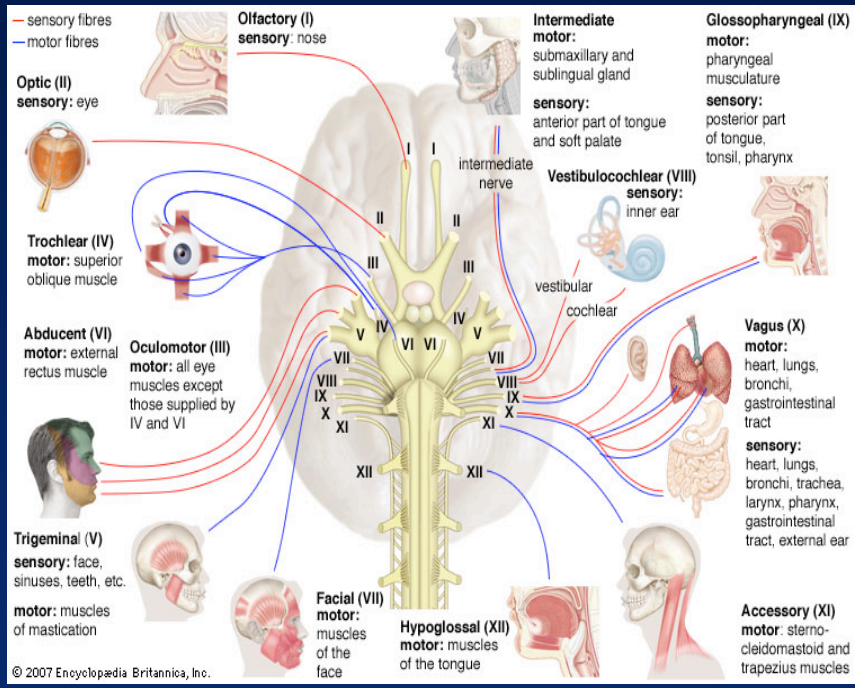
Intra-Operative Electrophysiology in Neuro-Otological Surgical Procedures: Auditory Anatomy



Intra-Operative Electrophysiology in Neuro-Otological Surgical Procedures: Facial Nerve Anatomy





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INTRAOPERATIVE MONITORING: Early ABR Literature

- Smith MFW. Conservation of hearing in acoustic schwannoma surgery. *American Journal of Otology* : 1985.
- McDaniel et al. Retrolabyrintine vestibular neurectomy with and without monitoring of 8th nerve potentials. *American Journal of Otology*: 1985.
- Silverstein et al. Hearing preservation after acoustic neuroma surgery using intraoperative direct 8th cranial nerve monitoring. *American Journal of Otology* : 1986.
- Kanzaki et al. Hearing preservation in acoustic neuroma surgery and postop audiological findings. *Acta Otolaryngologica*: 1986.
- Shelton et al. Hearing preservation after acoustic tumor removal: Long term results. *Laryngoscope 100*: 1990

INTRAOPERATIVE MONITORING: Early Facial Nerve Literature

- Olivecrona. Analysis of results of complete and partial removal of acoustic neuromas. *J Neurol Neurosurg Psychiatry 13*: 1950.
- Rand & Kurze. Facial nerve preservation by posterior fossa transmeatal microdissection in total removal of acoustic tumors. *J Neurol Neurosurg Psychiatry 28*: 1965.
- Silverstein et al. Routine identification of facial nerve using electrical stimulation during otologic and neurotologic surgery. *Laryngoscope 98*: 1988.
- Prass & Lueders. Acoustic (loudspeaker) facial electromyography monitoring. *Neurosurgery 19*: 1986.

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INTRAOPERATIVE MONITORING:
Neuro-Otological Surgical Procedures

- Facial nerve only
  - Chronic ear surgery
  - Mastoidectomy
  - Stapedectomy
  - Facial nerve decompression
  - Trans-labyrinthine CPA tumor removal
- Auditory system and facial nerve
  - Vestibular neurectomy (nerve section)
  - Endolymphatic sac shunt/decompression
  - CPA tumor removal
    - ✓ retrosigmoid approach
    - ✓ middle fossa approach

INTRAOPERATIVE MONITORING WITH ABR: Rationale for Surgeries

- Peripheral vestibular dysfunction (e.g., Meniere's disease)
  - Section of vestibular nerve for relief of vertigo
  - Goal of monitoring: hearing preservation
- Facial nerve exploration
  - Middle fossa approach for decompression of nerve
  - Goal of monitoring: preserve cochlear integrity
- Endolymphatic sac decompression/shunt
  - Decrease endolymphatic hydrops (pressure)
  - Goal of monitoring: document cochlear integrity during/after surgery

INTRAOPERATIVE MONITORING WITH ABR: Rationale for Surgeries

- Aortic aneurysm
  - Clip and/or excise aneurysm and prevent CVA
  - Goal of monitoring: prevent brain ischemia and neurologic deficit
- Brainstem tumor
  - Remove tumor and eliminate mass effect on CNS
  - Goal of monitoring: prevent brainstem ischemia and trauma, and prevent neurologic deficit

INTRAOPERATIVE MONITORING WITH ABR: Rationale for Surgeries

- Trigeminal nerve tumor
  - Vascular decompression or section for relief of pain
  - Goal of monitoring: hearing preservation; prevent 8th cranial nerve damage
- CPA (posterior fossa) tumor
  - Remove tumor; decompress 8th nerve and brainstem
  - Goal of monitoring: preserve hearing

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INTRAOPERATIVE MONITORING: ECochG/ABR Protocol

Stimulus Parameters

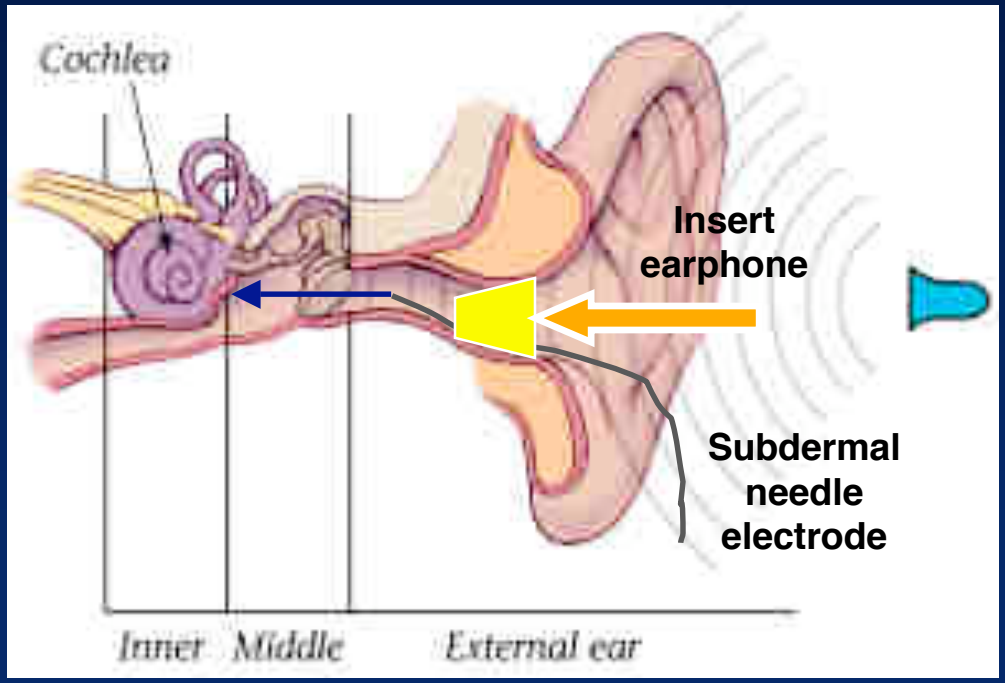
- Transducer: ER-3A insert earphones
- Type: Click
- Duration: 0.1 ms (100 microseconds)
- Polarity: Rarefaction
- Rate: 7.1/sec or 23.1/sec
- Intensity: High (> 80 dB nHL)
- Presentation: Monaural
- Masking: None

INTRAOPERATIVE MONITORING: ECochG/ABR Protocol

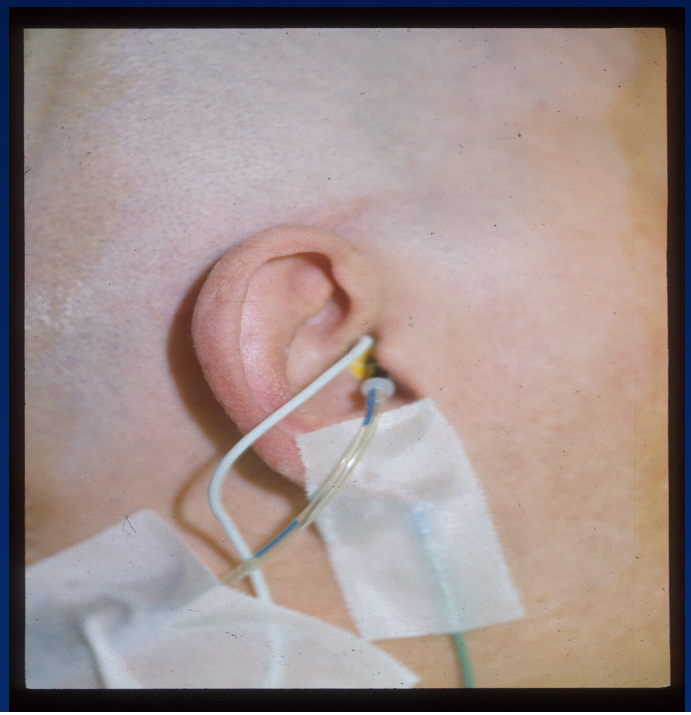
Acquisition Parameters

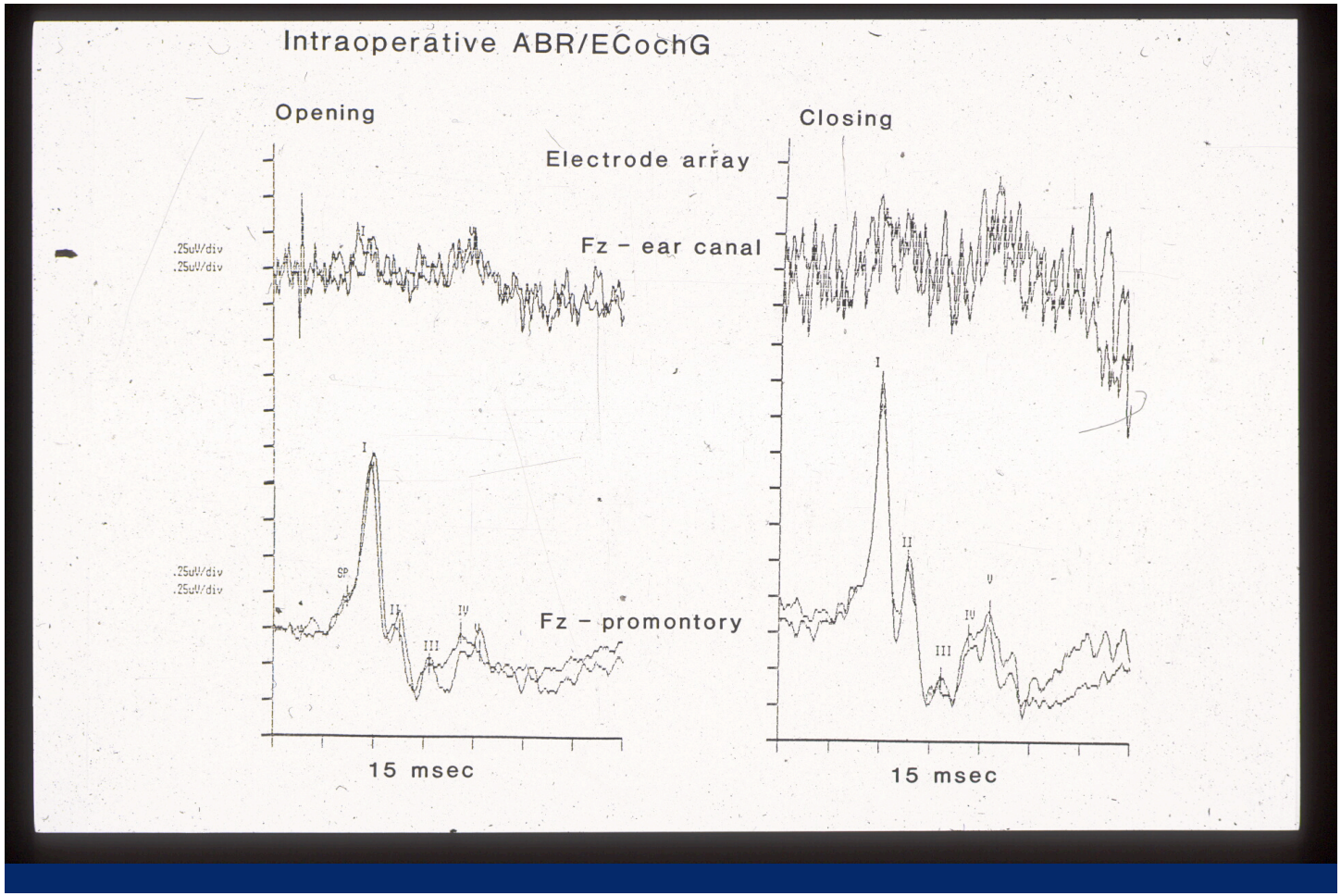
- Analysis time: 10 or 15 ms
- Pre-stimulus time: - 1 ms
- Filter settings: 30 to 1500 Hz
- Sweeps: variable (adequate SNR)
- Electrode sites:
  - One channel: Fz - TT promontory needle
  - Two channel: Fz - EAC (Tiptrode)
Fz - TT promontory needle

ECochG:
Trans-Tympanic Needle Promontory Electrode
(Schwaber & Hall. AJO 1990)



Trans-tympanic Needle Placement




Intraoperative ABR/ECochG
Opening
Closing
Electrode array
Fz – ear canal
.25uV/div
.25uV/div
.25uV/div
.25uV/div
SP
I
II
III
IV
V
Fz – promontory
15 msec
15 msec

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INTRAOPERATIVE MONITORING:
Effects of Pharmacologic Agents on ABR

- No effect
  - Althesin
  - Etomidate
  - Ketamine
  - Pentobarbitol
  - Anticholinergics
  - Fentanyl
  - Nitrous oxide (middle ear inflation)
  - Chemical paralyzers, e.g., pancuronium, metacurine, curare
- Adverse effects (modestly increase in inter-wave latencies)
  - Enflurane
  - Isoflurane
  - Sodium thiopental
  - Propofol
  - Halothane
  - Lidocaine
  - Sevoflurane

INTRAOPERATIVE MONITORING:
Effect of Body Temperature on ABR

- Normal body temperature is 37 degrees Centigrade
- Recorded body temperature varies with transducer site, e.g., oral, rectal, TM, central line)
- Relationship between temperature and latency is:
  - hypothermia increases inter-wave latencies
  - hyperthermia decreases inte-rwave latencies
- Latency shift is on the order of 0.2msec/degree of body temperature (+/- 37 degrees)

INTRAOPERATIVE MONITORING:
Techniques for Minimizing Measurement Artifact

- Maintain low interelectrode impedance (< 2000 ohms)
- Use short electrode wires
- Braid electrode wires
- Increase distance between recording vs. stimulating electrode cables
- Increase distance between transducer and electrode cables
- Don’t cross electrode wires with electrical wires for surgical or anesthetic equipment
- Keep electrode wires away from ventilation tubes
- Use hospital-grade grounded power plugs
- Use evoked response system designed for O.R. use

INTRAOPERATIVE MONITORING OF FACIAL NERVE: Trouble Shooting No Response

- Power of monitor is off (e.g., dead battery)
- Stimulus current intensity is too low
- Response threshold is too high (for Nerve Integrity Monitor)
- Electrode impedance is too high
- An electrode is disconnected
- Current shunting (e.g., electrodes continuous)
- Auditory monitor volume is too low
- Muscle relaxant (chemical paralyzer) on board
- 7th nerve is not being stimulated
- Another cranial nerve is being stimulated
- The 7th cranial nerve is injured

INTRAOPERATIVE MONITORING OF FACIAL NERVE: Acoustic Representation of Events

Stimulus	EMG Response	Acoustic Representation
Electrical	precisely timed	machine gun
Mechanical	singly polyphasic burst	syncrhonous click
Traction	multiple synchronous train	popping corn (maybe delayed)
Thermal	Initially widened baseline Then, multiple asynch	Initially silent Then, popping corn

INTRAOPERATIVE MONITORING: Factors in Interpretation

- Anatomic: external ear
  - Blood and irrigation fluid
  - Dislodged insert earphone
- Anatomic: middle ear
  - Blood and irrigation fluid
  - Ossicular chain disruption
- Anatomic: inner ear
  - "Masking" effect of drilling (TTS)
  - Labyrinthine damage
  - Interruption in blood supply
    - ✓ AICA
    - ✓ Internal auditory artery

INTRAOPERATIVE MONITORING: Factors in Interpretation

- Anatomic: 8th cranial nerve
  - Traction
  - Stretching
  - Compression
  - Severing
  - Ischemia (interuption of blood supply)
- Anatomic: brainstem and cerebellum
  - Traction
  - Compression
  - Ischemia

INTRAOPERATIVE MONITORING: Factors in Interpretation

- Physiologic
  - Systematic body temperature
  - Focal temperature (surgical site)
- Medical
  - Effect of anesthetic agents
  - Effect of chemical paralyzing agents

INTRAOPERATIVE MONITORING: Factors in Interpretation

- Technical factors: evoked response instrumentation
  - Stability of electrode placement
  - Stability of electrode impedance
  - Earphone placement
  - Patency of insert earphone acoustic tubing
  - Intact power cord connection to power outlet

INTRAOPERATIVE MONITORING: Sound Levels in the O.R.

Surgical Instrument	Location of SL Meter		
	Surgeon	Instrument	Monitor
Pneumatic drill 78 dBA	83 dBA	85 dBA	
CUSA	73	78	73
CO2 laser	71	79	74

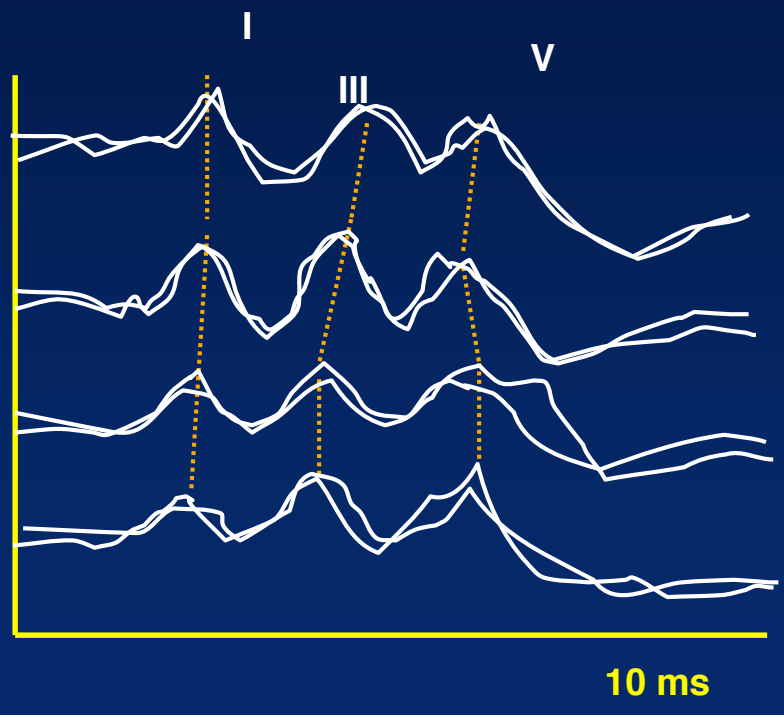
INTRAOPERATIVE MONITORING: Factors in Interpretation

- Technical factors: sources of electrical artifact
  - Bipolar electrocautery
  - Bovie knife
  - Electric drill
  - Laser
  - Microscope
  - X-ray viewbox
  - Other electrical O.R. equipment

INTRAOPERATIVE MONITORING:
Criteria for ABR Abnormality in wave I - V latency
(See Hall, 2007)

- Surgeon Alert
  - > 0.5 ms increase
  - Reliable and valid
- Surgeon Warning
  - > 1.0 ms increase
  - Reliable and valid
- Surgeon Verbal Report
  - Loss of ABR

Intra-operative Monitoring with ECochG/ABR: Tumor Removal



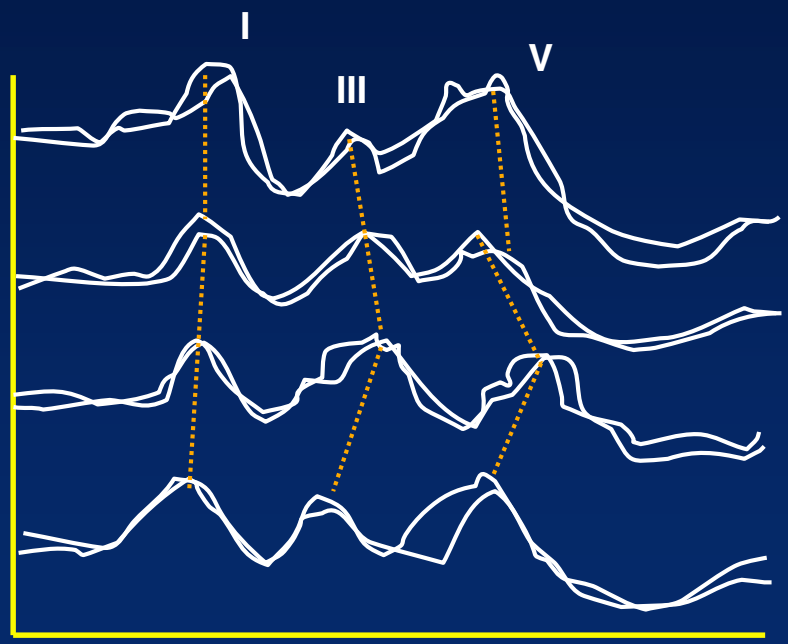
Opening
I - III = 2.90 ms
I - V = 5.00 ms

Tumor debulking
I - III = 2.50 ms
I - V = 4..80 ms

Tumor dissection
I - III = 2.20 ms
I - V = 5.05 ms

Closing
I - III = 2. 30 ms
I - V = 5.00 ms

Intra-operative Monitoring with ECochG/ABR: Vestibular Nerve Section



Opening
I - III = 2.30 ms
I - V = 4.20 ms

Cerebellar retraction
I - III = 2.80 ms
I - V = 4..30 ms

Nerve sectioning
I - III = 3.10 ms
I - V = 5.55 ms

Closing
I - III = 2. 30 ms
I - V = 4. 20 ms

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Intra-Operative Electrophysiology in Neuro-Otological Surgical Procedures: Recent Literature

- Atias et al. Hearing preservation using combined method of extra-tympanic electrocochleography and auditory brainstem responses during acoustic neuroma surgery. *International Journal of Audiology, 47*, 2008
- Methods
  - 74 patients undergoing AN surgery
    - ✓ 34% with small tumors (< 2 cm)
    - ✓ 51% with medial tumors (2.1 to 3.9 cm)
    - ✓ 15% with large tumors (≥ 4 cm)
  - 97% with retrosigmoid transmeatal surgical approach
  - Combined ECochG (tympanic membrane) and ABR recordings
  - Facial nerve EMG recordings
- Conclusions
  - Hearing preserved in 63% of patients
    - ✓ SRT < 50 dB HL
    - ✓ Speech discrimination > 50%
    - ✓ Hearing preservation related to tumor size and pre-op hearing
  - Facial nerve function preserved in 89% of patients

Intra-Operative Electrophysiology in Neuro-Otological Surgical Procedures: Recent Literature

- Yamakami et al. Hearing preservation and intraoperative auditory brainstem response and compound nerve action potential monitoring in the removal of smal acoustic neuroma via the retrosigmoid approach. *Journal Neurology, Neurosurgery & Psychiatry, 80*, 2008
- Methods
  - 22 patients with small AN tumors undergoing surgery
  - Combined cochlear nerve compound action potential (CNAP) and ABR recordings
  - Facial nerve EMG recordings
- Conclusions
  - Useful hearing (AAOHNS Guidelines) preserved in 82% of patients
  - Serviceable hearing preserved in 91% of patients
  - Changes in CNAP were correlated in real time with mechanical injury of nerve
  - Facial nerve function preserved in all patients

Intra-Operative Electrophysiology in Neuro-Otological Surgical Procedures: Recent Literature

- Youssef et al. Intraoperative neurophysiological monitoring in vestibular schwannoma surgery: advances and clinical implications. *Neurosurgery Focus, 4*, 200
- Methods
  - Review of literature with MEDLINE (PubMed) search
  - 288 articles (249 in English language)
  - Focused on 34 articles from 1990 to present
- Conclusions
  - Identification of pathognomonic CNAP, ABR and facial nerve EMG patterns are correlated with post-operative functional outcomes
  - "Recent advances in electrophysiological technology has contributed considerably to improvement in functional outcome of vestibular neuroma surgery in terms of hearing preservation and facial nerve paresis."