Cortical and Subcortical Functional Mapping

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Objectives

- Learn how to:
  - plan a functional mapping procedure
  - perform and interpret central sulcus localization via SSEPs phase reversal technique
  - perform and interpret cortical and subcortical motor mapping & monitoring via electrical stimulation
  - perform and interpret cortical and subcortical language mapping
  - interpret and utilize the information delivered by ECoG recordings during functional mapping
Planning

- History of present illness
  - Symptoms?
  - Seizures?
  - Neuroimaging?
  - Location of the lesion?
  - Mass effect?

- Clarify
  - Awake vs Asleep
  - Central Sulcus Localization and/or Electrical Stimulation?
  - Mapping and Monitoring?
  - Cortical/Subcortical?
  - Negative mapping?
  - Size of the surgical field and lesion location

Communicate with surgeon, anesthesia and your team

Awake Mapping: Pros and cons

- Pros
  - Direct communication with patient
  - Follow up exam
  - Lower and less variable mapping threshold
  - No anesthetic effects
  - Allows both motor and language mapping
  - Good choice for pts with high risk intubation/GA

- Cons
  - Risk of hypercapnia induced brain swelling
  - No airway protection
  - Decrease signal to noise ratio
  - Lower seizure threshold
  - Challenging management of triggered GTCS
  - Challenging in children, pts with psychiatric conditions
General Anesthesia for Motor Mapping

- TIVA (propofol + opiates)
- No muscle relaxant
- Avoid inhalational agents
- Avoid dexmedetomidine

Primary Eloquent Cortex: Variable thresholds

- Inhalational agents
- Deeper anesthesia

Dexmedetomidine and Motor Evoked Potentials

- Previously found to cause attenuation in amplitudes of tcMEPs (Mahmoud et al., 2007; Mahmoud et al., 2010)
- Review of 6 patients who received Precedex as adjunct in TIVA during scoliosis surgery. In 3 out of 6 patients, MEPs amplitude decreased on average by 67% in the upper and 21% in the lower limbs approximately 3hrs after starting Precedex; in one patient the threshold jumped from 80 mA to 180 mA

Simon et al, 2010

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Protecting Eloquent Structures

- **Cortical mapping**
  - Pfaudler and Stieber, 1994
  - Berger et al., 1989
  - Ceballos et al., 1996
  - Nolte et al., 1999

- **Subcortical mapping**
  - Deller et al., 2000
  - Sorek et al., 2004
  - Kerns et al., 2001
  - Nolte et al., 2011

- **Continuous monitoring**
  - Nolte et al., 2004
  - Hargreaves et al., 2007

Central Sulcus Localization: Phase Reversal Technique

- Diagram of brain with electrodes
- Waveform graphs indicating phase reversal technique

- Additional diagrams and waveforms related to brain mapping techniques
Electrical Stimulation Methods for Motor Mapping and Monitoring

- Single pulse bipolar stimulation technique—The Modified Penfield Method
  - Pros
    - Minimal current spread (2-3 mm, Raybould et al. 1983) maximizes the motor reaction
  - Cons
    - Increased incidence of seizures (~20% Serri et al. 1997, ~13% Yingling et al. 1999)
    - Not suited for age ≤5 years
    - Limited use in monitoring
    - Limited use in mapping the subcortical pathways (Oates et al. 2004)

- Multipulse monopolar stimulation technique
  - Pros
    - Good for PMC mapping
    - Decreased risk for seizures (~0.5% Neuloh et al. 2000)
  - Cons
    - Working great under general anesthesia
    - Taniguchi et al. 1993
    - Neuloh et al. 2004

Motor Mapping—Stimulation

- Penfield
- Multipulse train technique
- Dual paradigm
  - Rusinek et al. 1992
- Monopolar
- Bipolar

- Handheld stimulator
  - Via contacts of subdural strips or grids
Motor Responses

- Visual inspection of the contralateral hemibody
- Add-on EMG channels
  - increases sensitivity
  - requires broad face/arm/leg muscle sampling
- Add-on EEG monitoring for afterdischarges (ADs)
  - for safety and avoidance of false positive results

Recording

- Triggered CMAPs in the contralateral hemibody muscles
  - Face(tongue)
  - Arm(hand)
  - Leg(foot)
Alarm Criteria

- Key: continuous monitoring at PMC threshold
- Sudden: *decrease in amplitude
  *increase in latency
  *simplification of morphology
  (polyphasic to biphasic)
- Stop resection, irrigate with warm saline

Quinones - Ninoga et al, 2005
Calamante and Molyneux, 2008
Kondor et al, 2008
Kondor et al, 2007

Perform subcortical mapping
Subcortical Mapping-Monopolar Stimulation

Direct fiber stimulation threshold 1.8 mA
CST threshold-PMC threshold

Wallerian degeneration may result in negative stimulation
Dual cortical layer may result in increased threshold

Seidel et al, 2013

Monitoring with dcMEPs or Mapping with scMEPs?
BOTH!

- dcMEPs changes were reversible in only 60% cases
- dcMEPs changes
  - *frequency of stimulation
  - *brain shifts
  - *movement of the strip
  - *anesthetic changes/cold irrigation
  - *stimulation threshold

- scMEPs “false negatives”
  - *same muscle channels?
  - *spatial resolution of the resection cavity

Seidel et al, 2013
There are interlobar differences in cortical variability.

Wang et al., 2011

Threshold of temporal language cortex is 1.5 times higher than threshold of frontal language cortex.

Lesion in close proximity of language cortex increases its threshold 2.5 times.

Edema in close proximity of language cortex increases its threshold by 1.8 times.

Wang et al., 2011
**Functional connectivity in the human language system: a cortico-cortical evoked potential study**


**Mapping Subcortical Language Pathways**

- Fasciculus subcallosal mediolateral-transent
- Transcortical motor aphasia
- Fibers from ventral premotor cortex-anarthria
- Operculo-insular connections - complete speech arrest
- Arcuate fasciculus conduction aphasia, phonemic paraphasia, repetition disturbance
- Lat part SLF-speech apraxia

**Testing**

- **Naming Tasks**
  - Visual Object Naming
  - Objects presented as pictures or line drawings from standardized tests (e.g., Boston Naming Test)
  - Great task for surveillance because anomia is a common feature of postsurgical aphasia
  - 

*[Duffau et al., 2002]*
Sentence Comprehension
- read two sentences that appear identical but differ by one word that has been substituted for another with different or similar meaning
- comprehension of the superior temporal gyrus, auditory cortex, Wernicke's, prefrontal cortices, frontal semantic areas

Verbal Fluency and Repetition
- enumeration of months of year, days of week, counting forward/backward, ask patient to talk about hobbies, family
- Broca's: activate fasciculus

Word Generation
- ask patient to provide a list of words from a specific category, e.g., fruits or which start with a certain letter
- frontal language area

Challenges
- Soft voice
  → microphone
- Falling asleep
  → reduce sedation
- Dry mouth
  → soaked swab/oral moisturizer
- Stimulation triggered worsening of poor baseline OR fluctuation of a poor baseline?
  → get a baseline while sedated: is worsening reproducible with repeated stimulation?
  → ECoG: sedation?ADs?

Asleep–Awake–Asleep Cycle
- General anesthesia with propofol (or sodium thiopental)
- Head stabilized by Mayfield with implanted pins
- Hyperventilation prior to durotomy
- Extubate and awaken for mapping
- After mapping: intubate with fiberoptic laryngoscope, reinitiate general anesthesia

Huncke et al, 1998
Pouratian et al, 2004
Conscious Sedation Protocol

- Sedation initiated and maintained with propofol (or midazolam or dexmedetomidine)
- Infusion stopped 10-15 minutes before mapping
- Fentanyl (or sufentanil) used as analgesics
- Patient awake for mapping and during critical parts of resection
- Afterwards propofol restarted

Video presentation

ECoG Roles

- Appreciate depth of anesthesia
- Appreciate baseline epileptiform activity
- Monitor for ADs
Before Mapping

- Take a good history
- Ensure therapeutic AEDs levels
- Request ice cold saline available for cortical irrigation
- Assess pre-map ECoG
During Mapping

- ECoG: CLOSE to stimulation
- Filter stimulus artifact
- Muscle channel: Random activity
- Decrease stimulation intensity
- Decrease stimulation epochs
- Irrigate cortex directly with ice cold saline, Ringer lactate; IV benzos
- Pause stimulation and testing until abortion of electroclinical seizure and return to baseline

Summary

- Planning and communication
- Use all techniques available
- Motor mapping and monitoring
- Language mapping
- ECoG Recordings

THANKS!