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 exam
* lower and less variable mapping threshold
* no anesthetics 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 GTCSZ
* challenging in children, pts with psychiatric conditions
## Awake Mapping

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<th>oculi</th>
<th>mass</th>
<th>hand</th>
<th>brach-tri</th>
<th>delt-trap</th>
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General Anesthesia for Motor Mapping

- TIVA(propofol+opiates)
- No muscle relaxant
- Avoid inhalational agents
- Avoid dexmedetomidine
Primary Eloquent Cortex: Variable thresholds

Higher if:
- Inhalational agents
- Deeper anesthesia

Simon et al, 2010
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 5 out of 6 patients MEPs amplitudes decreased on average by 67% in the upper and 21% in the lower limbs approx 3hrs after starting Precedex; in one patient the threshold jumped from 80 mA to 180 mA

Representative Figure 1- Patient 2; F/17, MEP amplitude change over time
Protecting Eloquent Structures

- **Cortical mapping**
  - *Penfield and Jasper, 1954*
  - *Berger et al, 1989; Cedzich et al, 1996; Kombos et al, 1999*

- **Subcortical mapping**

- **Continuous monitoring**
  - *Kombos et al, 2001; Yingling C, 2011*
Central Sulcus Localization: Phase Reversal Technique
Successful CS Localization

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Wilder Penfield

January 26, 1891 – April 5, 1976


This is a press photograph from the George Grantham Bain collection, which was purchased by the Library of Congress in 1948. According to the library, there are no known restrictions on the use of these photos.
Electrical Stimulation Methods for Motor Mapping and Monitoring

- **Single pulse bipolar stimulation technique—The Modified Penfield Method**
  
  *Berger, Ojemann*—1999

  **Pros**
  
  - the minimal current spread (2–3 mm, Haglund et al. 1993) maximizes the tumor resection

  **Cons**
  
  - increased incidence of seizures (~20% Sartorius et al. 1997, ~11% Yingling et al. 1999)
  - not reliable for age < 5 years
  - limited use in monitoring
  - limited use in mapping the subcortical pathways (Keles et al. 2004)

- **Multipulse monopolar stimulation technique**
  
  *Kombos et al.*—1999, 2000, 2001; *Sala et al.*—2003

  **Pros**
  
  - good for PMC mapping
  - decreased risk for seizures (~0.5% Neuloh et al. 2004)
  - good for monitoring subcortical pathways (Sala et al. 2004, Neuloh and Schramm 2004)
  - works great under general anesthesia
    *Taniguchi et al.* 1993
    *Hern et al.* 1962,

  **Cons**
  
  - spreading
  - not useful for language mapping
Motor Mapping–Stimulation

- Penfield
- Multipulse train technique
- Dual paradigm
  - jayakar 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

Perform subcortical mapping

Quinones –Hinojosa et al, 2005
Calancie and Molano, 2008
Hsu et al, 2008
Kombos et al, 2001
Subcortical Mapping-Monopolar Stimulation

Cutoff 3 mA

< 3mA threshold significantly correlated with *postoperative deficits (sensitivity of 83%, specificity of 95%)
*dcMEPs instability

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 thresholds

**Kamada et al, 2009**

1 mA for 1 mm distance

No difference in the postoperative outcome, extent of resection, subcortical threshold between awake and anesthetized patients

**Nossek et al, 2011**
dcMEPs changes were reversible in only 60% cases

*Seidel et al, 2013*

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
Language Mapping
Pierre Paul Broca  
28 June 1824- 9 July 1880 

Carl Wernicke  
15 May 1848-15 June 1905 


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Korbinian Brodmann
November 17, 1868 – August 22, 1918

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Visual Language Cortex and Basal Temporal Language Area

Mani et al, 2008
In general, certain brain regions are responsible for specific functions: Dominant Perisylvian Regions for Language Mapping. Essential sites of language can be ≤ 2 cm². In 117 patients, 2/3 had 2 such sites; ¼ had 3 such sites separated by cortex unrelated to language. The localization of these areas has increased variability.

Ojemann 1979, 1989
There are interlobar differences in cortical excitability

Pouratian et al, 2004

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 2.6 times

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

Wang et al, 2011

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Set Up
DTI
Functional connectivity in the human language system: a cortico-cortical evoked potential study

Riki Matsumoto, Dileep R. Nair, Eric LaPresto, Imad Najm, William Bingaman, Hiroshi Shibasaki, and Hans O. Lüders 1
Fasciculus subcalossal medialis-transient 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


Duffau 2002, 2003
Naming Tasks
Visual Object Naming
*of objects presented as pictures or line drawings from standardized tests (e.g., Boston Naming Test)
*great task for surveillance because anomaia is a common feature of postsurgical aphasia
*Broca, Arcuate fasciculus, Insular connections

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
* posterior part of the superior temporal gyrus, auditory cortex, Wernicke’s, perisylvian 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, arcuate 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 areas
Challenges

- Soft voice
- Falling asleep
- Dry mouth
- Stimulation triggered worsening of poor baseline OR fluctuation of a poor baseline?

→ microphone
→ reduce sedation
→ soaked swab/oral moisturizer
→ 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 sufentanyl) used as analgesics
- Patient awake for mapping and during critical parts of resection
- Afterwards propofol restarted
ECoG-Roles

- Appreciate depth of anesthesia
- Appreciate baseline epileptiform activity
- Monitor for ADs
What About ADs?

Simon et al, 2010
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!