Awake Mapping during Surgery

Illinois Society of Electroneurodiagnostic Technologists

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None competing with the content of this talk.

Surgery for Epilepsy and Brain Tumors

Eloquent Cortex

- Preoperative Anatomy
- Handedness
- fMRI
- Tractography
- MEG
- Wada

Intraoperative Anatomy
- SSEP
- ECS

Lesion
- MRI
- FDG PET

Ictal Onset Zone
- Semiology
- Scalp Video EEG
- Ictal SPECT
- Extra-operative ECoG
- Stereo-EEG

Irritative Zone
- EEG
- MEG
- Intra- and extraoperative ECoG

Limitations

- Anatomy: individual variability
- distorted
- FMRI: essential vs. modulatory areas
- less accurate than in normal controls
- Functional Neuronavigation:
  - Brain shift, retraction, mass effect, resection, CSF leak

Intra-operative Functional Mapping

SSEP
- Central sulcus localization
- Direct Electrical Stimulation (ECS)
- Under general anesthesia
- Motor Mapping

Awake Mapping
- Language
- Other cognitive functions
- Somato-sensory
- Visual

Anatomy – Central Sulcus

- Superior frontal sulcus - preCS sign
  - the posterior end of the superior frontal sulcus joins the precentral sulcus in 85%

Superior frontal sulcus
- Precentral gyrus
- Precentral gyrus
- Central sulcus

Observations

- preCS sign
- Naidich & Brightbill
Median SSEP – Central Sulcus

P2: Postrolandic Positivity (preceded sometimes by an initial negativity)


Tibial SSEP

HS1
HS2
HS3
HS4
HS5
HS6

FIGURE 3. Somatosensory-evoked potential (SEP) waveforms in response to right tibial nerve stimulation recorded from the mesial surface of the brain. A black arrow indicates the most prominent positive activity at 4A and AS. Gray arrows point at positive peaks, and open triangles at negative peaks. Notice that the other electrodes show no clear responses.


FMRI in a patient who failed initial epilepsy surgery

SSEPs left posterior tibial

B Plate – phase reversal 4B/5B
C Plate – negativity at 5B (ignore labels – not reset)
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**Median SSEPs:**
- Negativity: A8 > 5, 10, 15 (sensory)
- Positivity: A6/7 > 11 (motor)

Grid repositioned based on SSEPs
No functional mapping performed

**Anesthesia during ECS/ECoG**

**General Anesthesia**
- Electrocorticography:
  - Propofol – discontinue for recording
  - Nitrous oxide – limited effect on EEG
  - Halogenated inhalations agents: MAC < 50%
- Motor Mapping:
  - EMG electrodes
  - No muscle relaxant
  - Cave: Nitrous oxide effect on CMAPs
  - Preferably: TIVA

**Anesthesia during Awake Mapping**

Asleep-awake-asleep (AAA)
- Local anesthesia
- Propofol or dexmedetomidine
- Short acting opioid: fentanyl or remifentanil
- Nasal endotracheal tube, fiberoptic placement

**Electrical Cortical Stimulation**

**Standard Stimulus Settings:**
- Bipolar electrode
- 5mm spaced tip
- 60 Hz
- Pulse duration: 1ms
- Train duration: 1-4 s
  - 1 second: motor
  - 4 seconds: language
- Constant Current
  - Awake: 2-8 mA
  - Under general anesthesia: 6-18 mA

**Intra-operative Functional Mapping**

SSEP
- Central sulcus localization
**Direct Electrical Stimulation (ECS)**
- Under general anesthesia
  - Motor Mapping
- Awake Mapping
  - Language
  - Other cognitive functions
  - Somato-sensory
  - Visual

**Motor Mapping**

Motor Mapping:
Motor Mapping: Challenges

Functional Anatomy
- Cortical
- Subcortical

Stimulation Paradigm
- Awake vs. general anesthesia
- Standard 50 Hz stimulation vs. modification

Brain plasticity
- Preoperative functional reorganization
- Postoperative plasticity: SSMA, face motor, frontal eye field

Subcortical Motor Mapping

Awake vs. general anesthesia
- Standard 50 Hz stimulation vs. modification

Brain plasticity
- Preoperative functional reorganization
- Postoperative plasticity: SSMA, face motor, frontal eye field

EMG mediated Motor Mapping

Seizure during Mapping

Modified Stimulation Protocol

High frequency (250 Hz), short duration train of 5 stimuli, every 2s
**Tractography and modified ECS**

Ohue S et al. Neurosurgery 2012

**Motor Mapping: GA vs. Awake**

- **General anesthesia**
  - Need of EMG electrodes
  - Less demanding for patient
  - Fairly standard anesthesia

- **Awake**
  - With or without EMG electrodes
  - Cooperative patient and anesthesiologist
  - Functional Testing: negative motor signs
  - Functional significance questionable

**Negative Signs**

- **Positive:**
  - Positive motor signs (clonic, tonic)
  - Sensory (in awake patients)
  - Visual

- **Negative:**
  - Language
  - Cognitive function
  - Negative motor signs

**Language Mapping**

- **Clinical Language Testing**
  - Spontaneous Speech
  - Repetition of word, phrases, sentences
  - Speech comprehension
  - Naming
  - Reading
  - Writing

Lezak M, 1983

**Intra-operative Language Testing**

- Most frequently used:
  - Counting
  - Picture Naming: “This is a …”
  - Reading Single Words


**This is a …**
Moonlight

**Arcuate fasciculus:**

dorsal phonological stream

**Inferior occipito-frontal fasciculus**

**Inferior occipito-frontal fasciculus**

**Intra-operative Language Testing**

- Easy to add:
  - Spontaneous speech
  - Repetition
  - Calculation

- More difficult in OR setting:
  - Comprehension (e.g. Token Test)
  - Writing

**Dominant Angular Gyrus - Calculation**

- Simple multiplication problems: single digit multiplications with one operand < 6 (4x4; 3x7; 2x6; 5x8 ...)
- Subtraction from 1 or 2 digit numbers (96 – 7, then 9 – 7 ...)
- Alternating multiplication/subtraction
- Blocks of 3: non-stimulated/stimulated/non-stimulated
- Patient blinded to stimulation
- Never to trains of stimulation in a row
- Three tasks per side

**Comprehension: Simple Token Test**


Duffau H et al. JNHP 2003
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Negative Mapping

Sanai N, NEJM 2008

Outcome: Negative Language Mapping

<table>
<thead>
<tr>
<th>Language</th>
<th>250 Pre-op</th>
<th>1 wk Post</th>
<th>1 mo</th>
<th>3 mo</th>
<th>6 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>159 (63.6%)</td>
<td>None</td>
<td>8 (3.2%)</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Deficit</td>
<td>91 (36.4%)</td>
<td>Worse</td>
<td>21 (8.4%)</td>
<td>16 (6.4%)</td>
<td>6 (2.4%)</td>
</tr>
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Summary

- Intra-operative mapping with SSEP, ECS and during awake craniotomy remains an essential component of epilepsy and brain surgery close to eloquent cortex, despite advancements in preoperative noninvasive mapping techniques.
- The approach to motor and language mapping is variable for different centers and further research is needed to optimize existing strategies.
- Stimulation protocols and well prepared testing materials are important to allow reliable and efficient mapping under intraoperative time restraints.

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