Introduction to EEG

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What is EEG?

• A graphic representation of the difference in voltage between two different cerebral locations plotted over time

• The scalp EEG signal generated by cerebral neurons is modified by
  • The electrical conductive properties of the tissues between the electrical source and the recording electrode on the scalp
  • The conductive properties of the electrode itself
  • The orientation of the cortical generator to the recording electrode
How is EEG Useful?

- Seizures
  - vs “spells”
  - Subclinical
  - Neonatal
- Epileptic syndromes
- Encephalopathic states
  - Metabolic
  - Anoxic
  - Death
- Dementing disorders
  - Prion disease
  - Viral encephalitides

EEG Spinoffs

- Sleep-deprived EEG
- Ambulatory EEG
- Video/EEG
- Electrocorticography
- Stereoecephalography
- Polysomnography
- QEEG and source localization
- EP’s
- MEG
General Principles

• Volume conduction

The EEG can be obtained because of the process of current flow through the tissues between the electrical generator and the recording electrode.

Cortical Generators

• It takes a combined synchronous electrical activity of approximately 108 neurons in a cortical area of about 6cm^2 to create visible EEG.
• The area of cortex required for the generation of interictal spikes may be as large as 20cm^2.
• EEG fields are primarily generated by the large, vertically oriented pyramidal neurons located in cortical layers III, V, and VI.
• Because of the attenuating properties of the skull, spatial, i.e. tri-dimensional summation of cortical activity, is critical for producing a voltage field recordable from the scalp.
Intrinsic Neuronal Sources of EEG

- Short lasting (< 2 ms), high amplitude individual fast (Na+) action potentials do not contribute to scalp-recorded potentials except during synchronous events
  - Physiologic such as sleep transients
  - Pathologic such as epileptic activity
- Calcium-mediated action potentials (calcium spikes) are voltage-generated and occur synchronously with dendritic EPSPs
  - They can contribute to the creation of the dendritic field sinks especially during epileptiform activity

Synaptic Sources of EEG

- The most significant source of EEG potentials is synaptic activity
- Each synapse acts like a battery, driving current in a small loop
- Both excitatory postsynaptic potentials (EPSPs) and inhibitory postsynaptic potentials (IPSPs) contribute to the synaptic activity recorded as EEG
Cortical Generators of EEG

The principal generators of EEG fields measured on the surface of the brain or at the scalp are graded synaptic potentials, i.e., EPSPs and IPSPs of the pyramidal neurons. At the synaptic site of an EPSP there is an active current sink (extracellular negative field). Positive ions migrate to the cell and depolarize the membrane. At the distal part of the cell (body and distal dendrites) a passive current source out of the cell is associated with extracellular positive field.

Cortical Generators

The EEG as a measure of spatially and temporally averaged activity of a large population of neurons favors the contribution of synchronously oscillating bipolar sources, while even high amplitude asynchronous activity may cancel itself.
Cortical Generators

The dorsal thalamus is considered the chief subcortical EEG rhythm generator synchronizing populations of neocortical neurons.

In normal conditions, both thalamic nuclei and cortical regions interact to produce the synchrony of cortical postsynaptic potentials (PSPs) during wakefulness and sleep.

Subcortical Synchronization of EEG

- The dorsal thalamus is considered the chief subcortical EEG rhythm generator synchronizing populations of neocortical neurons.
- In normal conditions both thalamic nuclei and cortical regions interact to produce the synchrony of cortical postsynaptic potentials (PSPs) during wakefulness and sleep.
- Local cortical connections seem to be more important in generating most alpha-frequency rhythms, although thalamo-cortical discharges may have limited influence on posterior dominant alpha rhythm.
EEG Technical Aspects

FIG. 12. Block diagram of major functional units of EEG machine. Filters and amplifiers are contained in EEG amplifier units.

Technical Aspects

Elective Session
EEG Frequencies

- Alpha (8-12 Hz)
- Beta (13-90 Hz)
- Delta (0.5-3 Hz)
- Theta (4-7 Hz)

Orderly Approach

- Frequencies
- Amplitudes (qualitative)
- Special waveforms
- Regulation
- Manner of occurrence
- Site
- Reactivity
- Interhemispheric coherence
  - Symmetry
  - Synchrony
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10/20 System

A

B

Referential vs Bipolar

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EEG Display

Age and Alpha Rhythm

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Normal Adult Awake

Muscle Potentials

Elective Session

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Hyperventilation

- Deep breathing at 20/min for 2-5 min
- Causing hypocapnea and cerebral vasoconstriction
- Causes polymorphic delta slowing (100-300 mcV)
- Abnormal if focal activity present

Hyperventilation: Which Are Incorrect?

1. More prominent response if serum glucose is low (<80 mg/dL)
2. More prominent response in supine position
3. More prominent response if the person is tall, white, thin and young
4. HV does not produce ep discharges in focal epilepsy
5. In children, delta slowing occurs diffusely, while in adults it occurs more posteriorly
6. The effect dissipates within 30 seconds
Hyperventilation: Answer

• More prominent effects on:
  • Younger, taller, thinner
  • Lower serum glucose (<80 mg/dL)
  • Erect position
  • Generalized epilepsy syndrome (rarely in partial onset)

• Build-up
  • Children: more prominent in occipital region
  • Adults: more prominent frontally
  • Dissipates within 60 seconds
Things You Can’t Miss

- Focal spikes
- Gen S&W
- PCR
- Focal slowing
- Diffuse slowing
- Burst-suppression
- ECS

Focal Spikes

Elective Session
Photic Stimulation

- Strobe light with 1.5 mil cd, duration of 10 µsec
- Distance of 20-30 cm
- IPS responses:
  - Photic driving: time locked occipital rhythmic activity (O)
  - Photoelectric artifact: due to light molecules (F)
  - Photomyogenic or photomyoclonic response: facial muscle contraction esp. in anxious person (F)
  - Photoconvulsive or photoparoxysmal response (O)
  - Abnormal if outlasts more than a few seconds

Photic Driving Response

96% of people with photosensitive epilepsy are sensitive to lights flashing at between 15 and 20 flashes per second
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Photomyogenic Response

Focal Slowing
Diffuse Slowing

Burst Suppression

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PEDs

Bi-PLEDs

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**Triphasic Waves**

<table>
<thead>
<tr>
<th>Fp2 - F8</th>
<th>F8 - T4</th>
<th>T4 - T6</th>
<th>T6 - O2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fp2 - F4</td>
<td>F4 - C4</td>
<td>C4 - P4</td>
<td>P4 - O2</td>
</tr>
<tr>
<td>Fz - Cz</td>
<td>Cz - Pz</td>
<td>Pz1 - F3</td>
<td>F3 - C3</td>
</tr>
<tr>
<td>C3 - P3</td>
<td>P3 - O1</td>
<td>Fp1 - F7</td>
<td>F7 - T3</td>
</tr>
<tr>
<td>T3 - T5</td>
<td>T5 - O1</td>
<td>ECG</td>
<td>50 μV/1 s</td>
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**Normal Sleep Phenomena**

<table>
<thead>
<tr>
<th>Fp1 - F4</th>
<th>F4 - F2</th>
<th>F2 - F1</th>
<th>F1 - F3</th>
<th>F3 - F5</th>
<th>F5 - F7</th>
<th>F7 - A2</th>
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<tbody>
<tr>
<td>F2 - T4</td>
<td>T4 - C4</td>
<td>C4 - C2</td>
<td>C2 - C4</td>
<td>C4 - C2</td>
<td>C2 - C4</td>
<td>C4 - C2</td>
</tr>
<tr>
<td>C4 - T5</td>
<td>T5 - A1</td>
<td>A1 - T6</td>
<td>T6 - P4</td>
<td>P4 - T6</td>
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<td>P3 - P2</td>
<td>P2 - P3</td>
<td>P3 - P2</td>
</tr>
<tr>
<td>T2 - Cz</td>
<td>Cz - T2</td>
<td>T2 - Cz</td>
<td>Cz - T2</td>
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**Elective Session**
Normal Paroxysms

- Arrhythmic
  - Lambda activity
  - Posterior slow waves of youth
  - Wicket spikes
  - Sleep
  - Small Sharp Spikes
  - Vertex waves
  - POSTS (Positive Occipital Sharp Transients of Sleep)

Lambda Activity

Elective Session
Posterior Slow Waves of Youth

Wicket spikes

Elective Session
Normal Paroxysms

- Rhythmic
  - Slow alpha variant
  - Mu rhythm
  - Arousal patterns
  - Rhythmic Mid-temporal Discharges
  - 14 & 6 Positive spikes
  - 6/sec spike and wave
  - Vertex spindles
  - SREDA (Subclinical Rhythmic Electrographic Discharges of Adults)
Slow Alpha Variant

Mu Rhythm

Elective Session
Arousal Patterns

Rhythmic Mid-Temporal Discharges

FP1-F7
F7-T3
T3-T5
T5-O1
FP2-F8
F8-T4
T4-T6
T6-O2

Headaches

40 μV
1 sec
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14&6 Positive Spikes

6/sec Spike and Wave

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Midline Theta & Vertex Spindles

SREDA

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Clinical Report

- Is the EEG normal or a variant?
  - no
  - yes
    - Compare with clinical data
    - Are findings as expected?
      - no
      - yes
        - Assess meaning and make recommendations
        - Specify general character of rhythms and waveforms:
          - Focal
          - Regional
          - Diffuse
          - Lateralized
          - Combination
          - Epileptiform
          - Non-epileptiform
          - Amplitude
          - Frequency of occurrence
          - Relation to state of alertness
          - Reactivity

Elective Session