Basic EEG

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Electroencephalography (EEG)

- Measure spatial distribution of voltage fields and variation over time
- Sum of excitatory and inhibitory postsynaptic potentials from apical dendrites of pyramidal cells in outer layer of cerebral cortex
- Modified by input from subcortical structures, e.g. thalamus, ascending reticular activating system
Transmembrane potential (depolarization) results in excitatory post-synaptic potentials typically on dendrites.

Local hyperpolarization leads to inhibitory post-synaptic potentials typically on neuron cell body.

Combination of EPSP and IPSP induces currents within and around the neuron and potential field recordable on the scalp. Duration of PSP 100ms ≈ average alpha wave.
Polarity

- The dendritic generators have two poles (dipole: + and -) and are oriented vertically.
- Scalp electrode signal detection requires synchronous discharge in approximately 10cm² of cortex.
- Differential amplifier records potential difference between two scalp electrodes.
- Upward deflection when input 1 is relatively negative compared to input 2.
### Polarity on single derivation

<table>
<thead>
<tr>
<th>Input 1</th>
<th>Input 2</th>
<th>Difference</th>
<th>Deflection</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 50</td>
<td>+ 80</td>
<td>− 30</td>
<td>Up</td>
</tr>
<tr>
<td>+ 50</td>
<td>+ 30</td>
<td>+ 20</td>
<td>Down</td>
</tr>
<tr>
<td>+ 50</td>
<td>+ 50</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>+ 50</td>
<td>-50</td>
<td>+ 100</td>
<td>Down</td>
</tr>
</tbody>
</table>
Montage

• Montage is a collection of derivations for multiple channels recorded simultaneously and arranged in a specific order
• Scalp electrodes applied according to the International 10-20 System
• Fp (frontopolar), F (frontal), C (central), P (parietal), O (occipital) and T (temporal)
• Odd numbers (left), even (right), A (ear)
The 10-20 International System of Electrode Placement
The 10-20 International System of Electrode Placement
Referential recording
- Common reference (e.g. ear, vertex), second input is always the reference
- Locate the site of maximal involvement when the reference is inactive
- Reference electrode may not be inactive

Bipolar recording
- Measure difference between nearby points (e.g. anterior-posterior, transverse)
- Localization by phase reversal
- Amplitude means potential difference, not necessarily the most active site
Bipolar recording
Normal EEG

- Maturational changes, wakefulness, drowsiness and sleep, background rhythm, symmetry
- **Delta** – frequencies below 4 Hz, during sleep in adults, in temporal region during wakefulness and generalized maximal anterior during drowsiness in normal elderly
- **Theta** – 4 Hz to less than 8 Hz, in children and young adults during wakefulness, during drowsiness in adults
- **Alpha** – 8 to 13Hz, posterior dominant rhythm, relaxed and eye closed during wakefulness, sinusoidal, right side higher
- **Beta** – above 13 Hz, most prominent anteriorly, increased during drowsiness, barbiturates, benzodiazepines
- **Normal sleep activity** (Vertex waves, spindles, positive occipital sharp transients of sleep, K complexes, delta)
EEG analysis

- Frequency
- Voltage
- Location
- Morphology
- Polarity
- State
- Reactivity
- Symmetry
- Artifact
Alpha rhythm
Beta rhythm
Vertex wave and sleep spindle
Posterior occipital sharp transients of sleep (POSTS)
K complex and POSTS
Lambda waves (occipital positive potentials in visual scanning)
Mu rhythm (7–11 Hz) from sensorimotor cortex, in wakefulness and drowsiness, asynchronous, asymmetric
Lateral eye movement in drowsiness
Encephalopathy

- Slowing of alpha rhythm, excess slowing during wakefulness, loss of alpha rhythm, loss of normal sleep transients, abnormal arousal pattern, frontal intermittent rhythmic delta (FIRDA), loss of normal variability, loss of reactivity to stimuli, burst suppression, electrocerebral inactivity
- Generalized periodic discharges 1Hz in dementia and myoclonus (CJD), triphasic waves, periodic lateralized epileptiform discharge (PLED) in HSV and stroke, generalized periodic epileptiform discharges (GPED) in post anoxia, SE and drugs; burst suppression (drug)
Breach rhythm (left side skull defect)
Attenuation of background activity (cerebral contusion)
Diffuse slowing post head trauma
Reactivity to sound (attenuation)
Reactivity (attenuation followed by delta activity)
Frontal intermittent rhythmic delta activity
Focal slowing and sharp waves due to cerebral tumor
Triphasic waves in hepatic encephalopathy
Right cerebral infarction in acute renal failure
Generalized polyspikes in myoclonic status epilepticus
Burst suppression pattern (post cardiac arrest)
Alpha coma (frontal, non-reactive)
Electrocerebral inactivity
Seizures in ICU

• Prevalence higher in those after convulsive status epilepticus and in neurological ICU
• Seizures in encephalopathy tend have slower frequencies, less defined onset and offset
• Diagnosis of seizure activity requires evolution in frequency, morphology or location of EEG pattern, possibly also clinical condition of the patient
• Evolution may be subtle, differentiation between ictal and interictal can be difficult
Seizure activity begins on left side
Clinical (convulsive) and electrographic seizure
Seizure ends
Nonconvulsive status epilepticus (focal)
Nonconvulsive status epilepticus (generalized)
Burst suppression on barbiturate
Diffuse slow activity
Generalized spikes and polyspikes
Generalized nonconvulsive status epilepticus
Periodic lateralized epileptiform discharge (PLED)
PLED evolved into electrographic seizure
Seizure activity ends
Artifacts that mimic seizures

Physiological
- Ocular – Movement, electroretinogram
- Muscle
- Sweat
- Tongue and mouth – Glossokinetic potential
- Vascular – ECG, pulse
- Movement – tremor, respiration
- Skull defect

Non-physiological
- Electrodes – disc, wire
- External source – 50Hz, ICU equipment
- Machine – Amplifier, setting
- Patient care – percussion, suctioning
Muscle artifact (relative sparing in mid line derivations)
Muscle artifact (shivering)
Filtered muscle artifact
Muscle artifact (chewing movement)
Snore artifact (groups of fast activity, mid line sparing)
Eye movement (fast down and slow up)
Sweat artifact (irregular delta activity slower than 1Hz)
Electrode artifact (mirror image)
Pulse artifact and electrode artifact
Rhythmic artifact (on hemodialysis)
Respirator artifact
F/29. Admitted for repeated convulsion. There was asymmetric limb twitching, pelvic thrusting and difficulty in open the eyes for examination. What did the EEG show? What may help to confirm the diagnosis?

Proposed answer: Normal posterior dominant alpha activity
M/35. Known epilepsy post head trauma and neurosurgery. Brought to A&E for convulsion. The patient was paralyzed and intubated in A&E, transferred to ICU and connected to ventilator. What did the 16-channel EEG show?

Proposed answer: Generalized electrographic seizure activity
F/26. Admitted ICU for status epilepticus. Convulsion stopped after put on propofol iv infusion. What did the EEG show and what would you do?

Proposed answer: Generalized electrographic seizure activity, increase antiepileptic
F/56. Known SLE and cerebral lupus on gabapentin. Admitted ICU for low BP and neutropenic fever. Gabapentin was withhold. Noted mental dullness. The following EEG disappeared after midazolam 2mg iv. What was the diagnosis?

Proposed answer: Muscle artifacts
M/61. Admitted for fever and confusion. CSF showed lymphocyte pleocytosis, mild elevation in CSF protein and normal blood glucose. What was the clinical possibility and what did the EEG show?

Proposed answer: Herpes simplex encephalitis, periodic lateralized epileptiform discharge (left)
F/62. End stage renal failure. Admitted for CAPD peritonitis. On cefepime for E.Coli in PD fluid. Noted mental dullness and mild limb twitching. What did the EEG show and what was the possible diagnosis?

Proposed answer: Clinical and electrographic seizure, triphasic waves, possibly cefepime related.
F/47. Presented with weight loss, poor memory, delusional disorder, ataxia and myoclonus. What did the EEG show? What was the possible diagnosis? What differential diagnosis has to be excluded?

Proposed answer: Creuzfeldt-Jacob disease, Hashimoto’s encephalopathy
M/57. Admitted for acute ischemic stroke. Noted impaired conscious state and recurrent right side focal convulsion. What did EEG show?

Proposed answer: Attenuation and slow rhythm on left side
F/50. Post renal transplant on Tacrolimus. Admitted ICU for repeated tonic-clonic convulsion. What did the EEG show and what was the likely diagnosis?

Proposed answer: Sharp and slow waves, consider posterior leucoencephalopathy syndrome
M/42. Admitted ICU post ROSC after 20min of CPR for sudden cardiac arrest due to VF. Remained comatose. EEG monitoring on therapeutic hypothermia. What did the EEG show and what would be the prognosis of this patient?

Proposed answer: Reactivity, favorable
References

• Prognostic value of continuous EEG monitoring during therapeutic hypothermia after cardiac arrest. AO Rossetti et al. Critical Care 2010 (14): R173
• EEG recordings of Electrodiagnostic Unit and ICU of Caritas Medical Centre for construction of scenarios