The normal Electroencephalography (EEG)

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Biophysical aspect of EEG

• Source of EEG activity
• Pyramidal cell
• EEG recorded one side, which adjacent to cortical surface, of a dipole.
• EEG recorded neuron population potentials (EPSPs, IPSPs)
• Time dilatation
Glutamate, Acetylcholine

Synapse

GABA

Excitatory post-synaptic membrane potential (EPSP)

Inhibitory post-synaptic membrane potential (IPSP)
Pyramidal cell works as a dipole.
Dipole

EEG: Recorded neuronal synchronization (EPSP and IPSP)

Time dilation
Orientation of Electrical field

At least 6 square cm of cortex must be activated in order for scalp EEG to detect a change in potential.
- Referential montage
  - Referential Cz
  - Referential ears
- Average reference montage
- Bipolar montage
  - AP longitudinal bipolar
  - Transverse bipolar
- Laplacian montage

Facts about Normal EEG

• Normal patterns
• No abnormal pattern
• Does not guarantee if brain has an exactly normal function.
• Normal variants
  • Between persons of the same age
  • More in wake than sleep
Steps of reading EEG

• Patient’s age
• State of consciousness

• Description of EEG activity
  • Dominant rhythm
  • Location/ Distribution
  • Reactivity (highly responsive, nonresponsive)

• Symmetry, synchrony, Regularity
• Quantity (continuous, Intermittent)

• Frequency
• Amplitude (millimeter) = voltage/sensitivity
• Wave form
  • Rhythmic, periodic, arrhythmic
  • Morphology (spike, sharp, biphasic, triphasic)
Posterior dominant rhythm: Ages dependence

- 4 months: 4 Hz
- 5 months to 1 year: 5-6 Hz
- 3 years: 8 Hz (>80% of age group)
- 9 years: 9 Hz
- 15 years: 10 Hz

- Term newborn: Chronological age
- Pre-term newborn: Conceptional age
Range of EEG waveforms

1. REGULAR, RHYTHMICAL WAVES (DELTA, THETA)
2. SINUSOIDAL WAVES (THETA to GAMMA)
3. SPINDLES (ALPHA, BETA)
4. IRREGULAR, ARRHYTHMICAL WAVES
5. COMPLEXES

Frequency (Hz)
- 1-3 delta
- 4-7 theta
- 8-12 alpha
- 13-30 beta gamma
- 30-100 ripples

Wave length
- 8-13 mu
- 11-16 spindle

Fisch, 1999

Bazhanov & Timofeev (2006)
Awake EEG

- Beta wave
- Alpha wave
- Mu rhythm
- Theta activity (in young age group)
- Physiologic artifacts in awake
Beta waves

- 13-30 Hz
- Amplitude < 20 uV
- Diffusely, more prominently in the frontal regions
Beta waves

• 13-30 Hz
• Amplitude < 20 uV
• Location: Diffusely, more prominently in the frontal regions

• More common in infants and young children less than 1 ½ years old.
• Enhanced by sedative, hypnotic, or anxiolytic drugs
  • Not dose dependent but up to individual’s sensitivity
• Enhance in a region of skull defect called “Breach rhythm”.
Alpha waves

- 8-12 Hz
- Sinusoidal wave forms
- 15-45μV
- posterior half of the head
- Reactivity: Eye closed/ eye opening
Blocked or attenuated by eye opened, attention, especially visual and mental effort.
Alpha rhythm, neurophysiological rhythm

• Frequency (age dependence):
  • about 1 Hz different between Rt./Lt. hemisphere
  • ¼ of normal adults, alpha rhythm is poorly visualized

• Morphology: Rounded or Sinusoidal wave forms

• Amplitude:
  • Right > Left
  • Age dependence
  • variable, mostly < 50uV (15-45uV)
  • 6-7% of normal adults showed voltage of < 5 uV
Alpha rhythm, neurophysiological rhythm

• Location:
  • Posterior half of the head; occipital, parietal, posterior temporal regions
  • Might extend into central region (Demonstrable by attenuation by eye opening)
  • May occasionally extend to F3,F4 but not Fp1, Fp2. (May be prominent in referential montages.)
Alpha rhythm, neurophysiological rhythm

- Reactivity:
  - Eye closed/ eye opening
  - Blocked or attenuated by attention, especially visual and mental effort.
  - Best seen in relative mental inactivity, physical relaxation
  - Extreme upward gaze tends to facilitate the posterior alpha rhythm (Mulholland, 1969; Mulholland and Evans, 1965)
  - Lateral eye deviations may have similar effects (Fenwick and Walkier, 1969).

- Squeak effect
Clinical correlation of alpha rhythm

• Slowing of the alpha is one of the earliest signs of diffuse brain injury.

• Alpha amplitude asymmetry of > 50% indicates focal injury to the hemisphere having lower amplitude.

• Some drugs could induce slow background
  • Phenytoin
  • Carbamazepine
**Mu rhythm**

- Rest-state of motor neurons
- 8-13 Hz, Alpha activity in central region, arc-like central rhythm
- Often asynchronous, asymmetry

- Blocked by contralateral limb movement, intension of movement, sensory stimulation and mental activity

- Commonly seen in adolescents and young adults (17-19%)
- Less commonly in elderly and children less than 4 years old
Theta activity

• 3.5-8 Hz

• Awake state
  • Small amount theta 6-7 Hz mixed with alpha
  • Frontal, frontocentral regions

  • Fm theta rhythm at the Frontal region
    • Relation to mental calculation, reading, etc.
    Yamaguchi Y et al, 1985

• Theta, midline theta rhythm
  • Temporal lobe epilepsy
    Ciganek et al, 1961
  • ¼ of non-epileptic group
    Westmoreland BF et al, 1985

• Sleep state
Theta activity in young age group

Girl, 6 y/o

Small amount theta 6-7 Hz mixed with alpha
Delta activity

- Posterior slow wave of youth
  - Young children to 20 years old or could be late as 25 years old
  - Maximum at 9-14 years old
  - Uncommon in age group less than 2 years old

- Amplitude not > 1.5 time of alpha rhythm or > 200 uV

- Attenuated by eye opening
- May be accentuated by hyperventilation or stress

- Consistent or persistent as ORIDA
Posterior Slow Wave of Youth (PSWYs)
Sleep EEG

• Non-Rapid Eye Movement (NREM) sleep
  • Stage 1: Drowsiness
  • Stage 2
  • Stage 3: Slow Wave Sleep > 20 - 50%
  • Stage 4: Slow Wave Sleep > 50%

• Rapid Eye Movement (REM) sleep

Stage 3: SWS > 20%
Sleep stages

Slow down muscle activity, muscle twitching

90-120 minutes / cycle
5-7 cycles/night

Adapted from www.centerforsoundsleep.com
Sleep NREM stage 1 (drowsiness)

• EEG activity in Transitional state
  • Attenuated alpha activity, 4-7Hz (Theta activity)
  • low amplitude, mixed frequency, waning of waking background

• Posterior Occipital Sharp Transient of sleep (POSTs)
  • Appear around ages 3 – 4 y/o

• Vertex wave
  • First appear at 6-8 weeks post term

• Slow rolling eye movements (< 0.5 Hz)
• Reduction of muscle artifact

• Hypnagagic hypersynchrony
• Hypnapompic hypersynchrony
Posterior Occipital Sharp Transients of sleep (POSTs)

- Fragmented background
- Attenuated alpha activity
- Increase in frontocentral region, occipital theta
- Fragmented background
Vertex (V) wave

Maximum amplitude at Cz, C3, C4

Might asymmetry but not persistent

At the end of stage 1 or beginning of stage 2

Bilateral synchronous diphasic sharply contour waves
Asymmetrical V wave
Vertex (V) sharp waves

• Bilateral synchronous diphasic sharply contour waves in central regions
  • initial negative / then positive deflection
• Appear by 6-8 weeks post-term
• Abnormal:
  • Persistent asymmetry >20%
  • Asynchrony : in hydrocephalus,
Repetitive V waves

8 years old
Slow rolling eye movements <0.5 Hz
Slow rolling eye movements (reference montage)
Hypnagogic hypersynchrony

Rhythmic bilateral synchronous high amplitude theta with widely distribution
Hypnagogic

- Abrupt onset during drowsiness

Hypnagogic hypersynchrony

- Rhythmic bilateral synchronous theta burst with widely distribution
- Amplitude 200-300 uV

- Most prominent at around 1 year, decrease toward 10 years old

Hypnapompic

- Associated with brief arousal from light sleep
NREM stage 2

• K complexes
  • A well-delineated diphasic wave, negative followed by positive
  • Duration \( \geq 0.5 \) seconds
  • Maximum amplitude in frontal derivations

• Sleep spindles
  • A train of sinusoidal waves, 11-16 Hz (most commonly 12-14Hz)
  • Maximum amplitude in central derivations
K complexes—sleep spindle

- Diphasic wave
- Usual symmetry, max-frontal
- Duration >=0.5 seconds
Sleep spindle

![Graph showing EEG activity with a spindle waveform at 12-14 Hz, central]
Spindle
12-14 Hz, central
V-waves
NREM stage 2

- K complexes
  - First appear between 8 and 12 weeks post-term
  - Spontaneous or in response to abrupt sensory stimulus (usually auditory)
NREM stage 2

• Sleep spindles
  • A burst of oscillatory brain activity
  • First appear between 6 and 8 post term; bilateral asynchronous
  • At age of one and a half years (18 months); bilateral synchronous
  • At age of 2 years; asynchronous = abnormal

• Three types:
  • Central 14 Hz: adults sleep, spindle coma
  • Frontal 10-12Hz: 5% of normal kids 3-12 years old
  • Nearly continuous 10Hz: related to drug effect (morphine)
K complexes with arousal

Fast component in adult: 8-10 Hz
Arousal

Fast component in adult: 8-10 Hz
Arousal

• Post 2 months → slow component
• Post 7 months → 4-4.5 Hz
• Adult → 8-10 Hz
NREM stage 3 (Slow Wave Sleep)

• Wave frequency 0.5-2 Hz (Delta activity)
• Peak to peak amplitude > 75 uV (frontal regions)
Slow wave sleep

High voltage >75 uV
Polymorphic, asynchronous
Slow wave - Delta activity (0.5-2Hz)
Slow wave sleep
Before Rapid Eye Movement (REM) sleep

• Saw tooth waves
  • Trains of 2-6 Hz sharply contour, triangular wave
  • Maximum amplitude over central head region

• Do not usually found in REEG
Sawtooth waves (15 sec/page)

- Trains of 2-6 Hz sharply contour, triangular wave
- Maximum amplitude over central head region
**REM -phasic**

Chaotic, multidirectional eye movement

- **Poorness EMG artifact**

- **Low voltage**

- Mixture of fast, theta, and delta rhythms, usually alpha activity 1-2 Hz slower than awake

Without K or sleep spindle
REM - tonic
Pediatric awake EEG

- Full term to age of 3 months old
  - Mixed delta-theta activities with central predominance
- 3 months old to 1 year old
  - Clearly identified PDR followed age groups
- 1–19 years old
  - Similar to adults
  - Higher amplitude than adults
Sleep EEG

Pediatrics
- NREM sleep
  - Hypnagogic/ Hypnapompic hypersynchrony
  - Arousal response
  - POSTs
  - Vertex sharp waves
  - K complexes
  - Sleep spindle
  - Slow Wave Sleep
- REM sleep

Adults
- NREM sleep
  - Arousal response
  - POSTs
  - Vertex sharp waves
  - K complexes
  - Sleep spindle
  - Slow Wave Sleep
- REM sleep
THANK YOU