Normal EEG in children

EEG workshop

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Electrode placement

• International 10-20 system
  – Minimum 21 electrodes
  – Odd-numbered electrodes are placed on the left side of the head, and even-numbered electrodes are placed on the right side of the head
  – Specific letters designate the anatomical area; for example “F” means frontal
International 10-20 system

Common Montage types

The difference in voltage between two electrodes

- **Bipolar:**
  Each channel represents difference between 2 adjacent electrodes
  - AP bipolar
  - Coronal / transverse bipolar

- **Referential:**
  Each channel represents the difference between a certain electrode and the designated reference position
  - ipsilateral ear
  - average
  - midline, etc.
AP bipolar montage (double banana): for localization

Referential montage: for amplitude measurement
EEG activity

- Waveform
- Frequency
- Amplitude
- Polarity
- Timing

Wave form

- Spike
  - Sharply contoured, duration 20-70 msec
- Sharp wave
  - Sharply contoured, duration 70-200 msec
- Sharp transient
  - Sharply contoured waveform
- Other morphology
  - spindles, arciform, saw-tooth
Wave form

- Monophasic wave
  - Single deflection: up or down

- Diphasic wave
  - 2 components on opposite sides

- Polyphasic wave
  - 2 or more components of different direction

Frequency

- Delta wave  < 4 Hz
- Theta wave  4-7 Hz
- Alpha wave  8-13 Hz
- Beta wave   > 13 Hz
Amplitude

Total vertical distance of wave

- Low < 20 μV
- Medium 20-50 μV
- High > 50 μV

Affected by barriers

Distribution

- Generalized / diffuse
- Lateraled
- Focal / localized
Polarity

Bipolar (input 1 – Input 2)
- Upward pen deflection
  - when input 1 is more negative than input 2
  - when input 2 is more positive than input 1
- Downward deflection
  - when input 1 is more positive than input 2
  - when input 2 is more negative than input 1

Referencial (Input 1 – Ref)
- negative is up and positive is down

Timing

- Synchronous
- Bilaterally synchronous
- Asynchronous
- Independent
Pediatric EEG

EEG in newborn

- Post conceptional age
- Duration at least 60 minutes
- Awake / Active sleep / Quiet sleep

- Continuity / Synchrony
- Symmetry / Reactivity
- Normal specific EEG pattern
Awake

• Posterior dominant rhythm (PDR)
• Posterior slow wave of youth (PSWY)
• Mu rhythm
• Beta activity
• Lambda wave

• Eye movement
• Artifact

PDR

• Alert, eye-closed, in rest state
• First seen at 3 months of age
• Maximum posterior head region
• Reactivity
  – Attenuation with eye opening, ± anxiety
PDR

- Higher amplitude over right hemisphere (< 50% difference) due to asymmetric skull thickness
- Amplitude ~ 50-100 μV
- Decreasing amplitude with increasing age due to increased bone density of the skull
PDR

Frequency in Children

3-4 months: 4 Hz
12 months: 5-6 Hz
2 years: 7 Hz
3 years: 8 Hz
9 years: 9 Hz
15 years: 10 Hz

PSWY

• Slow activity intermixed with PDR
• Moderate voltage (<120% of normal alpha rhythm voltage )
• May be asymmetry
• Best seen in 8-14 years

• Block with eye opening
• Disappear with the alpha rhythm during drowsiness and light sleep
Mu

- central arch-like rhythm of alpha frequency (usually 8-10 Hz)
- May be related to the functions of the sensorimotor cortex at rest
- Best seen between 8-16 years
- Asymmetrical

- Blocked unilaterally with movement of the contralateral extremity
- Not blocked by eye opening
Mu rhythm

- Frequencies more than 13 Hz
- Amplitude < 20 uV, usually < 10 uV
- Three band
  - 18-25 Hz band (common)
  - 14-16 Hz band (less common)
  - 35-40 Hz band (rare)

Increased by
- Drugs eg. barbiturate, benzodiazepine, chloral hydrate
  (18-25 Hz > 14-16 Hz)

Beta

- Frequencies more than 13 Hz
- Amplitude < 20 uV, usually < 10 uV
- Three band
  - 18-25 Hz band (common)
  - 14-16 Hz band (less common)
  - 35-40 Hz band (rare)

Increased by
- Drugs eg. barbiturate, benzodiazepine, chloral hydrate
  (18-25 Hz > 14-16 Hz)
**Beta due to medication**

**Lambda wave**

- Surface positive, check mark-like wave
- Occipital region
- During eye opening
- Visually scanning at complex picture (ceiling, TV etc.) with saccadic eye movement

- Best seen in 2-15 years
- May be asymmetrical
Lambda

Eye movement (EM)

Vertical EM (Fp1, Fp2)
- Eye opening
- Eye closure
- Eye blinking

Horizontal EM (F7, F8)
- To the left
- To the right
Eye movement (EM)

• Cornea $\rightarrow$ positivity
• Retina $\rightarrow$ negativity

• Nearest electrode of the direction of EM will pick up positivity, the opposite electrode will pick up negativity

Vertical EM

• Eye closure (relatively eyes go up)
  $\rightarrow$ Fp1 and Fp2 pick up positivity
  $\rightarrow$ downward deflection at Fp1-F7, Fp2-F8

• Eye opening (relatively eyes go down)
  $\rightarrow$ Fp1 and Fp2 pick up negativity
  $\rightarrow$ upward deflection at Fp1-F7, Fp2-F8
Eye closed            Eye opening

Horizontal EM

• Eye turn to the left
  → F7 pick up positivity, F8 pick up negativity
  → positive phase reversal at F7 (Hole)
  → negative phase reversal at F8

• Eye turn to the right
  → F8 pick up positivity, F7 pick up negativity
  → positive phase reversal at F8 (Hole)
  → negative phase reversal at F7
Sleep

Non-REM sleep
• Stage 1 (drowsiness)
• Stage 2
• Stage 3 & 4

REM sleep

Stage 1

• Alpha drop out
• Hypnagogic hypersynchrony
• POSTs
• Beta activity
• Vertex wave
Hypnagogic hypersynchrony

- Burst of generalized high voltage 3-5 Hz
- Maximum fronto-central
- Awake → sleep
- Begin 6 months
- Best seen 1-5 years
- Rare after 11-12 years

- Hypnapompic: sleep → awake
POSTs

- Positive occipital sharp transients of sleep
- 4-5 Hz, checkmark-like, isolated or in trains
- Esp. daytime nap, arousal → return to sleep
- Commonly asymmetry

- Age 4-50 years
- Best seen 15-35 years
**POSTs**

**Vertex wave**

- Sharp transient maximum Cz (vertex)
- Begin 8 weeks post term
- Age 1-4 years; spiky and high amplitude
- Runs of vertex
Stage 2

- Sleep spindles
- K-complex
- Delta wave
- (Vertex, POSTs)
Sleep spindles

- 11-14 Hz
- Maximum central, frontal (Cz, C3C4, F3F4)
- 2-5 seconds duration, may be spiky
- Lack of fusiform shape as in adult

- Begin 6-8 weeks post term; asynchronous but symmetrical
- Age 2 years; synchronous
K-complex

1. Vertex + spindles

2. Biphasic high amplitude slow wave
   > 0.5 seconds duration
   - Maximum Cz (vertex)
   - Begin 5 months
Stage 3 & 4

- Delta activity
  20-50% $\rightarrow$ stage III
  > 50% $\rightarrow$ stage IV

- (Sleep spindles)

Slow wave sleep
REM

• Sleep onset in newborn until 2.5 months, then NREM onset

• Rapid eye movement
• Relatively absent EMG
• Intermixed delta/theta, saw tooth appearance

• Rarely seen in routine pediatric EEG

Arousal

• Brief arousal period from sleep
• Abrupt change of the background

• Biphasic slow wave: begin 3 mo
• 4-5 Hz: begin 7 mo
• 8-10 Hz: adolescent

• Usually 4-5 seconds or longer
Photic stimulation

Done in dimly lit room, 30 cm away from eyes
Frequency 1-30 Hz

• Visual evoked response
• Photo myogenic response
• Photic driving response

Photic driving response

• Usually > 3 Hz
• Posterior head region
• Related to stimulus frequency

• Asymmetry is not associated with structural brain disease in the absence of other abnormalities
Hyperventilation test

- Duration 3 minutes; adequate
- Normal response: build up of diffuse, synchronous high voltage delta activity
- More prominent posteriorly in age < 8 yrs
- Change usually resolve within 60 seconds
HV response (11 yo)