EEG Maturation and Normal Variants

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Objectives:

- Discuss special recording techniques in neonates
- Developmental maturation and chronobiology of EEG
- Common normal EEG variants in children and adults

Neonatal EEG Methods and Maturation
Neonatal Montage

- Montage in preterm or newborn with head circumference < 35cm

Neonatal EEG

- Monitoring during EEG
  - EKG, respiration, eye movements, and chin EMG is routinely done - assess behavioral state

- Technician should note:
  - Post-conceptional age in weeks/days
    - PCA = gestational age + chronological age
  - Behavior state(s) of the newborn during EEG
  - Medications, temperature, surrounding milieu
  - Artifacts from movements, handling or environment

Neonatal Behavior States

- Awake
- Active sleep (REM sleep)
- Quiet sleep (NREM sleep)
- Newborn cycles in and out of cycles rapidly
  - 60-90 minutes EEG may show all stages in a NORMAL baby
Behavioral State

<table>
<thead>
<tr>
<th>State</th>
<th>Respirations</th>
<th>Eye Movements</th>
<th>Chin EMG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awake</td>
<td>Irregular</td>
<td>Eyes open Random movements</td>
<td>Phasic</td>
</tr>
<tr>
<td>Active Sleep</td>
<td>Irregular</td>
<td>Eyes closed Rapid oscillatory movements</td>
<td>Little to none</td>
</tr>
<tr>
<td>Quiet Sleep</td>
<td>Regular</td>
<td>Eyes closed Little movements</td>
<td>Tonic</td>
</tr>
</tbody>
</table>

EEG/Sleep Chronobiology

- Sleep 0-2yrs 2-6yrs Adults
  - NREM sleep 50% ~60-70% 75-80 %
    - Dominant N3 N3 N2
  - REM sleep 50% ~30-40% 20-25 %

Newborn EEG - Four Key Rules

- Continuous
- Discontinuous
- Asynchronous
- Synchronous
- Adult EEG Patterns
- Transient EEG Elements (Graphoelements)
- REM AWAKE NREM

Conceptional Age (Weeks)
Gradient in Maturity: Newborn EEG Reading Paradigm

Conceptional Age (Weeks)

REM

AWAKE

NREM

Discontinuous
Asynchronous

Continuous/
Synchronous

Lag ~ 6-8 wks

Neonatal EEG – Each Page

- Determine behavioral state
  - Lack of state alternation may be abnormal in 90 min EEG
  - EEG differentiate state only after > 32 - 34 weeks GA
- Evaluate
  - Temporal organization
  - Topographic features
  - Behavior states cycling and gradient of maturity
  - Age-specific patterns and developmental landmarks
- Deviations for normal spectrum

EEG Landmarks

- Tracé alternant
- Tracé discontinu
- Frontal Sharp Transients
- Temporal Theta Bursts
- Beta Delta Complexes
- Sleep Spindles

Hrachovy, In: Levin & Lüders, 2002
Summary: EEG Continuity

- 22 - 30 weeks CA: Tracé Discontinu
  - Burst and quiescent periods
  - Invariant pattern
- 30 – 36 weeks CA: Tracé Alternans
  - Gradual development of more continuous rhythms
- 36 – 46 weeks CA:
  - Continuous EEG in REM and Awake
  - Tracé alternant in NREM

Tracé Discontinú (CA 26 wk)

- Periods of quiescence up to 1 minute
- Bursts of \( \Delta > \theta > \alpha \) activity up to 20 sec riding on each other and mixed frequency
- Bursts are simultaneous between hemispheres but individual waves are not bilaterally synchronous
29-30 Weeks Conceptual Age

Tracé Discontinu (CA 30 wks)

Tracé Discontinu (CA 26 wk)

Tracé Discontinu (CA 26 wk)
TRACÉ ALTERNANT

EEG Landmarks

Conceptional Age (Weeks)
FRONTAL SHARP WAVES

- $F_1, C_3$
- $F_2, C_4$
- $C_2, O_1$
- $C_4, O_2$

Hrachovy et al., 1990

36 Weeks Conceptual Age

EEG Landmarks

- Trace discontinuo
- Trace alternant
- Frontal Sharp Transients
- Temporal Sharp Transients
- Vertex Sharp Transients
- Beta Delta Complexes

This EEG of a term newborn shows
TEMPORAL THETA BURSTS
BETA-DELTA COMPLEXES

- Beta – Delta complexes (Delta brush)
  - Delta wave with overriding 18-22Hz and 8-12Hz frequencies
  - Central predominance
  - 26 – 38 weeks CA
- Temporal Bursts
  - 4.5 – 6 or faster bursts
  - Independent bitemporal distribution

Delta Brush

Temporal Theta
**Temporal Theta Bursts**

**Beta-Delta Complexes**

30-32 Weeks Conceptual Age

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**Summary – Robust Landmarks in Neonatal EEG**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Appears</th>
<th>Disappears</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active Sleep</td>
<td>30 weeks</td>
<td>NA</td>
</tr>
<tr>
<td>Wakefulness</td>
<td>34 weeks</td>
<td>NA</td>
</tr>
<tr>
<td>Quiet Sleep</td>
<td>36-48 weeks</td>
<td>NA</td>
</tr>
<tr>
<td>Delta Brush</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active Sleep / Awake</td>
<td>30 weeks</td>
<td>30 weeks</td>
</tr>
<tr>
<td>Quiet Sleep</td>
<td>30 weeks</td>
<td>48 weeks</td>
</tr>
<tr>
<td>Encoches Frontales</td>
<td>32 weeks</td>
<td>48 weeks</td>
</tr>
<tr>
<td>Temporal Theta</td>
<td>29 weeks</td>
<td>35 weeks</td>
</tr>
</tbody>
</table>

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**EEG Landmarks**

- Frontal Sharp Transients
- Temporal Alpha
- Temporal Theta Bursts
- Beta Delta Complexes
- Vertex Transients
- Sleep Spindles

- Tracé alternant
- Tracé discontinu
- Tracé alternant

Conceptional Age (Weeks)
EEG Maturation – *Awake*

- 40 weeks term - Continuous mixed frequency
- 8-12 weeks CA – Posterior Dominant reactive rhythm
- Posterior background appears ~ 4 months
- Lower limit of normal background
  - 1 yr at least 5 Hz
  - 4 yrs at least 6 Hz
  - 5 yrs at least 7 Hz
  - 8 yrs at least 8 Hz
- Delta activity may be intermixed through adolescence (termed posterior slow waves of youth)
- From 3-12 yrs response to hyperventilation can be dramatic (rhythmic 3 Hz activity)

EEG Maturation – *Drowsiness (N1)*

- Rhythmic theta activity develops by 6 months
- Hypnagogic hypersynchrony
  - Generalized 3-5 Hz high amplitude rhythmic activity
  - Most pronounced within the first 5 years of life
  - Can have intermixed sharply contoured activity
- Alpha dropout predominates after 6 years of age

EEG Maturation – *Sleep (N1-2)*

- Sleep spindles appear around 1-2 months age
  - Initially prolonged and asynchronous
  - Become synchronous by 2 years of age
- V-waves K-complexes appear by 3-5 months age
  - Initially blunt
  - Become sharply contoured, may be asymmetric
- POSTs
  - Appear at 1-3 years, well developed by adolescence
This EEG of a 6 month old infant is suggestive of

Early Sleep Spindles (3 mo)

Asymm Vertex Trans - K Complexes
Other Common EEG variants – Children and Adults

This EEG of a 4 year-old female with history of staring episodes shows

- Hypnagogic Hypersynchrony
  - Synchronous delta/theta at onset of sleep
  - Most typical in young age
    - Diminishes with age
  - Sometimes notched or with spiky component
    - But spikes never have 1:1 correlation with after-following slow
  - Hypnapompic hypersynchrony – seen at transition to awake state
HYPNAGOGIC HYPERSYNCHRONY

Incidence in Normal Children

Posterior Slow Wave Of Youth

- Young age
- Awake EEG
- Occipital distribution
- Delta with over-riding normal alpha
- No disturbance of background
- Usually synchronous
- Common finding mistaken for pathological slow
SSS – Small Sharp Spikes

- A.k.a – BETS (benign epileptiform transients of sleep)
- Single, small (5-10uV), no after-slow
- Anterior or mid temporal maximum but may be wide spread
- Uni- on bilateral, independent or synchronous
- ~ 20% of normal EEGs – light sleep

Lambda Waves

- Biphasic
- Occipital, usually synchronous
- Surface Positive
  - Confused with POSTS but awake state
  - Awake – elicited by patterned design
  - Reduced by eye closure, reducing ambient room light
  - Most common in young patients
Mu Rhythm

- Normal rhythm in ~ 25% normal EEG
- Characteristics
  - Awake rhythm, usually asynchronous
  - 7-12Hz, archiform (comb like)
  - C3 or C4 maximum
  - Disappears: move or touch extremity
- Commonly mistaken for runs of sharp waves due to spikiness.
Breach Rhythm

- Rhythm over previous craniotomy/injury signifying “breach” in the layers of skull
  - Usually beta, >15Hz, >30uV amplitude
  - Usually focal and pervasive in the record
  - Mixed with sharp transients
  - Sometimes hard to differentiate from epileptic sharp waves
  - May be confused with ictal pattern or paroxysmal fast

Wickets

- Benign physiologic variant
- Seen > 30 years, 3-5% of normal EEG
- Commonly mistaken for temporal epileptiform discharges

- Characteristics
  - Drowsy or awake resting
  - Theta-alpha range (6-11Hz)
  - Usually asynchronous and shifting sides
  - Not disturb background, no after-slow
  - In trains or isolated
Psychomotor Variant

- Also called Rhythmic Mid-temporal Theta Bursts of Drowsiness (RMTD)
- Rhythmic 4-7Hz bursts
- Uni- or bilateral maximum temporal
- Some evolution of amplitude
- Notched morphology
- Drowsiness or awake
- ~ 2% of normal EEG
- Commonly mistaken for temporal lobe sharp waves or epilepsy
This EEG of 14 year-old male who reports hypnic jerks suggests

14/6 HZ Spikes Occur In ~15% of 6-15 year-old EEGs

- 14 and/or 6 Hz spikes
  - Sharply contoured
  - Occipital (surface) positive
  - Could be asynchronous
  - Predominantly occur in drowsiness
  - 14 Hz are more common
- Commonly misinterpreted as Epileptiform discharges
  - Leading to erroneous diagnosis of seizure disorder
SREDA: Subclinical Rhythmic EEG Discharge in Adults

- Infrequent, < 2% EEG
- Awake > drowsy (not sleep)
- Abrupt onset or rapid temporal evolution with wide spread distribution
  - Centroparietal, vertex, temporo-parietal-occipital – could be synchronous, asymmetric
- Sharp, rhythmic 4-7/s, rarely delta
- Could be longer (~30 seconds or more) in duration

1 of 3 (15s page) 60 yr old complaining of memory problems

2 of 3 (15s page)
THANK YOU