Educational Goals

- Normal developmental maturation of EEG
- Recognize normal variants on the EEGs of Sleep Studies
- Recognize artifacts that can mimic pathologic EEG abnormalities on Sleep Studies
- Recognize seizure patterns & epileptiform activity on EEG of Sleep Studies

Content

- Developmental Maturation of EEG
- Variants
- Artifacts
- Seizures & Epileptiform Activity

Neonates & Infants: Normal EEG Patterns
Tracé Discontinu

- EEG rhythm after 20 weeks of gestation.
- Bursts of high amplitude (≤200μV) activity interspersed with relative quiescence (amplitude ≤25μV).
- Inter-bursts-interval (IBI) lasts on an average 8 seconds with more synchrony before 30 weeks, then becoming more asynchronous, evolving into Tracé Alternans by 34 weeks.

Tracé Alternans: Quiet Sleep

- EEG rhythm during quiet sleep starting 34 weeks.
- Bursts of high amplitude (≤200μV) activity interspersed with relative quiescence (amplitude ≥25μV).
- Inter-bursts-interval (IBI) lasts on an average 2-4 seconds with more synchrony with conceptional age (70% at 34 weeks to 100% at 40 weeks).
- Evolves into mature continuous slow waves by 2 months.
Central Sharp Waves in the Newborn

Positive Sharp Waves in the Newborn

Frequency of Sharp Transients by Conceptual Age

Delta Brushes (ripples of prematurity)
- Delta wave with superimposed burst of 8-20 Hz activity.
- Occur in wakefulness & quiet sleep.
- Occur in rolandic, occipital & temporal region, rare to never in frontal regions.
- Develop at 34 weeks & disappear by 44 weeks of gestation.

Active Sleep
- Continuous record of 4-7 Hz theta-delta activity of 25-50 μV amplitude (similar to wakefulness).
- Neonates enter into active sleep from wakefulness.
- First cycle has more delta activity of higher amplitude with frontal sharp waves.
- Subsequent cycles have more theta activity of lower amplitude.
Artifacts Variants and Epileptiform Activity Observed on PSG in Children

Sanjeev V. Kothare, MD, DCH, FAAP, FAASM

---

**Active Sleep**

**Frontal Sharp waves** *(Encoches frontales)*

- **High amplitude** ($\geq 150 \mu V$), symmetrically occurring, of broad biphasic morphology.
- **Maximum at the transition from active to quiet sleep.**
- **Appear from 34 weeks, disappear by 48 weeks.**

---

**Asymmetrical (abnormal) Frontal Sharp Waves: Encoches Frontales**

---

**Classification of EEG Background Activity**

1. Normal
2. Intermittent or persistent immaturity (dysmaturity)
3. Mildly abnormal
   - Marked discontinuity during the discontinuous portions of the tracing
   - Mildly excessive arrhythmic asymmetry for chronological age
   - Poor concordance between clinical and electrophysiologic sleep states
   - Mild Poverty of Atypical Background Patterns for Chronological Age (e.g., mild decrease in monomorphous occipital delta activity, rhythmic occipital or temporal theta activity, briskness)
   - Mild focal abnormalities (e.g., excessive sharp waves in temporal or occipital areas, focal spike occurrence)
4. Moderate abnormal
   - Moderate excessive discontinuity during the discontinuous portions of the tracing
   - Moderate excessive arrhythmic asymmetry for developmental age
   - Poorer of atypical background patterns for chronological age
   - Definite focal abnormalities (e.g., persistent focal delta activity or focal depression of expected background patterns such as beta/alpha)
   - Persistent low voltage (generalized reduction of voltage <25 $\mu V$ for all derivations)
5. Marked abnormal
   - Markedly excessive discontinuity for age, despite the preservation of some age-appropriate background patterns
   - Buried suppression pattern
   - Generalized arrhythmic asymmetry
   - Extremely low voltage (<5 $\mu V$)
   - Depression or suppression of all frequencies
---

Infancy, Childhood & Adolescence
Evolution to Mature Sleep Patterns

- The transition from wakefulness to non-REM (quiet) sleep occurs by 2-3 months.
- Infants now transit from wakefulness to non-REM & then REM sleep (active sleep).
- Mature non-REM sleep stages (N1-3) occur by 4-6 months.

Evolution From Quiet Sleep (Trace) to Continuous SWS

Sleep Architecture in Children vs Adults

- Present by 6 weeks.
- 12-14 Hz in central region.
- Frontal spindles are slower at 10-12 Hz.
- Duration: may be as long as 6-8 seconds in young infants, then decrease to 1-3 seconds in children, & 0.5-1.5 seconds in adults.
- Frequency: 4-6/minute (range 1-10)
- Inter-hemispheric asynchrony is seen until 2 years, after which largely synchronous.
- Indicates N2 sleep

Spindles

Long Spindles During Infancy

Asynchronous Spindles
**Vertex waves**
- Earliest forms seen at 3-4 months.
- Well developed at 5 months.
- Maximum at 3-4 years.
- High voltage, 250 m-second in duration, of biphasic morphology.
- May occur in frequent runs.
- Shifting asymmetry seen commonly, without pathological significance.

**Vertex Sharp Waves**

**K Complexes**
- Seen after age 5 months.
- Triphasic morphology, broad field.
- 500 m-second in duration.
- Followed by an over-riding spindle like activity.
- Indicates N2 sleep.

**K-complex**

**Epileptic K Complex**

**Hypnogogic Hypersynchrony**
- Dominant rhythm from 6 months to 5 yrs.
- 2-7 Hz activity.
- May be notched.
- Uncommon after age 10 years (2%).
Hypnogogic Hypersynchrony

Waking rhythms

Voltage:
- Adults: 15-45 μV.
- Children: 50-75 μV, 9% >100 μV.

Posterior Dominant Rhythm (Hz)

<table>
<thead>
<tr>
<th>Age</th>
<th>3mo</th>
<th>6mo</th>
<th>12mo</th>
<th>3yr</th>
<th>5yr</th>
<th>8yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freq (Hz)</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Slow Alpha Variant

Neonatal Seizures
Artifacts Variants and Epileptiform Activity
Observed on PSG in Children

Sanjeev V. Kothare, MD, DCH, FAAP, FAASM

Video withheld.

Benign Sleep Myoclonus

Video withheld.

Video withheld.

Video withheld.
EEG Variants

Rhythmic Mid-Temporal Theta of Drowsiness (RMTD)
- 5-7 Hz, sharply contoured, with flattened upper contour.
- Unilateral, bilateral or shifting laterality.
- In drowsiness.

Wicket Waves (temporal alpha activity)
- Intermittent trains of arciform waveforms.
- 6-11 Hz frequency.
- During drowsiness & sleep.
- Temporal region with shifting laterality.
- 1% of adults over 30 years.
Artifacts, Variants and Epileptiform Activity Observed on PSG in Children

Sanjeev V. Kothare, MD, DCH, FAAP, FAASM

14 & 6 Spikes (Ctenoids)

- Seen in drowsiness and light sleep.
- Peak incidence in mid-adolescence.
- Comb shaped, in posterior temporal rhythm.
- Best seen in long (especially inter-hemispheric) inter-electrode distance montages.

Benign Epileptiform Transients of Sleep
Small Spikes of Sleep (BETS, SSS)

- Low voltage ($
\leq
$ 50 $\mu$V) biphasic fast spike without a significant slow wave.
- Non-repetitive.
- Occur in light sleep in temporal leads with shifting laterality.
- 20-25% of adults.
Phantom Spike-Wave
6 Hz Spike-Wave

- 5-6 Hz evanescent spike & wave pattern.
- Adolescents & adults.
- 0.5-1% of EEG recordings.
- Two patterns
  - FOLD: female, occipital, low amp, drowsy.
  - WHAM: waking, high amp, anterior, male.

Phantom Spike-Wave (6Hz Spike-Wave)

Slow Rhythmic Epileptiform Discharges of Adults
(SREDA)

- Occurs during drowsiness.
- In adults > 50 years.
- Rhythmic evolving theta-delta activity over posterior temporal-parietal regions.
- Bilaterally synchronous or focal.
- Lasts 20 seconds to a minute.

Midline Theta Rhythm
µ Rhythms

- 8-10 Hz rhythm of the sensori-motor cortex.
- 17-19% of young adults, only 5% of children <4yrs.
- Blocked by movement in opposite hand.
- May be asymmetrical for prolonged periods.

Reactive µ Rhythm

• High voltage faster frequency “arciform” activity that occurs in the region of a skull defect.
• Is not considered abnormal per se.
• Most prominent over central or temporal regions.
• Caution regarding interpreting ‘spikes’ in same area.

Breach Rhythm

- Superimposition of a slow wave on the background rhythm.
- Maximum prevalence between 8-14yrs.
- Occur in 15% of teenagers, rare after 21yrs.
- Blocks with eye opening & disappears in drowsiness.
- May not be synchronous or symmetrical.

Posterior Slow Waves of Youth (Youth Waves; Mittens)
Posterior Slow Waves of Youth

Lambda Waves
- Sharply contoured occipital transients, time locked to saccadic eye movements associated with looking at patterned or visually complex stimuli (scanning).
- Positive polarity, bi or triphasic & triangular morphology.
- Blocked by darkness, eye closure, looking at blank screen/paper.
- Most prevalent at 3-12 years, declining in frequency with age.

Lambda Waves
Reactive Lambda waves

Asymmetric Lambda

Positive Occipital Sharp Transients of Sleep (POSTS)
- Surface positive sharp transients, singly or in trains.
- From 4yrs to 50 yrs, most common in young adults.
- Are synchronous, but may be asymmetrical.
Artifacts Variants and Epileptiform Activity
Observed on PSG in Children

Sanjeev V. Kothare, MD, DCH, FAAP, FAASM

Positive Occipital Sharp Transients of Sleep (POSTS)

Patting Artifact

Video withheld.
Artifacts Variants and Epileptiform Activity Observed on PSG in Children

Sanjeev V. Kothare, MD, DCH, FAAP, FAASM

Patting Artifact

Neonatal Seizure

Rocking Artifact

Sobbing Artifact

Hiccough Artifact
Artifacts, Variants, and Epileptiform Activity Observed on PSG in Children

Sanjeev V. Kothare, MD, DCH, FAAP, FAASM

Lateral Eye Movements

Eye Blinking Artifact

Unilateral Eye Blink

Lateral Rectus Spikes

Hyperekplexia
Artifacts, Variants, and Epileptiform Activity Observed on PSG in Children

Sanjeev V. Kothare, MD, DCH, FAAP, FAASM

Chewing Artifact

Glossokinetic Artifact

La La La

Pacifier Artifact

Bruxism Artifact

High-frequency Ventilator Artifact

Telephone Artifact
Artifacts Variants and Epileptiform Activity Observed on PSG in Children

Sanjeev V. Kothare, MD, DCH, FAAP, FAASM

- Phone Ringing
- Electrode-box Unplugged from Computer: Mistaken for Status Epilepticus in ICU
- Popping Artifact
- 60 Hz Artifact
- Pulse Artifact
- Respiratory Artifact
Artifacts Variants and Epileptiform Activity
Observed on PSG in Children

Sanjeev V. Kothare, MD, DCH, FAAP, FAASM

Cardio-ballistic (EKG) Artifact

Salt Bridge Artifact

Sweat Artifact

Epileptiform Activity

Hypsarrhythmia

Hypsarrhythmia: Tonic Seizure
Artifacts, Variants, and Epileptiform Activity Observed on PSG in Children

Sanjeev V. Kothare, MD, DCH, FAAP, FAASM

Hypsarrhythmia: Burst Suppression in Sleep

Hypsarrhythmia: Electro-decremental Response

Centro-Temporal Spikes; BREC

Video withheld.

Benign Epilepsy of Childhood with Occipital Paroxysms

Childhood Absence Epilepsy: 3 Hz Spike-Wave Discharges

Copyright (c) 2012 Boston Children's Hospital
Artifacts Variants and Epileptiform Activity
Observed on PSG in Children

Sanjeev V. Kothare, MD, DCH, FAAP, FAASM

Copyright (c) 2012 Boston Children's Hospital

3 Hz Spike Wave Discharge

Slow Spike Wave Discharge

Video withheld.

PSG: 120 seconds epoch

Continuous Generalized Spike Wave Discharges

Prevalence of epileptiform activity in healthy children during sleep

Oscar Sapo Copleva, Ilaha Daryali, Loku Khorandeh-Goval, David Gezal *

* Children’s Hospital, Harvard Medical School, Boston, Massachusetts, USA.

METHODS

We assessed the prevalence of epileptiform abnormalities during sleep in healthy children aged 2-18 years. We used standard sleep EEG criteria to identify epileptiform activity. The study was approved by the institutional review board.

RESULTS

We evaluated 100 children, 50 with and 50 without a history of epilepsy. None of the children had clinical or EEG evidence of epilepsy. We identified a total of 12 cases of epileptiform activity, including 6 with 3Hz spike waves, 4 with slow spike waves, and 2 with tonic seizures. These findings were consistent with previous studies.

CONCLUSION

Epileptiform activity is common in healthy children during sleep. Further research is needed to understand the clinical significance of these findings.

Copyright (c) 2012 Boston Children's Hospital