Introduction to Neonatal EEG

Presented by: Sucheta Joshi, MD, MD
Slides by: Renée Shellhaas, M.D., M.S.

July 10, 2018
Outline

• Neonatal EEG peculiarities
• Neonatal EEG background
• Normal named patterns
• Sharp waves
• BRDs & Seizures
• Neonatal EEG & Prognosis
Conventional Neonatal EEG is the gold standard for the diagnosis and quantification of neonatal seizures and for assessment of EEG background.

10-20 system, modified for neonates
Technical considerations

• EEG montage is different from older children/adults
  – Use neonatal montage until PMA 46-48 weeks

• Compressed screen display
  – 15mm/sec (20sec/page)

• Extra-cerebral channels:
  – Eye movements
  – Respirations
  – EKG
  – EMG
  – Video
Basic approach to Neonatal EEG

• Know the…
  – Postmenstrual age of the patient
    • EGA + Legal Age = PMA
  – Medications

• Try to limit exposure to clinical history before reading the EEG.

• Do not over-read!
  – It is a serious error to interpret an artifact or a normal sharp wave as a pathologic pattern.
Basic approach, cont

• Behavioral state
  – Can’t tell by EEG until ~30 weeks PMA
  – Awake – eyes open
  – Asleep – eyes closed
    • active sleep – eyes closed, REMs, irregular respirations
    • quiet sleep – eyes closed, no REMs, regular respirations
    • transitional sleep (aka indeterminate sleep)
  – Look for all the clues (tech’s notes, EMG lead, respiratory channel, eye leads)
Approaching the Neonatal EEG Background

• Determine PMA & behavioral state, then:

• Basic organization of the background
  – Continuity and discontinuity
  – Symmetry
  – Synchrony
  – Amplitude
  – Reactivity
  – Specific composition of the background
Discontinuity

- Continuous – relatively steady amplitude

- Discontinuous – “on periods” and “off periods”

- The first thing to happen when a full-term baby gets sick.
## EEG Background Evolution

<table>
<thead>
<tr>
<th>Age (CA)</th>
<th>Awake</th>
<th>Active sleep</th>
<th>Quiet sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>24-29 weeks</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
</tr>
<tr>
<td>30-34 weeks</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
</tr>
<tr>
<td>35-36 weeks</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
</tr>
<tr>
<td>37-40 weeks</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
</tr>
<tr>
<td>41-44 weeks</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
</tr>
<tr>
<td>45-46 weeks</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
<td>![Waveform]</td>
</tr>
</tbody>
</table>
Term baby – tracé alternant
Excess Discontinuity – PMA 39 weeks
Discontinuous background – PMA 38 weeks
Normal vs Excessive Discontinuity

- Maximal normal interburst intervals:
  - < 30 weeks PMA: 35 seconds
  - 31-33 weeks PMA: 20 seconds
  - 34-36 weeks PMA: 10 seconds
  - 37-40 weeks PMA: 6 seconds (TA pattern)

- Amplitude of interburst:
  - <35 weeks PMA: <25μV is normal
  - >35 weeks PMA: >25μV
Rating Discontinuity
(in term baby)

- **Normal**: Continuous (except tracé alternant)
- **Mildly excessive**:
  - Continuous awake & a little discontinuous when asleep
  - <7 seconds interburst intervals (IBI)
  - Should still be synchronous
- **Moderate**: >7-<15 seconds IBI
- **Severe**: > 15 seconds IBI

- **N.B.**: If the background is discontinuous, we cannot say that there are excessive negative sharp waves!
Excessive Discontinuity vs. Burst Suppression

- **Excess discontinuity** – bursts of normally composed EEG signal are separated by abnormally long interburst intervals, with variation depending on behavioral state.

- **Burst suppression** – not reactive; abnormally composed EEG signals are separated by abnormal low-voltage quiescent periods.
A caveat re: continuity

• Usually, having a continuous record is good.

• BUT… a monotonous, invariant EEG background without state changes and without reactivity to stimulation suggests CNS insult.
Symmetry

• The amplitude, frequency, and waveform compositions should be symmetric.

• Abnormal: > 2:1 asymmetry.

• If the asymmetry is limited to amplitude, think of:
  – Incorrect EEG lead placement
  – Scalp edema (ex: ECMO babies)
  – Subdural collections
Synchrony

- **Normal synchrony:**
  - < 29 weeks PMA: 100%
  - 30-34 weeks PMA: 70% (!)
  - 35-36 weeks PMA: 85%
  - >37 weeks PMA: 100%

- **Some patterns are almost always synchronous**
  - Monorhythmic occipital delta
  - Encoches frontales
  - Anterior dysrhythmia

- **Asynchrony:** >1.5 seconds separating hemispheres’ activity
  - Encephalopathy (meningitis, HIE)
  - Cerebral dysgenesis (absent corpus callosum)
PMA: 42 weeks
Amplitude

• Neonatal EEG should be robust.

• Abnormalities:
  – Isoelectric
  – Depressed and undifferentiated
    • Reduction in the expected rich mixture of frequencies; usually <10μV
  – Persistent low voltage
    • <5-10μV awake, <10-25μV quiet asleep
    • Definitely abnormal if persists >43 weeks PMA
Reactivity

• Clinical and/or EEG response to external stimulation or internal arousal
  – Clinical response: EMG activity, respiratory pattern changes
  – EEG response: frequency change, increased continuity, decreased amplitude (go from sleep to waking patterns)

• Absence of reactivity: abnormal
  – Pathological thalamo-cortical disruption or marked immaturity
Reactivity, bottom line

• Any change is a good sign
Regular respirations
Normal arousal
Normal named patterns:
Some look scary, but they aren’t

• These depend on PMA.
• Monorhythmic occipital delta (24-34 wks)
• Delta brushes (24-36 wks; peak 34 wks, sometimes seen at term during quiet sleep)
• Rhythmic temporal theta (24-34 wks)
• Anterior dysrhythmia (35-44 wks)
• Encoches frontales (34-44 wks)
Delta Brushes / Monorhythmic Occipital Delta
Delta Brushes

Encoches Frontales
31 weeks CA - rhythmic temporal theta
Anterior Dysrhythmia
Sharp waves

- SHARP WAVES ARE ARTIFACT UNTIL PROVEN OTHERWISE.
- A believable electrographic field.
- Stand apart from the background.
- Usually followed by a slow wave (+/- in neonates).
- Not a physiologic (normal) sharp wave.
Sharp waves, cont.

- Normal sharp waves
  - Ex: encoches frontales

- Negative sharp waves
  - Imply increased risk of seizures
    - Caveat for discontinuous background
  - Few data exist for negative sharps in <33-34wks PMA
  - Location:
    - Normal to have C-T sharps at rate <1/min if symmetric (C3 and C4; T3 and T4) until ~50wks PMA (Clancy J Child Neuro 1989;4:30-38)
    - Occipital sharp waves are abnormal
    - Trains/couplets/triplets are abnormal
Sharp waves, cont

• Positive sharp waves
  – Nothing to do with seizures
  – Increased chance of structural abnormalities
    • Hydrocephalus, PVL, IVH, HIE, stroke, inborn errors of metabolism, etc.
    • Positive rolandic sharp waves were always associated with white matter lesions in Aso, et al (EEG/neuropath study; J Child Neuro 1990;5:224-228)
      – Very specific, not sensitive
Sharp waves, cont

• Abnormal sharp waves over the midline/vertex:
  – Worry about sagittal sinus thrombosis
  – (do an MRV when baby has brain MRI)
Dysmaturity

- Dysmaturity = patterns seen would be normal for a baby of ≥2 wks younger PMA.
  - Ex: you see prominent delta brushes in a 43 week PMA infant.
  - If transient, prognosis ok; if persistent, prognosis less good (Holmes & Lombroso 1993).

- If you call an EEG “dysmature” you mean that if the baby were ≥2 weeks younger, you would have called it normal.
  - If there is a seizure don’t use the term “dysmature”.
Overall Background Classification

- Mildly abnormal:
  - Mild excess discontinuity
  - Mild simplification of mixture of frequencies
  - Mild focal abnormalities (like excess sharp transients or focal voltage attenuation)
Background Classification

• Moderately Abnormal
  – Moderately excessive discontinuity
  – Moderately excessive asynchrony
  – Poverty of expected background rhythms
  – Definite focal abnormalities
  – Persistent low voltage (<25μV)
Background Classification

• Markedly abnormal:
  – Markedly excessive discontinuity (can have some preservation of age-appropriate background patterns)
  – Burst suppression
  – Gross interhemispheric asynchrony
  – Extreme low voltage (<5μV)
  – Depressed and undifferentiated
  – Isoelectric
Table I. Visual interpretive criteria of normal and abnormal EEGs in near-term and term infants*

<table>
<thead>
<tr>
<th>Conventional EEG characteristics</th>
<th>Normal</th>
<th>Mildly abnormal background</th>
<th>Moderately abnormal background</th>
<th>Markedly abnormal background</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Continuity:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous</td>
<td>Continuous in awake (W) and active sleep (AS) states</td>
<td>Continuous in W and AS states</td>
<td>Reduced continuity</td>
<td>Few or no continuous EEG segments</td>
</tr>
<tr>
<td>Discontinuous</td>
<td>IBI† &lt; 4 seconds in quiet sleep (QS)</td>
<td>IBI 4 to &lt; 7 seconds in QS</td>
<td>IBI 7 to ≤15 seconds</td>
<td>IBI &gt; 15 seconds</td>
</tr>
<tr>
<td><strong>Amplitude:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awake or AS: 25 to 50 μV (p-p)‡</td>
<td>Awake or AS: 25 to 50 μV (p-p)</td>
<td>Awake or AS: 5 to 15 μV asleep: 10 to 25 μV</td>
<td>&lt; 10 μV (&quot;depressed and undifferentiated&quot;)</td>
<td></td>
</tr>
<tr>
<td>QS: IBI 4 ≥ 25 μV</td>
<td>QS: some IBI 4 &lt; 25 μV</td>
<td>&quot;persistent low voltage&quot; some IBI 4 &lt; 5 to 10 μV</td>
<td>All EEGs &lt; 2 μV (&quot;isoelectric&quot;)</td>
<td></td>
</tr>
<tr>
<td>Symmetry</td>
<td>Symmetric</td>
<td>Symmetric</td>
<td>Symmetric</td>
<td>Symmetric</td>
</tr>
<tr>
<td>Synchrony</td>
<td>In QS, the bursts of discontinuous portions of EEG are nearly 100% synchronized¶</td>
<td>In QS, a few of the bursts may not be synchronized</td>
<td>May show persistent asynchrony in the discontinuous EEG segments</td>
<td>May show persistent asynchrony in the discontinuous EEG segments</td>
</tr>
<tr>
<td>Lability of biobehavioral states</td>
<td>Spontaneous cycling among W, AS, and QS and reactive to external stimuli</td>
<td>States cycle spontaneously and react to external stimuli</td>
<td>Poor state differentiation and modest responses to external stimulation</td>
<td>No recognizable states; (&quot;undifferentiated&quot;) little or no EEG response to external stimuli</td>
</tr>
<tr>
<td>Composition of EEG background</td>
<td>Rich variety of frequencies and specific, named patterns, such as “delta brushes”</td>
<td>Rich variety of frequencies and specific, named patterns, such as “delta brushes”</td>
<td>Poorly developed background with paucity of features</td>
<td>Poverty of all background patterns with few or no specific patterns, such as “delta brushes”</td>
</tr>
</tbody>
</table>

*Near term is defined as conceptional age of 34 to < 37 weeks; term, as conceptional age > 37 weeks.
†IBI, interburst intervals of the discontinuous portions of the EEG.
‡All voltages presented as peak-to-peak values.
§Asymmetry is present if the ratio of the amplitudes of 2 homologous brain regions is > 2:1.
¶Bursts are synchronized if there is < 1.5 seconds separating the onset of the bursts between the left and right hemispheres.
39 weeks PMA – Markedly abnormal background
B[1]RDs and Seizures

• B[1]RD = brief [ictal/intermittent] rhythmic discharges (<10 seconds)
  – Would be a seizure if just a bit longer…

• Seizure = sudden, repetitive, evolving and stereotyped ictal pattern with a clear beginning, middle, and ending, an amplitude of at least 2µV, and a minimum duration of 10 seconds.
SEIZURE
Seizures in neonates

- Most neonatal seizures are subclinical.
- 60% of neonatal seizures last <90 seconds.
- Usually high seizure burden (mean 7/hr).
- Often seen in just one electrode.
- Often surface-positive sharp waves.
- Background patterns can persist during seizures.
- Simultaneous independent seizures.
Status epilepticus in neonates

• Rarely a single seizure longer than 30min.
• Instead, use alternate definition:
  – >50% of the EEG made up of seizures.
Summary: What to look for

• Symmetry & Synchrony
• Continuity / Discontinuity
• State Changes / Reactivity
• Normal graphoelements (enkoches frontales, anterior dysrhythmia in full term; delta brushes, monorhythmic occipital delta in premies).
• Abnormal sharp waves
  – Negative = Risk of Seizure
  – Positive = Structural Abnormality
• Seizures
Neonatal EEG and Prognosis

- Normal/Mildly abnormal EEG = generally good prognosis
  - Remember context, though. Babies with Down syndrome (for ex) can often have normal neonatal EEG but can be expected to have abnormal developmental outcome.
  - Various studies showed term babies with HIE and normal EEG had 90+% normal outcome at 1+ years (Selton 1997, Takeuchi 1989, etc.)
Neonatal EEG and Prognosis

• Timing matters:
• 173 neonates with HIE (Takeuchi & Watanabe 1989)
  – Mildly abnormal EEG on DOL 0-1: normal development
  – Persistent mildly abnormal EEG on DOL 12: neurologic deficits
Neonatal EEG and Prognosis

• Markedly abnormal background → poor outcome (ex: Tharp 1983).

• Moderately abnormal background → some good, some not-so-good
  
  • If improved background in first week, outcome at 1+ years is usually good.
  
  • If no improvement or worsening EEG in first week, outcome usually poor.
  
  • Ideally, these babies should be targets for neuroprotection or other intervention.
Seizures and Prognosis

• Babies with neonatal seizures are at high risk for death or neurologic morbidity.
  – Mortality: 25-40% (may be higher in preterm)
  – Developmental delay: 67% @ 2-3 yrs
  – Cerebral palsy: 63% @ 2-3 yrs
  – Post-neonatal epilepsy: 17-56%

Mizrahi, Epilepsia 2001;42(S7):102.
Scher, Pediatr Neurol 1989; 5:17-24
Scher, Pediatrics 1993; 91:128-134.
The EEG background probably drives the prognosis more than the presence of seizures.
Conclusions

• Neonatal EEG interpretation includes:
  – symmetry, synchrony, reactivity, continuity, normal and abnormal patterns, seizures

• Neonatal EEG is useful for prognosis
  – Normal background = 😊
  – Markedly abnormal background = 😞
  – Moderately abnormal background = 🤔
References to keep at hand
