Neonatal EEG

Elia M Pestana Knight, MD
Outline and Goals

• Technical Considerations
• Clinical aspects of Neonatal EEG
• Visual analysis of Neonatal EEG
  – Normal neonatal EEG across different gestational age groups
When to use Neonatal Montage?

Definitions

- Neonate: Newborn infant less than 4 weeks of age
- Preterm: Conceptional age usually 24 to <34
- Near term: Conceptional age 34 to <37 weeks
- Term: Conceptional age 37 weeks and above
When to use Neonatal Montage?

- From time of birth until baby reach full term age
- Up to 46-48 weeks Gestational age

- Some centers read the EEG in Neonatal Montage until sleep spindles are present in the record.
Technical Considerations
Electrode Placement

10-20 system modified for neonates

Know that electrodes T7 and T8 are label T3 and T4 in other institutions

Most of the neonatal EEG activity if found in the central regions
Other Polygraphic Parameters
or
Extracerebral Channels

• Electrooculogram
• Electromyogram
• Electrocardiogram
• Pneumograph
• Video
  – The alternative is a good EEG technician or nurse annotating the EEG record.
Instrument settings

- Skin impedance: ~10
- Time constant of 0.3 seconds
- Low frequency filter (high-pass filter) = 0.005-0.01Hz or 0.5Hz
- High frequency filter (low-pass filter) = 70 Hz
- Sensitivity
  - EEG channels 7 µV/mm
  - EOG 7 µV/mm
  - EKG 50 – 300 µV/mm
  - EMG 50 µV/mm
Compressed Screen Display

- 20 seconds per page/screen or speed 15mm/sec

- Why?
We follow the French school of EEG recording. Allows better display of very slow activity, asymmetries and asynchronies.
Duration of the Recording

• Long enough to capture awake and sleep cycles
  – At least 2-3 hours

• Continuous
  – With Video
Clinical Aspects of the Neonatal EEG
What clinical information you need to know before you read a Neonatal EEG?

• Conceptional age (CA) or corrected age of the patient

• Medications

• State of the patient

• Environment annotations
Conceptional age (CA) or corrected age of the patient

- CA = Estimated Gestational Age (GA) + Legal Age or Chronological Age

- Example: 4 week old baby born at 30 weeks GA
  - CA = 34 weeks
Medications and other therapies

- Morphine
- Barbiturates
- Benzodiazepines
- Other antiepileptic drugs

- Cooling protocol
  - Head cooling
  - Total body cooling

ALL decrease the VOLTAGE of the EEG
Behavioral States

- Awake – eyes open
- Asleep – eye closed
  - Active sleep (REM) irregular respirations
  - Quiet sleep (no REM) regular respirations
- On ventilator
- On incubator
- Lines and drips
- Feeding

Sources of Artifacts
Sleep/Wake Cycles can only be differentiated by EEG after 31 weeks CA
EEG Awake/Sleep Cycles
Awake and Active Sleep (AS)
Similarities

• Morphology:
  – both have mixed frequencies in the background

• Respirations:
  – both have irregular respirations
EEG Awake/Sleep Cycles
Awake and Active Sleep (AS)
Differences

- **Awake**
  - Movement artifacts
  - EOG: REM + Slow eye movements
  - EMG: continuous high activity

- **Active Sleep**
  - No movements artifacts
  - EOG: REM only
  - EMG: low activity with brief bursts of higher activity

Active Sleep always follows wakefulness in neonates
Active sleep accounts for 50% of the total sleep time in neonates
Quiet Sleep

- EOG: no eye movements
- Respiration: regular
- No movements artifacts
- EEG:
  - Trace alternant: Quiet periods of voltage >25µV, alternating with bursts 100-200µV
  - Slow quiet sleep: continuous high amplitude delta activity over all brain regions.
  - Encoches frontalis
Transitional sleep or undetermined sleep

- Sleep stage that can no be classified as described before
- No clear active or quiet sleep pattern
Environment Annotations

- Loud noises
- Flashes of light
- Nursing / Parental care

 transient attenuation of the EEG background
25 day old baby girl born at 39 weeks GA

Arousal from QS
What about nursing and parental care?
Artifacts
Fixing electrodes

CA 41 weeks
Patting Artifact

CA 41 weeks
Patting Artifact
Visual Analysis of the Conventional Neonatal EEG
Background Assessment

• Can be done once you know:
  – 1. Conceptional age
  – 2. Behavioral state
Basic Organization of the Background

• Continuity and discontinuity
• Symmetry
• Synchrony
• Amplitude
• Reactivity
• Specific composition of the background or graphoelements
Continuity

Continuous EEG
Refers to relatively steady amplitude

Discontinuous EEG
Refers to “on periods” (BURST) and “off periods” (INTERBURSTS)

Interburst interval (IBI): discontinuation portion of the EEG
Awake, 28 week GA, corrected age 41 weeks
Discontinuous EEG

Normal EEG - Neonatal 27 weeks
EEG Background Evolution

FIG. 6.23. Overview of conceptional age.

From Eberode & Pellieg
Normal discontinuous and continuous patterns

- **Trace discontinu** = up to 34-35 weeks
  - Quiet periods of voltage <25µV (often <10µV)

- **Trace alternant** = between 34-35 weeks until term during QS
  - Quiet periods of voltage >25µV, alternating with bursts 100-200µV

- **Trace continue** = 40 weeks and above
  - Irregular delta and theta of 50-100µV during awake and AS
25 day old baby girl born at 39 weeks GA

<table>
<thead>
<tr>
<th>Trace Alternant</th>
</tr>
</thead>
</table>

Quiet Sleep
Symmetry

• Amplitude, frequency and waveform elements of the neonatal EEG should be SYMMETRIC

• Asymmetry: ration of the amplitude of 2 homologous brain regions is 2:1
Asymmetry

• If asymmetry is only amplitude:
  – Incorrect EEG placement
  – Scalp edema
  – Subdural collections

• If asymmetry is of frequency, amplitude and graphoelements
  – Stroke
  – Structural lesions
Amplitude

- Measured in voltage
- Voltage: peak to peak value
- Amplitude of the graphoelements decreased from 24 wks CA to term
Amplitude abnormalities

- Isoelectric EEG
- Depressed or undifferentiated
  - Poor or reduced mixture of frequencies; usually < 10 µV
- Persistent low voltage
  - <5-10µV awake
  - <10-25µV quiet sleep
  - Persistent beyond 43 weeks CA
Synchrony

• Refers to the bursts and graphoelements
• Burst are synchronized if there is < 1.5 seconds separating the onset of the bursts between the right and left hemisphere
• Graphoelements that are always synchronous
  – Encouches frontales
  – Anterior frontal dysrhythmia
  – Monorhythmic occipital delta
• Normal synchrony
  – < 29 wks CA: 100%
  – 31-23 wks CA: 70%
  – >37 wks CA: 100%
Encouches frontales, QS
25 day old baby girl born at 39 weeks GA

Anterior frontal dysrhythmia

Encouches frontales
Asynchrony

• Burst are asynchronous if there is > 1.5 seconds separating the onset of the bursts between the right and left hemisphere

• Etiology
  – Diffuse encephalopathy (meningitis, HIE, etc)
  – Cerebral dysgenesis (absence of the corpus callosum)
Asymmetry and Asynchrony

Figure 7
Neonate with a left middle cerebral artery territory infarct. Voltage asymmetry (suppression of EEG activity) over the left temporal region [Figure 8]

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Reactivity

- Clinical and/or EEG response to external stimulation or internal arousal
- Clinical response:
  - Active movements
  - Respiratory pattern changes
- EEG response:
  - Frequency changes
  - Increased continuity
  - Decreased amplitude
  - Change from sleep to awake pattern

Photic stimulation does not produce photic driving in the term neonate
Absence of Reactivity

- Normal only in marked immaturity

- Absence of reactivity indicates pathological thalamo-cortical disruption
25 day old baby girl born at 39 weeks GA
Reactivity Sequence 1

25 day old baby girl born at 39 weeks GA

Transitional Sleep
Reactivity Sequence 2

25 day old baby girl born at 39 weeks GA
Reactivity Sequence 3

25 day old baby girl born at 39 weeks GA

Awake
Graphoelements

- Monomorphic occipital delta
- Delta brushes
- Rhythmic temporal theta
- Anterior dysrhythmia
- Encouches frontales

- 24-34 weeks
- 24-36 weeks, peak 34 weeks, sometimes seen at term during quiet sleep
- 24-34 weeks
- 35-44 weeks
- 34-44 weeks
Central delta brushes, right temporo-occipital theta

32 weeks CA, sleep
Development of Graphoelements
<table>
<thead>
<tr>
<th>Age (in weeks)</th>
<th>27–28</th>
<th>29–30</th>
<th>31–33</th>
<th>34–35</th>
<th>36–37</th>
<th>38–40</th>
<th>41–44</th>
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<tbody>
<tr>
<td><strong>EEG feature</strong></td>
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<tr>
<td>Major characteristics (background activity)</td>
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<tr>
<td>Tracé discontinu (discontinuity, seconds)</td>
<td>+++(&gt;80%)</td>
<td>++</td>
<td>+ (50%)</td>
<td>+/-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>SATs high amp</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+/-</td>
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<td>NA</td>
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<td>complexity</td>
<td>+/-</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>+++</td>
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<td>+++</td>
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<td>Sleep–wake</td>
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<td>+</td>
<td>++</td>
<td>+++</td>
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<tr>
<td>cycles</td>
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<td>AS 50%</td>
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<td>Tracé alternant</td>
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<td>Tracé continu</td>
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<td>++</td>
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<td>Synchrony</td>
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<td>+</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
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<tr>
<td>(of EEG ‘bursts’)</td>
<td>&gt;80%</td>
<td>&lt;50%</td>
<td>&gt;50%</td>
<td>&gt;70%</td>
<td>&gt;80%</td>
<td>~100%</td>
<td>100%</td>
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<tr>
<td>Minor characteristics (paroxysmal wave forms)</td>
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<tr>
<td>Delta brushes</td>
<td>+/-</td>
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<td>+++</td>
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<td>++</td>
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<td>+/-</td>
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<td>Location</td>
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<tr>
<td>Occurrence</td>
<td>W, AS,QS</td>
<td>W, AS,QS</td>
<td>QS</td>
<td>QS</td>
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<tr>
<td>Theta activity</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>+/-</td>
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<tr>
<td>Location, predom</td>
<td>O</td>
<td>T,O</td>
<td>T,O</td>
<td>T,O</td>
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<tr>
<td>Delta activity</td>
<td>-</td>
<td>+(AS)</td>
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<td>-</td>
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<td>+</td>
<td>++</td>
<td>+</td>
<td>+/-</td>
<td>-</td>
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<tr>
<td>Sporadic sharp waves</td>
<td>+/-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+/-</td>
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</tbody>
</table>
Normal Sharp Waves

• Sporadic sharp waves are present during all preterm and term recordings
• Most of them are artifacts until proven otherwise

• Ex:
  – Enconches frontalis
  – C3, C4 and T3 and T4 sharp waves at the rate <1/min if symmetric
Sharp wave or Artifact?
Abnormal Sharp Waves

- Negative sharp waves
  - Electrographic field
  - Stand from the background
  - Followed by slow wave
  - Unclear relation with neonatal seizures and subsequent risk for epilepsy

- Occipital sharp waves

- Midline or vertex sharp waves
  - Concerning for sagittal sinus thrombosis (MRI + MRV)
Abnormal Sharp Waves

• Positive Sharp Waves
  – No related to seizures
  – Associated with structural brain abnormalities
    • Hydrocephalus, PVL, IVH, HIE, stroke, inborn errors of the metabolism, etc
  – Positive rolandic sharp waves are associated with white matter lesions
Sharp transients
Sharp transients
Encouches frontales
25 day old baby girl born at 39 weeks GA
25 day old baby girl born at 39 weeks GA

Active Sleep
25 day old baby girl born at 39 weeks GA

Active Sleep
25 day old baby girl born at 39 weeks GA

Quiet Sleep

Anterior frontal dysrhythmia

Sharp
25 day old baby girl born at 39 weeks GA

Quiet Sleep
25 day old baby girl born at 39 weeks GA

Quiet Sleep
CONCLUSIONS

• Analysis of the neonatal EEG begins with the Conceptional Age

• Neonatal EEG interpretation includes: continuity, symmetry, synchrony, normal and abnormal patterns, sleep/wake cycle and seizures