Continuous EEG monitoring of the premature infant in the NICU

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CIP, Paris 2011
A method that at a very early stage diagnose those babies which would benefit from early interventions:
A method that at a very early stage diagnose those babies which would benefit from early interventions:

- important tool in clinical practice.
- possible to introduce a better strategy in the follow up approach of the premature infant.
Why early EEG-monitoring???
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Brain injury at an early stage,
Why early EEG-monitoring???

Brain injury at an early stage,
Brain maturation process

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Why early EEG-monitoring???

- Brain injury at an early stage,
- Brain maturation process
- Guide us in clinical practice

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Why early EEG-monitoring???

- Brain injury at an early stage,
- Brain maturation process
- Guide us in clinical practice
- Intervention therapy

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What do we know about EEG in the premature
EEG in the premature infant

Reflects third trimester development

Changes with behavioral state cycles

Dependent on advancing postconceptional age

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<table>
<thead>
<tr>
<th>EEG</th>
<th>Frequencies</th>
<th>Amplitude</th>
</tr>
</thead>
</table>

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## EEG -frequencies

<table>
<thead>
<tr>
<th>Name</th>
<th>Frequency [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>delta</td>
<td>0.1-4</td>
</tr>
<tr>
<td>theta</td>
<td>4-7</td>
</tr>
<tr>
<td>alpha</td>
<td>8-13</td>
</tr>
<tr>
<td>beta</td>
<td>13-15</td>
</tr>
<tr>
<td>gamma</td>
<td>30-90</td>
</tr>
</tbody>
</table>

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Background EEG according to amplitude and pattern

A. Continuous pattern

B. Discontinuous pattern

C. Undifferentiated pattern.

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Comparison of the continuities for the three groups of preterm infants.

(A) Continuous patterns;

(B) Discontinuous patterns.
the percentage of continuous patterns increased with increasing PCA

the percentage of discontinuous patterns increased with increasing PCA
Relationship between amplitude and PCA

Okumora A. et al; Pediatr Neurol (23); 2005
Most striking EEG features

Temporal and occipital delta waves:
1. most frequent
2. more numerous than the frontal

Delta waves synchronization was also an important criterion, which can be explained by the subcortical thalamic drive and/or by progressing synaptogenesis in the corpus callosum.

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Amplitude-integrated electroencephalography (aEEG)

- Continuous monitoring
- Information on background activity
- Detect significant brain dysfunction
- Seizure detection
Suggested classification aEEG patterns in preterm and term infants

Continuous (C): minimum (5-10 µV and maximum 10–25(50)µV

Discontinuous (DC): minimum amplitude variable, but below 5 µV, and maximum amplitude above 10 µV

Burst suppression (BS): discontinuous background with minimum amplitude without variability at 0–1(–2)µV,

Bursts with amplitude >25 µV

Low voltage (LV): continuous background pattern of very low voltage (around or below 5 µV)

Inactive, flat (FT): mainly inactive (isoelectric tracing) background below 5 µV
Sleep-wake cycling (SWC)

- No SWC
- Imminent/immature SWC
- Developed SWC

Hellstr m-Westas et al, Neuroreviews, 2006
Seizures

- abrupt rise in the minimum amplitude
- simultaneous rise in the maximum amplitude followed by a short period of decreased amplitude.
- Single seizure: a solitary seizure
- Repetitive seizures: single seizures appearing more frequently than at 30-min intervals
- Status epilepticus: continuously ongoing seizure activity >30 min

Hellström-Westas et al, Neureviews, 2006
Cyclical rhythmical variations
Left: GA 29 weeks; IVH grade IV: Discontinuous low-voltage pattern with repetitive seizures (arrows) confirmed by clinical epileptic activity.

Right: GA 29: without PIVH: Predominantly continuous pattern (encircled) with intermittent episodes of discontinuous high-voltage pattern and cyclical sinusoidal variations describing sleep-wake cycles
aEEG- possible limitations?

- Short lasting or localized seizures may be missed
- Does not differentiate the wave type
- Does not differentiate between the brain hemispheres
- Only records activity from a limited area in the brain

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Continuous multi-channel EEG recording
Montage suggestion

10 self-adhesive electrodes where:

- 8 active electrodes placed symmetrically over both hemispheres.
- Open space over the fontanel for ultrasound and echo Doppler measurements

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EEG-”cap”

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EEG-examples – GA 28 weeks

EEG after 71 hours of recording

Electrode impedance

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Artifacts

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Oscillation 10 Hz  GA 27 weeks
Artifacts

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Muscle activity (GA 29 weeks)
Artifacts

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Suction
Artifacts
Automated analyses

Future

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Automated analysis of long-term continuous EEG monitoring (LTM) in premature infants

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Oslo University Hospital, Norway
Method

• Absolute Band Power (ABP) was used to measure brain activity and it is defined as the integral of all the power values within its frequency range and expressed in µV^2

• The ABP values of each second in all the bands were exported to the SAS System (SAS Institute Inc, Cary, NC, USA)

• Total ABP (tABP) was calculated for each band resulting in 4 tABPs (δ-tABP, Φ-tABP, α-tABP and β-tABP)
Method

The recordings were edited in two different ways to remove artifacts

1. **Visual editing**
   
   Unreadable EEG and EEG with impedances above 40 kΩ in any channel was discarded

2. **Automated editing**
   
   Mathematical removal of respectively 5, 10, 15 or 20% of the highest tABP values
Results
The recorded δ–tABP in one infant

EAPS Copenhagen 2010
Conclusion:

This demonstrates that visual editing of LTM may be substituted by mathematical trimming of the EEG data.

This could be implemented in automated EEG analyses in preterm infants.
IntABP of A: the δ-band, B: the Φ-band, C: the α-band and D: the β-band during the first three days of life.

There is a significant increase of tABP from d1 to d3 (P<0.001) and a significant difference between the two groups for all the bands (P<0.001). There is no significant difference in the increase of tABP from d1 to d3 within the groups (Schumacher E, Stiris T et al, Pediatr res. 2011)
Burst coverage (range / interquartile range) as detected in 11 infants by 3 assessors and 2 different algorithms
Conclusion:
Revised algorithm results in detections comparable to human eye.
EEG at 6 weeks of life in very premature neonates

Conclusion: At 6 weeks of life, EEG may be helpful in refining neurological risk in very premature neonates.

Significance: EEGs recorded at 6 weeks of age may be a valuable predictive tool in addition to early EEG and cranial ultrasound.
tABP on day 1-3 and outcome at 2yrs of age

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Schumacher E, Stiris T; prelim data
Thank you
aEEG

**Moderately abnormal**: >10 uV and <5 uV.

**Severely abnormal**: <10 uV and <5 uV

**Seizures**: sudden increase in voltage accompanied by narrowing of the band followed by a brief period of suppression.

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