Case: Part 3

- Despite treatment with intravenous lorazepam, non-convulsive seizures persist.

- Diagnostic evaluation is ongoing: MRI Brain reveals gyral swelling in the left occipital region.
Case: Part 3

- Cerebral lesion: ongoing risk factor for seizures
- Management plan:
  - Administer additional anticonvulsants.
  - Use EEG to evaluate response to treatment.
- Problem:
  - Not enough man power to allow continuous review of EEG by a technologist or neurophysiology trained neurologist.
- Can automated techniques like quantitative trend displays help identify electrographic seizures?
Quantitative EEG Trends for Seizure Identification
Monday, December 5, 2011

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Disclosure

No Disclosures.
Learning Objectives

• To understand the concept of quantitative EEG trending displays
• To learn how to apply quantitative EEG trending displays to facilitate ICU EEG monitoring
Continuous EEG Monitoring Poses Numerous Challenges

- Large volume of information
  - Prolonged recordings: 24-48 hours or more
  - 19-channels of data
  - Displayed at 10-20 seconds per screen

- Potentially overwhelming
  - Multiple simultaneous recordings
Standard EEG Display

24 hours @ 15 seconds / page

5760 pages

9 - 21 channels

10 - 15 seconds per screen
What do we *Really* mean by ‘Continuous’ Monitoring?

- **Continuous EEG recording**
- **Intermittent interpretation**
  - by neurophysiologists remote from the bedside
  - routine review occurs once or twice daily
  - more frequent review guided by clinical need

- **Potential for delay between**
  - seizure occurrence
  - seizure recognition & treatment
A Potential Strategy to Enable More Continuous EEG Interpretation

Quantitative EEG (QEEG)

• Transformation of raw EEG using
  – Time compression
  – Channel reduction
  – Colour coded graphical display
Origins of Quantitative EEG: The Cerebral Function Monitor (CFM)

- Developed in late 1960s to assess depth of anesthesia in adult cardiac surgery
- Introduced to the neonatal ICU in the 1970s & 80s by Rosen & Svenningsen
- Pioneered for use in infants with asphyxia by Hellstrom-Westas and deVries
How is CFM Calculated?

- **Filtering** (bandpass filter between 2-15 Hz)
- **Rectification** (to a single polarity)
- **Compression** in time (1 mm/min)
- **Semi-logarithmic display** of amplitude
  - Linear between 0-10uV, logarithmic between 10-100uV

\[
\text{CFM} = \text{amplitude-integrated EEG (aEEG)}
\]
Modern Cerebral Function Monitor
Reduced montage:
2 or 4 scalp recording electrodes
CFM Split-Screen Display

3 hours per screen

10 - 15 seconds per screen

aEEG

Raw EEG
QEEG: A New Perspective on EEG

• Provides an overview of the temporal evolution in the seizure burden
  – Seizure frequency, distribution, duration
  – Response to therapy

• Highlights slowly-evolving changes in the EEG background
  – Focal or hemispheric slowing
    • *e.g.* to monitor for impending ischemia due to vasospasm
  – Burst suppression
    • *e.g.* assessment of the inter-burst interval
Potential Applications of QEEG Trending

- Facilitate review of prolonged EEG recordings by expert electroencephalographers
- Provide real-time summary of EEG data that is potentially easier to interpret by bedside caregivers
  - Relatively static display
  - Does not require constant surveillance
Properties of EEG Amenable to QEEG Analysis

- Amplitude (Power)
- Frequency
- Symmetry
- Rhythmicity
- Continuity
Fourier Transformation

“frequency-specific power”
“power spectrum”

Concept by Sue Herman
# Quantitative EEG Algorithms

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<td>Burst-suppression index</td>
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Envelope Trend

4 hours per screen

Seizures

Akman et al., Epilepsy Research (2011) 93:66-72
Color Density Spectral Array
(CDSA = CSA = DSA = Color Spectrogram)

Frequency (0-20 Hz)

Time

Frequency-specific Power

Low

High

4-8 hours per screen
Panel of Multiple QEEG Trends

From Hirsch & Brenner, Atlas of EEG in Critical Care, 2009
How Accurate are QEEG Trends for Seizure Identification?
• Sample of 27 cEEGs performed in a pediatric ICU
  – 17 recordings with seizures & 10 without seizures
• Recruited 3 neurophysiologists
  – Experienced in conventional EEG, but not QEEG
• Trained for one hour
  – Introduced to theoretical basis of CDSA, aEEG
  – Examined 5 recordings, with access to raw EEG
• Testing:
  – Presented with CDSA/aEEG display only, raw EEG concealed
  – Asked to mark all events “suspected to be seizures”
8-Channel Display
Double-Distance A-P Bipolar Montage
Testing Display - CDSA
Testing Display- aEEG

[EEG montage with channels Fp1-C3, C3-O1, Fp1-T3, T3-O1, Fp2-C4, C4-O2, Fp2-T4]
Sensitivity vs. False Positive Rates

CDSA: 83.3%  aEEG: 81.5%

CDSA: 0.06/h (= every 16 h)
aEEG: 0.05/h (= every 20 h)

Median performance; error bars indicate range

Stewart et al., Neurology 2010;75:1501–1508
Factors Reducing Sensitivity

- Low amplitude seizures (especially on CDSA)
- Focal seizures
- Short seizures (especially on aEEG)
- Abundant interictal epileptiform activity
Example of Missed Seizures due to Low Amplitude
Causes of False Positive Identification

Artifacts

- Movement
  - Chest percussion, chewing, oscillating beds
- Electrical artifact
  - Pumps, drips, ECMO, heating/cooling devices
- Electrode “popping”
- Periodic Epileptiform Discharges
- Burst suppression background
Example of False Positives due to PLEDs
Seizure detection using digital trend analysis: Factors affecting utility

Cigdem I. Akman\textsuperscript{a,b,*}, Vesna Micic\textsuperscript{a}, Anita Thompson\textsuperscript{c}, James J. Riviello Jr.\textsuperscript{a,b}

_Epilepsy Research_ (2011) 93:66-72

- Seizure amplitude
- Background amplitude
- Seizure duration
- User experience
- Combination of multiple trends
CSA is superior to Envelope Trend
Envelope Trend is superior to CSA

Akman et al., Epilepsy Research (2011) 93:66-72
Next Question...

- How well do these tools work in the hands of
  - EEG technologists
  - ICU bedside nurses
  - ICU fellows

Can we translate these techniques from the EEG Lab to the Bedside?
Sensitivity for Each Group of Users

Hahn et al., unpublished
False Positive Rate for Each Group of Users

Hahn et al., unpublished
Automated Seizure Detection

• Commercially available computer algorithms
  – Developed using a library of EEGs containing seizures
  – Calibrated to optimize sensitivity / specificity

• Can be linked to bedside alarm or email alert

• Alarm prompts manual review of QEEG / EEG

• Frequent false alarms may be a nuisance
  – Importance of low false positive rates

Akiyama et al., unpublished
Conclusions

• QEEG trends are useful tools for both ‘expert’ and ‘non-expert’ users

• Accuracy for seizure identification is variable
  – Depends more on the recording than on user expertise

• QEEG trends do not replace careful review of raw EEG

• More research is needed to understand
  – Accuracy of different QEEG modalities
  – Optimal design of QEEG trending panels
How to Get Started with QEEG

- Create separate panels for each available algorithm:
  - CDSA / CSA / color spectrogram
  - Amplitude-integrated aEEG
  - Envelope trend
- Use 8 channels of EEG (un-averaged)
  - *e.g.* Double-distance A-P bipolar montage
- Learn the appearance of seizures and artifacts for each panel
- For a given patient, use the panel that best depicts seizures
- Try different combinations of panels
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