CEEG Monitoring Implementation: Practical Issues

12/5/11

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## Disclosure

<table>
<thead>
<tr>
<th>Name of Commercial Interest</th>
<th>Relationship</th>
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<tbody>
<tr>
<td>Lundbeck, Inc.</td>
<td>Local PI for industry sponsored study</td>
</tr>
<tr>
<td>Fidelity Biosciences Research Initiative</td>
<td>Research grant</td>
</tr>
<tr>
<td>National Association of Epilepsy Centers</td>
<td>Board member</td>
</tr>
<tr>
<td>American Board of Clinical Neurophysiology</td>
<td>Board member</td>
</tr>
<tr>
<td>American Clinical Neurophysiology Society officer</td>
<td>Officer</td>
</tr>
<tr>
<td>ICU EEG Monitoring</td>
<td>Clinical practice</td>
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American Epilepsy Society | Annual Meeting
Learning Objectives

At the conclusion of this activity, participants should be able to:

• Implement appropriate and efficient technical aspects of continuous EEG monitoring in the ICU
• Understand the limitations of current CEEG monitoring, and identify areas for future research
Clinical Practice

- Goal: Improve neurologic outcome in critically ill children
- Rapidly diagnose electrographic seizures
- Communicate diagnosis efficiently to treating ICU physicians
- Institute appropriate therapy
  - Confirm efficacy of treatment
  - Avoid overtreatment
- Utilize resources efficiently and control costs
## Continuous EEG in ICU

| Staffing and Training | • Physicians  
|                       | • Technologists  
|                       | • Nurses  
| Technical Aspects of CEEG | • Electrode type and number  
|                       | • Equipment / Video  
|                       | • Quantitative EEG  
| CEEG Review | • Protocols  
|              | • Real-time vs. intermittent review  
|              | • Networking  
|              | • Communication with ICU team  
| Future Directions | • Outcome studies  
|                  | • Treatment trials  

# Current State of CEEG: Survey Results

<table>
<thead>
<tr>
<th>Area</th>
<th>Responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEG availability</td>
<td>All times 24/7</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>Limited additional hours</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>Only standard weekday hours</td>
<td>12%</td>
</tr>
<tr>
<td>Remote reading</td>
<td>Possible for all records</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Possible for some records</td>
<td>43%</td>
</tr>
<tr>
<td></td>
<td>Not possible</td>
<td>22%</td>
</tr>
<tr>
<td>NCS management</td>
<td>&gt;=5 patients/yr</td>
<td>86%</td>
</tr>
<tr>
<td></td>
<td>&lt;5 patients/yr</td>
<td>14%</td>
</tr>
<tr>
<td>cEEGs/mo</td>
<td>&lt;1</td>
<td>17%</td>
</tr>
<tr>
<td></td>
<td>1-5</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td>6-20</td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td>&gt;20</td>
<td>13%</td>
</tr>
</tbody>
</table>
ICU CEEG Team: Staffing

- Dependent on local resources
- Hook-ups
  - EEG technologists
    - In-house vs. on-call
    - Expanded lab hours
  - Limited EEG arrays by ICU nurses, residents
- Screening for EEG changes
  - Clinical neurophysiology fellows
  - Advanced EEG technologists
  - Continuous or intermittent
- Interpretation / clinical recommendations
  - Attending staff: 24 hour availability
Qualifications of CEEG Personnel

- Physician: Clinical electroencephalographer
  - Board Certification
    - American Board of Psychiatry & Neurology
      Clinical Neurophysiology
    - American Board of Clinical Neurophysiology
  - Fellowship training in clinical neurophysiology
- Specialized training
  - CEEG equipment: recording, safety, troubleshooting
  - Effects of acute brain injuries and drugs on EEG activity, ICU artifacts
  - Use, yield and limitations of quantitative EEG
Qualifications of CEEG Personnel

- EEG Technologist
  - ABRET Registered EEG Technologist (R. EEG T.)
- Specialized CEEG Technologist
  - ASET National Competency Skill Standards for ICU/cEEG Monitoring
  - Registration in CLTM by ABRET
  - Special training
    - CEEG use, routine maintenance, troubleshooting
    - Ictal and interictal electrographic patterns and artifacts commonly encountered in the ICU

ASET = American Society of Neurodiagnostic Technologists
ABRET = American Board of Registration of Electroencephalographic and Evoked Potential Technologists
Electrodes

- Disk: Plastic silver-chloride / metal
  - Imaging compatibility (CT & MRI)
  - Infection control
- Needle
  - Emergency situations
  - Not appropriate for long-term recordings
- Subdermal wire electrodes
- Caps / template systems
- Apply with collodion, EC2 paste
- Maintenance every 24 hrs

Images courtesy of John Ives, Kathleen Principe, Ken Jordan
Electrode Location and Number

- International 10-20 system
- Minimum of 8 electrodes
- 16 or more electrodes optimal
- Inadequate spatial sampling
- Inability to distinguish artifact from cerebral activity
- Poor quality of uninterpretable study if any of few electrodes are dislodged or artifactual
# Limited Montages

<table>
<thead>
<tr>
<th></th>
<th>Subhairline (1)</th>
<th>Hairline (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>Methods</td>
<td>Commercial limited EEG</td>
<td>Reformatted from standard 10-20 digital</td>
</tr>
<tr>
<td>Channels</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Duration</td>
<td>24 hours</td>
<td>2-3 min samples</td>
</tr>
<tr>
<td>Seizures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>68%</td>
<td>72%</td>
</tr>
<tr>
<td>Specificity</td>
<td>98%</td>
<td>92%</td>
</tr>
<tr>
<td>PLEDs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>39%</td>
<td>54%</td>
</tr>
<tr>
<td>Specificity</td>
<td>92%</td>
<td>97%</td>
</tr>
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</table>

1. Young GB et al. Neurocrit Care 2009
EEG Machines / Video / Audio

- Fixed vs. portable units
  - Small footprint
  - Wall-mounted
  - Flexibility
- Video strongly recommended
  - Correlate clinical behavior with EEG features
  - Avoid misinterpretation of artifacts
- Integration with ICU monitors (BP, ICP, IV pumps)
Networking

- Speed of data review depends on network speed
- Remote review
  - In-hospital
    - Fast enough to review video
  - Out-of-hospital (balance cost and speed)
    - Desktop sharing
    - Terminal server applications
    - Virtual application servers
- Storage
- Security
- Information technology support staff
ICU CEEG Protocols

- Usually developed by both EEG and ICU staff
- CEEG ordered for patients meeting certain criteria
  - Disease
  - Severity of illness / altered mental status
- Allocate resources to most critical patients
  - Include indications for emergent / urgent studies
- Avoid inappropriate overuse of CEEG
  - Disorders with low likelihood of seizures
  - Excessively long duration of monitoring
- Adjust for local resources and as new evidence becomes available
Review

- Frequent enough to influence clinical management
- At least twice daily
  - May occasionally require continuous or frequent review until patient stabilized
- Written reports daily
  - Interim verbal reports to clinical team as needed
- Remote review should be available

- Optimal
  - Continuous review of raw EEG, quantitative trends, and video by trained personnel
Interrater Reliability

- Interrater reliability for seizures in ICU population (1)
  - 90 10s epochs from 23 comatose patients
  - 9 readers kappa
    - Experienced 0.5
    - Less experienced 0.29

- Research terminology (2)
  - 5 readers; 58 EEG samples from 11 SAH patients
  - Moderate agreement for main terms; others slight to fair
  - Agreement lower with longer EEG segments (20 min)

The ACNS Subcommittee on Research Terminology for Continuous EEG Monitoring: Proposed Standardized Terminology for Rhythmic and Periodic EEG Patterns Encountered in Critically Ill Patients

Lawrence J. Hirsch,* Richard P. Brenner,† Frank W. Drislane,‡ Elson So,§ Peter W. Kaplan,||
Kenneth G. Jordan,¶ Susan T. Herman,# Suzette M. LaRoche,** Bryan Young,†† Thomas P. Bleck,†‡
Mark L. Scheuer,† and Ronald G. Emerson*

Journal of Clinical Neurophysiology • Volume 22, Number 2, April 2005
Quantitative EEG Trends

- No studies on sensitivity and specificity for seizure detection in ICU
- Nearly limitless combinations of trend type, electrodes / brain regions, and time displays
  - Difficult to standardize
- Use of quantitative trends is encouraged
  - May detect gradual or subtle changes that are not visible with review of raw EEG
- Can not be used alone for seizure or ischemia detection
  - Adjunct to review of raw EEG
Centralized Monitoring

- Central monitoring station
  - Raw EEG
  - Video?
  - Quantitative EEG
- Staffing
  - EEG technologists
  - Monitoring technologists
- Applications for remote monitoring of multiple patients
  - Optimized for laptops, tablets, iPad
Communication with ICU Team

- Gather information about clinical status of patient
  - Medications, mental status, interim procedures
- Provide reports which are clinically useful for ICU team
  - Timing
  - Verbal vs. written
  - Complex interpretations may necessitate face-to-face interaction
  - ICU EEG rounds (in ICU or via remote review)
- Education for ICU attendings, fellows, nurses
- Shared research projects
- Consultations for seizure management
Impact on Clinical Care

- Retrospective
- 300 emergent cEEG studies in 287 consecutive adults and children
- Duration: mean 51 hrs, median 24 hrs, range 2-432 hrs

- Normal 19.0%
- Abnormal background 30.6%
- Epileptiform 22.3%
- Electrographic seizures 28.0%

Impact on Clinical Care

No AEDs prior to CEEG (n =101)

- Seizures (20)
  - Start AEDs (20, 100%)
    - Start AEDs (21, 26%)
    - No AEDs (60, 74%)

No seizures (81)

AEDs prior to CEEG (n =199)

- Seizures (64)
  - Change AEDs (63, 98.5%)
    - Change AEDs (21, 15.5%)
    - No change (99, 73.5%)

- No seizures (135)

Stop AEDs (15, 11%)

Conclusions

- We can detect seizures with ICU CEEG, but not always quickly and efficiently
- Wide variability in practice of CEEG
  - Optimal practices will change as technology evolves
  - Inadequate evidence-base to support large-scale adoption
- Have a written protocol for ICU-EEG
- Choose staffing / equipment based on local resources
- Develop training materials for staff
- Incorporate quantitative EEG
- Facilitate remote review
# Future Directions for CEEG

<table>
<thead>
<tr>
<th>Current State</th>
<th>Optimal State</th>
<th>Outcomes</th>
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<tbody>
<tr>
<td>Limited staffing and equipment</td>
<td>24 hour staffing; faster hookups</td>
<td>Guideline development</td>
</tr>
<tr>
<td>Variable EEG interpretation</td>
<td>Uniform interpretation</td>
<td>Interrater reliability</td>
</tr>
<tr>
<td>Raw EEG</td>
<td>Better quantitative software and alarms</td>
<td>Trials to determine QEEG diagnostic accuracy</td>
</tr>
<tr>
<td>Limited understanding of pathophysiology</td>
<td>Knowledge of which patterns injure the brain</td>
<td>Clinical trials of seizure treatment</td>
</tr>
<tr>
<td>Intermittent review</td>
<td>Continuous real-time monitoring</td>
<td>Studies of cost-effectiveness</td>
</tr>
</tbody>
</table>
Acknowledgements

- ACNS Critical Care EEG Monitoring Committee
  - Larry Hirsch, Nicholas Abend, Suzette LaRoche, Cecil Hahn, Nathan Fountain, Peter Kaplan, Cormac O’Donovan, Frank Drislane, James Riviello, Paul Garcia, Josh Goldstein, Mark Quigg, Ron Emerson, Liberty Simmons, Andrew Evans, Richard Brenner, Kenneth Jordan, G. Bryan Young, Thomas Bleck, Mark Scheuer, Nathalie Jette, Mark Scher, Tammy Tsuchida, Taeun Chang, Paula Gerber, John Kerrigan, Yafa Minazad, Stephan Schuele

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