Continuous EEG: A Standard in Canada?

Victoria McCredie MBChB
Neurointensivist
Sunnybrook Health Sciences Centre

Critical Care Canada Forum
28th October 2015
No conflicts of interest to disclose.
Outline

- Indications for cEEG
- What should we be aiming for?
- Barriers within Canada
- Possible facilitators
Premise of Neurocritical Care

A fundamental goal in the critical care management of patients with neurological disorders is:

1. Identification
2. Prevention
3. Treatment

of secondary cerebral insults that are known to exacerbate outcome.
Overall aims of neuromonitoring/EEG

1. Identify secondary cerebral insults that may benefit from specific treatments (reversible)

2. Improve pathophysiological understanding of cerebral disease in critical illness

3. To guide and individualize therapy

4. Assist with prognostication

Modern uses of cEEG

1. Detection of subclinical seizures
2. Detect early cortical dysfunction
   - Evolving ischemia in subarachnoid hemorrhage
3. Detect severity of cortical dysfunction
   - Prognostication, especially in cardiac arrest
4. Differentiate from non-seizure events
   - define spells/movements (using video)
5. Guide treatment of burst-suppression
Continuous electroencephalography

- Used with increasing frequency in critically ill patients to provide insight into brain function and identify electrographic/non-convulsive seizures
- Often impacts clinical management, most often by identifying electrographic seizures and status epilepticus
- Most electrographic seizures have no clinical correlate, and thus would not be identified without CEEG monitoring.
- There are increasing data showing that electrographic seizures and status epilepticus are associated with worse outcome.
Concerns within ICU

- Recognition that 67-90% of seizures in comatose patients are non-convulsive
- Non-convulsive seizure duration and delay in diagnosis are associated with increased mortality
- Increasing utilization of cEEG vs. increasing healthcare costs
- Physicians urgently need guidance as to which EEG patterns warrant aggressive monitoring and treatment

Claassen et al. Neurology 2004; 62: 1743-1748
Young et al. Neurology 1996; 47: 83-89

Vespa et al. CCM 2007; 35: 2830-2836
Oddo et al. CCM 2009; 37: 2051-2056
Spectrum of EEG Abnormalities in Critical Illness

1. Background Abnormalities
2. Sleep, State Changes and Spontaneous Variability
3. Periodic/Rhythmic Discharges
4. Cyclic and Stimulus Induced Patterns
5. Seizures/Status

+PLUS artefacts distinct to ICU environment
### Seizures in Critically Ill Patients

<table>
<thead>
<tr>
<th>Critical Illness</th>
<th>Seizures*</th>
<th>Status Epilepticus</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBI</td>
<td>12-50%</td>
<td>8-35%</td>
</tr>
<tr>
<td>Intracerebral hemorrhage</td>
<td>10-30%</td>
<td>1-21%</td>
</tr>
<tr>
<td>Hypoxic-ischemic encephalopathy</td>
<td>5-59%</td>
<td>30%</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>4-19%</td>
<td>10-14%</td>
</tr>
<tr>
<td>Ischemic stroke</td>
<td>6-27%</td>
<td>1-10%</td>
</tr>
<tr>
<td>Non-neurological illness</td>
<td>4-15%</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

Sutter et al. CCM 2013; 41: 1124-1132
Herman et al. J Clin Neurophysiology 2015; 32: 87-95
Status epilepticus (SE)

- Generalized convulsive SE (GCSE) is a clinical diagnosis that does not require EEG
- Non-convulsive seizures (NCSz) after GCSE: 48%
- Non-convulsive SE (NCSE) after GCSE: 14%

Refractory Status Epilepticus

- Almost exclusively non-convulsive
- RSE occurs in 9-43% of patients with SE
- RSE morbidity and mortality (42-61%) is high, and significantly higher compared to non-RSE
- RSE may initially respond to iv therapies, but many patients subsequently develop NCSz, detectable only with cEEG

Claassen et al. Epilepsia 2002; 43: 146-153
Rossetti et al. Neurocrit Care 2011; 14: 4-10
Holtkamp et al. J Neurol Neurosurg Psychiatry 2005; 76: 534-539
Vooturi et al. CI Neurology & Neurosurg 2014; 126: 7-10
Stecker et al. Epilepsia 1998; 39: 18-26
Claassen et al. Neurology 2001; 57: 1036-1042
Does monitoring and treatment change outcome?
• Nationwide Inpatient Sample (NIS) managed by AHRQ

• Adults, ICD-9 codes for mechanical ventilation + routine EEG or continuous EEG

• In-hospital mortality for ventilated pts who received cEEG was 25% vs. 39% receiving routine EEG only (adjusted OR of 0.63 (95% CI 0.52-0.76, p < 0.001)

• cEEG is favourably associated with inpatient survival in mechanically ventilated patients, without adding significant charges to hospital stay

Seizure burden is independently associated with short term outcome in critically ill children

Eric T. Payne,¹ Xiu Yan Zhao,² Helena Frndova,³ Kristin McBain,³ Rohit Sharma,¹ James S. Hutchison³ and Cecil D. Hahn¹

- Maximum hourly seizure burden quantified for each subject
- Maximum percentage of any given hour occupied by electrographic seizures.
- This variable was subsequently categorized as: no seizures; <20% per hour; 20–50% per hour; and >50% per hour
Increasing seizure burden was independently associated with neurological decline at hospital discharge, even after adjusting for diagnosis and illness severity.
Outline

- Indications for cEEG
- What should we be aiming for?
- Barriers within Canada
- Possible facilitators
Aims:

1. Provide better guidance for EEG monitoring
2. Improve implementation of EEG in ICU practice
Recommendations

- Recommend urgent EEG (within 60 min):
  - In SE that do not return to functional baseline within 60 min after administration of AED
  - In refractory SE

- Recommend cEEG for seizure detection in patients with refractory SE

Claassen et al. ICM 2013; 39:1337-1351
Suggestions for cEEG

1. Seizure detection in SE that do not return to functional baseline within 60 min after administration of AED
2. Seizure detection in comatose ICU patients with unexplained and persistent altered consciousness
3. Ischemia detection in comatose SAH patients where neurological examination unreliable
4. Assist with prognostication of coma after CA
Consensus statements

Consensus Statement on Continuous EEG in Critically Ill Adults and Children, Part I: Indications

Susan T. Herman,* Nicholas S. Abend,† Thomas P. Bleck,‡ Kevin E. Chapman,§ Frank W. Drislane,⁎
Ronald G. Emerson,|| Elizabeth E. Gerard,¶ Cecil D. Hahn,⁎ Aatif M. Husain,**†† Peter W. Kaplan,**
Suzette M. LaRoche,§§ Marc R. Nuwer,|||| Mark Quigg,¶¶ James J. Riviello,## Sarah E. Schmitt,***
Liberty A. Simmons,** Tammy N. Tsuchida,††† and Lawrence J. Hirsch§§§

Consensus Statement on Continuous EEG in Critically Ill Adults and Children, Part II: Personnel, Technical Specifications, and Clinical Practice

Susan T. Herman,* Nicholas S. Abend,† Thomas P. Bleck,‡ Kevin E. Chapman,§ Frank W. Drislane,⁎
Ronald G. Emerson,|| Elizabeth E. Gerard,¶ Cecil D. Hahn,⁎ Aatif M. Husain,**†† Peter W. Kaplan,**
Suzette M. LaRoche,§§ Marc R. Nuwer,|||| Mark Quigg,¶¶ James J. Riviello,## Sarah E. Schmitt,***
Liberty A. Simmons,** Tammy N. Tsuchida,††† and Lawrence J. Hirsch§§§
## NCS Guidelines: cEEG in SE

**Table 10 Indications for cEEG in SE**

<table>
<thead>
<tr>
<th>Indication</th>
<th>Rationale</th>
<th>Grade</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent clinical seizure or SE without return to baseline &gt; 10 min</td>
<td>Ongoing non-convulsive status despite cessation of motor activity 18–50 %</td>
<td>Class I, level B</td>
<td>[30, 54, 80, 81]</td>
</tr>
<tr>
<td>Coma, including post-cardiac arrest</td>
<td>Frequent non-convulsive seizures, 20–60 %</td>
<td>Class I, level B</td>
<td>[25, 82, 209–215]</td>
</tr>
<tr>
<td>Epileptiform activity or periodic discharges on initial 30 min EEG</td>
<td>Risk of non-convulsive seizures, 40–60 %</td>
<td>Class I, level B</td>
<td>[80, 216]</td>
</tr>
<tr>
<td>Intracranial hemorrhage including TBI, SAH, ICH</td>
<td>Frequent non-convulsive seizures, 20–35 %</td>
<td>Class I, level B</td>
<td>[209–212, 214]</td>
</tr>
<tr>
<td>Suspected non-convulsive seizures in patients with altered mental status</td>
<td>Frequent non-convulsive seizures, 10–30 %</td>
<td>Class I, level B</td>
<td>[25, 211, 213]</td>
</tr>
</tbody>
</table>

Brophy et al. Neurocrit Care 2012; 17: 3-23
Outline

- Indications for cEEG
- What should we be aiming for?
- **Barriers within Canada**
- Possible facilitators
Agreement with ESICM

A) ESICM Recommendations
- Encephalitis with altered LOC
- CA (after rewarming)
- CA (during hypothermia)
- ICH with altered LOC
- r/o SE in SAH
- TBI with unexplained decreased LOC
- Refractory SE
- SE not returning to baseline

B) ESICM Suggestions
- Unexplained altered LOC without primary brain injury
- Encephalitis: To aid in prognosis
- Ischemic stroke with unexplained altered LOC
- Detecting DCI in SAH
- Severe TBI at risk for NCSE

Park & Boyd. ICM 2015; 41: 1869-1870
## EEG Utilization

<table>
<thead>
<tr>
<th></th>
<th>ESICM Indication</th>
<th>No ESICM indication</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EEG completed</strong></td>
<td>12</td>
<td>9</td>
<td>21</td>
</tr>
<tr>
<td><strong>No EEG completed</strong></td>
<td>32</td>
<td>167</td>
<td>199</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>44</td>
<td>176</td>
<td>220</td>
</tr>
</tbody>
</table>
Limitations of cEEG in ICU

1. cEEG:
   • Time consuming, expertise, cost effectiveness, interrater disagreement, disconnected with other systemic monitors

2. Language:
   • Need improved and consistent procedural terminology coding to accurately capture how we use cEEG in ICU (SE, detect ischemia, determination of prognosis)

Perceived Barriers in Canada

- **76% disagreed** they were able to obtain standard EEG as quickly as is optimal for patient care
- 45% have technical capacity for cEEG at their hospital
- 82% disagreed they were able to obtain cEEG as quickly as is optimal
- (94% adults, 60% pediatric)
- 75% believed routine EEG (67% cEEG) should be standard of care for comatose critically ill patients
- 74% reported difference between ideal EEG and actual EEG for patients admitted on Friday (**mean 2.7 days**, SD 0.9)

Davies-Schinkel et al. AJRCCM 2012; 185: A1619
Davies-Schinkel et al. AJRCCM 2012; 185: A1618
Perceived barriers

1. Lack of EEG technicians
2. Physicians to interpret EEG
3. Finances
Outline

• Indications for cEEG
• What should we be aiming for?
• Barriers within Canada
• Possible facilitators
Facilitators

• *Can we learn how to improve our EEG availability by comparing practices with our pediatric colleagues?*

• *Are educational strategies to interpret EEG recordings a way of overcoming this specific barrier?*
Training

- 9 pulmonary critical care fellows during neurosurgical ICU rotation
- Covered didactics, clinical exposure, EEG interpretations
- 25 question evaluation tool: assessed pre and post course
- Evaluation scores increased from $7.56 \pm 2.24$ to $16.67 \pm 2.96$ ($P < .001$).

Chau et al. C Crit Care 2014; 29: 1107-1110
Implementation & Cost

Seizures were seen in 23 patients (25%), 19 were in status, of which 18 were successfully treated.

Transfers to the main hospital were prevented in 53 patients, producing a cost savings of $145,750.

Kolls et al. Neurocrit Care 2015; 23: S1-S289
Standardize terminology

Many widely used EEG terms lack consensus definition and exhibit high interrater variability

- “epileptiform discharges”
- “seizures”
- “triphasic waves”

Why do this?

- No uniformly accepted nomenclature for ICU EEG patterns
- No consensus which patterns are associated with neuronal injury, which require treatment, and how aggressively to treat.

- Interrater agreement for most terms in the ACNS critical care EEG terminology was high:
  - Substantial to almost perfect interrater agreement ($\kappa > 0.8$) for most of the terms, with the exception of triphasic morphology

Gaspard et al. Epilepsia 2014; 55: 1366-1373
Simplified montages

- 70 patients with metabolic disorder, epilepsy or acute brain injury
- 4 channel sub-hairline vs. 16 channel montage
- Seizure detection
  - sensitivity = 68%; 95% CI 45–86%
  - specificity = 98%; 95% CI 89–100%

Young et al. Neurocrit Care 2009; 11: 411-416
Test characteristics for seizures

- Sensitivity = 54-72%; 95% CI 45–86%
- Specificity = 98-100%; 95% CI 89–100%
- PPV 94-100% (95% CI 70–100%)
- NPV 86-87% (95% CI 75–95%)
- Interrater agreement $\kappa$ score 0.68 (95% CI, 0.43–0.93)

Young et al. Neurocrit Care 2009; 11: 411-416
Kolls and Husain. Epilepsia 2007; 48:959–965
Hybrid models

• It seems sensible to pursue a system that would combine the advantages of both systems:

  • Ease of application of the sub-hairline montage with good spatial coverage of the full-montage recordings

  • Sub-hairline EEG may meet the clinical requirements in patients with less heterogeneous background and well-defined clinical questioning

• It is important to be aware of the strengths and limitations of this technology.
What is our setup?

- Routine 30 minute EEG available 8-5pm weekdays
- One dedicated EEG machine in ICU
- Not network connected for real time
- All EEGs retrospectively read by trained neurophysiologist
- Quantitative and raw EEG displayed at bedside
- Weekends: template system, 2 neurointensivists, alternate with general intensivists
Template system

- ICU RN/MD applied template then registered technologist applied leads with collodion using 10-20 system
- Measured impedance values acceptable, no difference in subjective quality of recordings, 3 hour reduction in time required to initiate EEG recording with templates

Questions left unanswered…

- How can subclinical seizures be treated safely and effectively?
- Does prompt seizure detection with cEEG monitoring and successful treatment improve short- and long-term outcomes?
- How do we ensure proper use of health care resources?
Conclusions

• Seizures and status epilepticus are common in the general ICU setting, even in patients **without a primary neurological diagnosis**

• Most critically ill patients with SE have non-convulsive seizures/status epilepticus

• Early recognition of SE allows for prompt treatment and increases the likelihood of treatment success and prevention of further neuronal damage

• Each centre in Canada is likely to have similar barriers to cEEG, but the solution may need to be adapted to local environment
The chief function of the body is to carry the brain around.
Thank You.
Questions?

Victoria.McCredie@Sunnybrook.ca
**Status epilepticus (SE)**

- **OLD:** >30 min of continuous seizures or intermittent seizures without recovery of consciousness
- **NEW:** > 5 min, or repeated seizures without recovery of consciousness
- Clinical data suggest that generalized tonic-clonic seizure seizures are unlikely to stop on their own after 5 min
- Longer they go on, the harder they are to stop

NCSz and NCSE

- ≥ 10 seconds for non-convulsive seizure
- ≥ 30 min for non-convulsive status epilepticus

**Primary criteria**

1. Repetitive generalized or focal spikes, sharp waves, spike-and-sharp wave complexes at ≥ 3/sec
2. Repetitive generalized or focal spikes, sharp waves, spike-and-sharp wave complexes < 3/sec and a secondary criterion
3. Sequential rhythmic, periodic, or quasi-periodic waves at ≥ 1/sec and unequivocal evolution in frequency morphology, or location

**Secondary criterion**

- Significant improvement in clinical state, resolution of epileptiform activity and improvement in background EEG patterns (e.g. re-appearance of posterior dominant “alpha” rhythm) temporally coupled to acute administration of a rapidly acting antiepileptic drug.

Young et al. Neurology 1996
Chong & Hirsch. JCN 2005