The yield of continuous EEG monitoring in the intensive care unit at a tertiary care hospital in Saudi Arabia: A retrospective study [version 1; peer review: 1 approved, 1 not approved]

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Abstract

Background: The practice of continuous EEG monitoring (CEEG) in the intensive care unit (ICU) has been spreading over the past decade. Building an effective ICU CEEG program with sufficient quality demands adequate EEG equipment and significant human resources. While this is available in large tertiary care centers where the practice of CEEG has developed, it may not be available in developing healthcare systems. This study sought to provide data generated from a CEEG program in the adult ICU at a tertiary healthcare center in Saudi Arabia, shedding light on the real-life utility of CEEG in a developing healthcare system.

Methods: This is a retrospective review of CEEG findings, along with mortality and duration of hospitalization of patients who had CEEG during a 12-month period at the adult ICU at the King Abdulaziz University Hospital (KAUH) in Jeddah, Saudi Arabia.

Results: A total of 202 CEEG records were identified. A total of 52 patients had non-convulsive seizures (NCS); 10 clearly fulfilled criteria for non-convulsive status epilepticus. There were 120 patients that had clinical seizures upon presentation. Among them, 36 (30%) had NCS on EEG. The proportion of patients who were deceased at 60 days was higher in patients who had NCS (42%) than those who didn’t (26%, $\chi^2 (2, n=200) = 4.4$, $p=0.03$). The duration of hospital stay was longer for those who had periodic or rhythmic CEEG patterns ($\chi^2 (2, n=200) = 7.6$, $p=0.02$) but there was no significant relationship with mortality at 60 days.

Conclusion: This study demonstrates a real-world experience from a tertiary care center in Saudi Arabia, a developing healthcare system. Findings are consistent with prior experience with ICU CEEG, demonstrating that finding ictal, rhythmic or periodic patterns is associated with morbidity and mortality. Further studies are needed to demonstrate how the practice of CEEG may alter patient outcomes.

Keywords
Neurocritical care, EEG, non-convulsive seizures, status epilepticus, Saudi Arabia
Introduction
Continuous electroencephalography (CEEG), the practice of continuously recording an electroencephalogram and a time-synchronized video of the patient, is commonly utilized to monitor critically ill patients with acute brain injury or altered mental status\(^1\). CEEG is instrumental in the diagnosis and management of nonconvulsive seizures (NCS) and status epilepticus, detection of cerebral ischemia, prognostication of outcomes after cardiopulmonary arrest, and evaluation of abnormal movements and altered mental status\(^2\). The practice of CEEG monitoring critically ill patients in the intensive care unit (ICU) has been spreading over the past decade, particularly in Europe and North America\(^3,4\). Building an effective ICU CEEG program with sufficient quality demands not only adequate EEG equipment but also significant human resources\(^5\). This includes trained electroencephalographers and technologists who have enough time to devote to reviewing the large amounts of EEG data that are generated through continuous monitoring\(^6\). While this is available in large tertiary care centers where the practice of CEEG has developed, it may not be available in developing healthcare systems. Most of the published CEEG data also come from these advanced centers in North America and Europe.

This study sought to provide data generated from a CEEG program in an adult ICU at a tertiary healthcare center in Saudi Arabia, aiming to shed light on the real-life utility of CEEG in a developing healthcare system outside North America and Europe.

Methods

Data gathering
This is a retrospective review of ICU CEEG findings, as well as mortality status and duration of hospitalization of all patients who underwent CEEG monitoring during a 12-month period from September 2016 to August 2017 at the adult ICU at the King Abdulaziz University Hospital (KAUH) in Jeddah, Saudi Arabia. This is an academic, tertiary-care, 600-bed hospital. Its adult ICU is comprised of 30 beds and is divided into medical and surgical divisions. CEEGs are requested by ICU physician or neurologists according to the clinical needs. An EEG technologist is available during the day time to set up ICU CEEGs. EEG leads are placed using the 10–20 international system of lead placement. CEEGs are digitally recorded, including synchronized video recording of the patient. The duration of CEEG monitoring is decided by the neurology consultation or ICU physicians. Studies whose duration was less than 2 hours were not included in the study as they were considered extended but not long-term studies. An epileptologist with fellowship training in CEEG interpretation reviewed the records on daily basis and reported them using the American Clinical Neurophysiology Society (ACNS) ICU EEG consortium proposed nomenclature for ICU EEG reporting, and the Salzburg criteria for non-convulsive status epilepticus\(^7\). Management decisions were made by the physicians in the ICU and neurology services.

Data analysis
Reports of CEEGs performed in the adult ICU during the study period were retrieved from the hospital’s electronic medical records (EMR). The author extracted key data from the reports, including background characteristics, the presence of rhythmic and periodic patterns or NCS. The author retrieved relevant demographic and clinical patient data from the hospital’s EMR, including diagnoses, ICU and hospital stay, and mortality status at 60 days. Frequencies, percentages, means, standard deviation, and Chi square were performed using the IBM SPSS Statistics for Windows, version 20.0.

Ethical approval
This study was approved by the Institutional Review Board of KAUH as a retrospective study of anonymized clinical data with waiver of additional patient consent.

Results
A total of 202 CEEG records fulfilling the criteria were identified; complete, raw figures are available as Underlying data\(^8\). There were 116 female patients. The mean age was 53 (standard deviation=21). The duration of CEEG recording varied, with 48 (24%) recorded for 2–6 hours and 154 (76%) recorded for 6–24 hours. Table 1 shows the frequency of clinical diagnoses of our patients. The most common diagnostic categories were cerebrovascular disease and epilepsy. Table 2 shows the frequency of CEEG findings. Among the 52 patients that had NCS on CEEG, 10 patients clearly fulfilled criteria for non-convulsive status epilepticus. There were 120 patients that had clinical seizures upon presentation prior to CEEG monitoring. Among them, 36 (30%) had NCS on EEG. The proportion of patients who were deceased at 60 days was significantly higher in patients who had NCS (42%) than those who didn’t (27%, \(\chi^2\) (2, n=200)= 4.4, p=0.03) (Table 3). There was no significant difference in the duration of hospital stay between those who had seizures and those who didn’t (p=0.2) (Table 3). The duration of hospital stay was longer for those who had periodic or rhythmic CEEG patterns (\(\chi^2\) (2, n=200)= 7.6, p=0.02) but there was no significant relationship with mortality at 60 days (Table 3).

Discussion
The practice of using CEEG in the ICU has developed rapidly over the past decade, particularly in North America and Europe\(^1,5\). This study is one of the first to report the experience of using ICU CEEG in Saudi Arabia, a country with a rapidly developing healthcare system outside North America and Europe.

| Table 1. Frequencies and percentages of relevant clinical diagnoses in the study sample. |
|---------------------------------|---------|
| Diagnosis                       | n (%)   |
| Cerebrovascular disease         | 53 (26%)|
| Epilepsy                        | 50 (25%)|
| Sepsis/Metabolic                | 40 (20%)|
| Brain tumor                     | 8 (4%)  |
| CNS infections                  | 24 (12%)|
| Post arrest                     | 10 (5%) |
| Traumatic brain injury          | 6 (3%)  |


Table 2. Frequencies and percentages of non-convulsive seizures (NCS), generalized periodic discharges (GPD), lateralized periodic discharges (LPD), GRDA (generalized rhythmic delta activity), and LRDA (lateralized rhythmic delta activity) in the study sample.

<table>
<thead>
<tr>
<th>Variable</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCS</td>
<td>52 (26%)</td>
</tr>
<tr>
<td>GPD</td>
<td>22 (11%)</td>
</tr>
<tr>
<td>LPD</td>
<td>20 (10%)</td>
</tr>
<tr>
<td>GRDA</td>
<td>22 (11%)</td>
</tr>
<tr>
<td>LRDA</td>
<td>14 (7%)</td>
</tr>
</tbody>
</table>

Table 3. Cross-tabulation of mortality and duration of hospital stay in relation to the presence of seizures and periodic or rhythmic patterns on CEEG.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mortality</th>
<th>Hospital Stay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Death within 60 days</td>
<td>&lt;1 week</td>
</tr>
<tr>
<td>EEG Seizures</td>
<td>No</td>
<td>40 (27%)</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>22 (42%)*</td>
</tr>
<tr>
<td>Periodic or rhythmic patterns</td>
<td>No</td>
<td>16 (25%)</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>46 (33%)</td>
</tr>
</tbody>
</table>

*p<0.05.

Prior studies have not definitively proven that utilizing CEEG leads to better outcomes. This, coupled with the significant resources required to effectively run an ICU CEEG program, may lead decision makers in healthcare systems to hesitate to support the development of CEEG practices. This study presents local data that demonstrate the need for CEEG. The data also raises questions whether CEEG is being utilized optimally. For example, few patients with brain tumors had CEEG, even though this is a patient population at risk of NCS. This suggests a need for a protocol for CEEG in the ICU, with focus on indications, required duration of monitoring, and management of NCS.

This study is a retrospective analysis with limitations. Data extracted from the EMR did not allow clarity with regards to the mental status of patients, use of sedatives, and other management decisions. Physicians did not follow a clear protocol when deciding the duration of the CEEG study. Longer studies may lead to higher detection rates of relevant CEEG patterns. The number of cases in some diagnostic categories was not high enough to permit subgroup analyses. The clinical setting is that of a developing program with limited resources and must be interpreted in this context. Further studies from developing healthcare systems like Saudi Arabia’s are needed to illuminate how the practice of CEEG monitoring may be integrated in the region.

Data availability
Open Science Framework: The yield of continuous EEG monitoring in the ICU at a tertiary care hospital in Saudi Arabia: A retrospective study. [https://doi.org/10.17605/OSF.IO/Q56J3](https://doi.org/10.17605/OSF.IO/Q56J3).

This project contains all raw de-identified data associated with this study.

Data are available under the terms of the Creative Commons Zero “No rights reserved” data waiver (CC0 1.0 Public domain dedication).

Grant information
The author(s) declared that no grants were involved in supporting this work.
References

Open Peer Review

Current Peer Review Status: ✔️ ☓

Version 1

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Robert C. Tasker
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The author has described a practice of continuous EEG monitoring in an intensive care unit in a University Hospital in Jeddah, Saudi Arabia.

I have a number of comments that will help readers better understand what these data mean, and how they might reflect on the implications for ICU practice.

Method (page 3)

1. In the first paragraph (line 8) the author describes "CEEG are requested by ICU physician or neurologists according to the clinical needs". In order to understand the significance of some of the analyses provided, it would be helpful to know what were the inclusion criteria, or the 'standard operating procedure' for the ICU. For example, were all patients comatose, and the clinician was unable to assess a clinical response?

2. In the first paragraph (lines 13-15) the authors describes "The duration of CEEG monitoring is decided by the neurology consultation or ICU physicians":
   • In order to understand the significance of some of the analyses later in the manuscript, it would be helpful to know when CEEG was started and finished in relation to admission and discharge/death.
   • It would also be helpful to know the timing of when NCS occurred.

3. Since this population has been gathered from ICU admissions, it would be helpful to have some description of ICU severity-of-illness, according to the risk-adjustment score used by the unit. The examination of any illness feature that might be associated with death needs to be adjusted for severity of illness. There were 62 observed deaths in 200 cases - what was the expected number of deaths from the admission data?

Results (pages 3 and 4)

1. The presentation of findings in the Results section and the Abstract is a little confusing:
   • The author has a starting population of 202 patients undergoing CEEG monitoring. Then, the denominators being used in the data summaries are n=120, and n=200. I think that a
flow chart would help here.

2. Table 2 can be summarized as text, which will make room for a flow-diagram and better review of the data presented in Table 3.

3. Table 3 needs some attention to data accuracy. For example, in Row 2 (Hospital stay data) the percentages add up to 101%, which is just a rounding error. In Row 3 (Hospital stay data) the percentages add up to 99%.

4. Yes, the author has found some associations with death, and length of stay, but does the information gained from CEEG have the potential to help with decision making? For example, if we imagined that CEEG was a ‘diagnostic test’, then:
   - The pre-CEEG probability of death in this population was 31%. The finding of EEG-seizures could change your pre-test to a post-test probability of death of 39%. I don't think that physicians would find this a helpful piece of information. That is, it is not about death, rather it is something we should use to identify a need for treatment, for example.
   - Similarly, the pre-CEEG probability of hospital stay >1 month was 32%. The finding of periodic or rhythmic patterns could change the pre-test to post-test probability of hospital stay >1 month to 34%. Again, I don't think that physicians would find this a helpful piece of information.
   - Obviously, both of these points would need to be tested and validated in a prospective study (as well as knowing details of when these CEEG features were found), but it may lead to a change in emphasis in the first paragraph of the Discussion.

Discussion (pages 3 and 4)

Based on the above results, one could conclude that identifying EEG seizures on CEEG does not provide a significant 'quantum' in prognostic evidence. Similarly, identifying periodic or rhythmic patterns on CEEG does not provide a significant 'quantum' in identifying cases that will be likely be in-hospital >1 month.

I am wondering whether the focus should be on 'what are we doing the CEEG': surely it is to identify something that we can/should treat; and, to identify something that will help us determine that we no longer need to do CEEG.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
No

If applicable, is the statistical analysis and its interpretation appropriate?
No

Are all the source data underlying the results available to ensure full reproducibility?
Partly
Are the conclusions drawn adequately supported by the results?
Partly

**Competing Interests:** Researcher in the ‘Pediatric Status Epilepticus Research Group’ (PSERG); Journal reviewer; Senior Editor

**Reviewer Expertise:** Pediatric Neurocritical Care; Pediatric ICU

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

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**Peter W Kaplan**
Department of Neurology, Johns Hopkins Bayview Medical Center, Johns Hopkins University School of Medicine, Baltimore, MD, USA

How many of the NCSE were focal versus generalized?

Did not the mortality vary with etiology of NCSE and PDs?

I would add in the final section on limitations of the study that there is perforce selection bias as the EEG techs were not available during certain periods (if I remember, overnight and other times) and this should be stated.

Possibly an EEG example of NCSE should be provided.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
I cannot comment. A qualified statistician is required.

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** EEG

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

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