



Bringing EEG Back to the Future: Use of cEEG in Neurocritical Care

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Continuous EEG Is Associated With Favorable Hospitalization Outcomes for Critically Ill Patients.

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Objective: To characterize continuous electroencephalography (cEEG) use patterns in the critically ill and to determine the association with hospitalization outcomes for specific diagnoses. **Methods:** We performed a retrospective cross-sectional study with National Inpatient Sample data from 2004 to 2013. We sampled hospitalized adult patients who received intensive care and then compared patients who underwent cEEG to those who did not. We considered diagnostic subgroups of seizure/status epilepticus, subarachnoid or intracerebral hemorrhage, and altered consciousness. Outcomes were in-hospital mortality, hospitalization cost, and length of stay. **Results:** In total, 7 102 399 critically ill patients were identified, of whom 22 728 received cEEG. From 2004 to 2013, the proportion of patients who received cEEG increased from 0.06% (95% confidence interval [CI]: 0.03%-0.09%) to 0.80% (95% CI: 0.62%-0.98%). While the cEEG cohort appeared more ill, cEEG use was associated with reduced in-hospital mortality after adjustment for patient and hospital characteristics (odds ratio [OR]: 0.83, 95% CI: 0.75-0.93, $P < .001$). This finding held for the diagnoses of subarachnoid or intracerebral hemorrhage and for altered consciousness, but not for the seizure/status epilepticus subgroup. Cost and length of hospitalization were increased for the cEEG cohort (OR: 1.17 and 1.11, respectively, $P < .001$). **Conclusions:** There was a >10-fold increase in cEEG use from 2004 to 2013. However, this procedure may still be underused; cEEG was associated with lower in-hospital mortality but used for only 0.3% of the critically ill population. While administrative claims analysis supports the utility of cEEG for critically ill patients, our findings suggest variable benefit by diagnosis, and investigation with greater clinical detail is warranted.

Commentary

The recognition of the need to have specialized care for critical patients with neurologic illness or neurologic complications of systemic illness, along with the dual goal of improving survival and optimizing functional neurological outcome, has led to the surge of neuro-critical care as a recognized neurology subspecialty since the 1980s.¹ Multidisciplinary intensive care unit (ICU) teams have demonstrated improvement in outcomes of diverse patient populations, such as ischemic stroke, intracerebral hemorrhage, subarachnoid hemorrhage, and traumatic brain injury.^{1,2}

Along with multidisciplinary teams, specialized technology has emerged as a useful tool to assess neuro ICU patients' condition when physical examination is limited. The use of electroencephalography (EEG) in the intensive care setting has been integrated and expanded within the last 20 years. Different modalities of EEG are used including short-term spot EEG acquisitions (rEEG) and continuous, long-term, video EEG (cEEG).³ This modality implies real live monitoring by trained nursing or EEG technology staff and has become a staple in the toolbox of neuro ICU care. Furthermore, computerized

multivariable analysis of the raw EEG in montages and arrangements that inform the team of neurophysiologic changes in an automated fashion and real time, known as quantitative EEG or qEEG, has significantly facilitated the integration of this technology to the everyday work of the ICU team.

Within the ICU setting, cEEG is most useful in the identification, localization, characterization, quantification and follow-up of subclinical or subtle clinical seizures.³ It allows the implementation of management goals and therapeutic targets, such as seizure cessation or burst suppression pattern.⁴ It may precede and predict neurologic decline and improvement.⁵ It is also useful in the prediction and prevention of secondary injury such as ischemia and aids in identifying and localizing regional structural lesions in real time.⁶ Continuous EEG can help in the assessment of altered mental status and rarely contributes to establishing a specific etiology to an unclear presentation. But it occasionally does, such is the case for findings described in association with some autoimmune encephalopathies.⁷

The benefits from cEEG as a diagnostic modality acquisition reside in it being noninvasive, long lasting, and having



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real-time results with spatial and temporal resolution. These characteristics are not easily achieved with any other clinically used diagnostic modality.

Efforts from the neurophysiology community to elucidate the physiologic meaning of patterns of unclear clinical significance have resulted in a comprehensive, rather descriptive, terminology that has allowed both the clinical and research communities to start speaking a common language when interpreting and reporting EEG findings.⁸ This terminology has also facilitated our understanding of the pathophysiologic and prognostic implications of some of these findings.⁹ However, there are no clear parameters regarding when to use one EEG modality over another, when to start it, and for how long to monitor our patients under cEEG. Also, the impact of this diagnostic modality on mortality, functional recovery, cost, and length of stay has been studied but is not clear.³

Hill et al underwent an extensive data review of patients within a single health-care national database which represents about 20% of nationwide discharges. This included a sample of over 7 million critical care adult patients who required mechanical ventilation from years 2004 to 2013. The study focused on the patients who had cEEG at some point during their hospitalization and compared them to the group who didn't, in regard to in-hospital mortality, length of stay, and cost of hospitalization. They also analyzed patients according to the indication for monitoring. They found the use of cEEG dramatically expanded from about 0.6% to about 0.80% over the 10-year span. Only about 1.2% of the population with seizures or less, for other neurological diagnoses, had cEEG. The group who had cEEG had lower in-hospital mortality rate independent of the severity of their condition. This was true for all groups except the seizure group. The cEEG group also had longer stay and higher cost of care, which was not the case for rEEG.

Even in the most recent years of the study, cEEG was much underutilized. I suspect the problem would be less in more recent years as cEEG has become a more ubiquitous tool, at least for larger and urban hospital settings. The stated reduced mortality is a powerful argument to support its use, but one has to keep in mind in-hospital deaths in the ICU setting are heavily influenced by the determination of goals of care, advance directives, and access to long-term ventilator care facilities. This is even more the case for the group of patients with extensive intracranial bleeds and other devastating conditions. In further support of the potential benefit of cEEG is the fact that the group who had it seemed to have had more comorbid conditions and longer hospital stays than the ones who didn't and still had a lower mortality rate.

It is very interesting to see the group of patients with status epilepticus did not show the same mortality benefits observed in other groups. This may raise a question regarding the consequences of treatment and the urge to act when information is available. This calls for further understanding into the meaning of unclear EEG patterns, some of which can be misinterpreted as status epilepticus. Mortality of ICU patients with status epilepticus has been described to be relatively lower at hospital discharge but rather large within a year thereafter¹⁰ and much related to functional outcome.

The results regarding length of stay and cost of care may be related to the ability to find and treat comorbid conditions such as subclinical seizures in patients who were otherwise classified in the nonseizure groups. Without considering the functional outcome at the time of discharge, I end up hoping that the patients monitored under cEEG had timely treatment of subclinical seizures and better neurological outcomes in the long term even if that resulted in longer hospital stay and higher cost.

New technology such as qEEG along with easily applied electrode bands and caps and remote live monitoring capabilities will bring cEEG to more hospitals settings. The described improvement in mortality for ICU population supports the investment in these technologies beyond its current use. However, the results seen in 2 discrete neurologic conditions cannot be necessarily relevant to all critical care pathologies.

Despite strong efforts from the clinical neurophysiology and neurointensive care communities,⁶ we still need to further understand and socialize the advantages and limitations of cEEG in neurocritical care. We need to continue making cEEG acquisition and interpretation available for more institutions and for more than only monitoring known seizures. Continuous EEG has the capability to aid in the identification of early secondary lesions and can help us guide treatment or understand the course of fluctuating neurologic conditions. Multiple studies have shown the elevated prevalence of seizures and status epilepticus on ICU population with altered mental status of unclear etiology.¹¹ Many of these emerging conditions are treatable, and along with improving mortality, we will be making a positive impact on the functional status of these patients at the time of discharge and thereafter.

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