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The impact of an interdisciplinary electroencephalogram educational initiative for critical care trainees ☆,☆☆

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ABSTRACT

Purpose: The purpose of this study is to evaluate the effectiveness of an interdisciplinary electroencephalogram (EEG) educational module for critical care training. Electroencephalogram is increasingly used for diagnosis, monitoring, and treatment decisions in critically ill patients with neurologic and nonneurologic disorders. Continuous EEG monitoring has an expanded role in the intensive care unit as an additional evaluation tool for critically ill patients with altered mental status.

Materials and methods: During a neurosurgical intensive care rotation, pulmonary critical care fellows participated in an EEG curriculum covering didactics, clinical exposure, and EEG interpretations. Using 25-question evaluation tools, including EEG interpretations, participants were assessed before EEG instruction and after curriculum completion.

Results: Nine fellows completed the pilot study. Evaluation scores increased from 7.56 ± 2.24 to 16.67 ± 2.96 ($P < .001$).

Conclusions: An interdisciplinary approach was effective for increasing EEG knowledge in critical care fellows as measured by the assessment tools. As an added potential benefit, the pulmonary fellows also learned about sleep disorder–related EEG. This model can be replicated in other institutions for trainees of other specialties interested in critical care.

1. Introduction

In critically ill patients, electroencephalogram (EEG) monitoring, including bedside continuous electroencephalogram (cEEG), is being increasingly recognized as a relevant tool for the monitoring, diagnosis, and/or treatment of important altered neurologic states such as subclinical seizures, nonconvulsive status epilepticus, cerebral ischemia, barbiturate coma, and brain death [1]. Continuous electroencephalogram monitoring has revealed a higher incidence of seizure activity in critically ill patients with primary neurologic and nonneurologic abnormalities. Seizures in critically ill patients are often nonconvulsive, making diagnosis more challenging [2], and in neurointensive care patients, the incidence of nonconvulsive seizures in patients who undergo monitoring has been reported as high as 34%, with 10% in nonconvulsive status epilepticus [3-5]. Up to 10% of comatose patients without clinical signs of seizure in a medical intensive care unit (ICU) setting were found to be in nonconvulsive status epilepticus with cEEG monitoring [6,7]. Seizures occur in up to 40% of patients after hypoxic-ischemic encephalopathy, with 30% reported in status epilepticus [8-11]. In a surgical ICU, cEEG monitoring was instrumental in the evaluation of patients with neurologic perturbation after cardiac surgery in the early postoperative period [12]. Continuous electroencephalogram monitoring is currently a focus of active investigation for its potential impact on clinical outcomes [13], and to guide the rising use of EEG in the ICU setting, in 2013, the Neurointensive Care Section of the European Society of Intensive Care Medicine released the following recommendations: "…The panel recommends EEG in generalized convulsive status epilepticus and to rule out nonconvulsive seizures in brain-injured patients and in comatose ICU patients without primary brain injury who have unexplained and persistent altered consciousness. We suggest EEG to detect ischemia in comatose patients with subarachnoid hemorrhage and to improve prognostication of coma after cardiac arrest. We recommend continuous over intermittent EEG for refractory status epilepticus and suggest it for patients with status epilepticus and suspected ongoing seizures and for comatose patients with unexplained and persistent altered consciousness… [1]". These recommendations have the potential to promote further use of EEG in the ICU setting.

Continuous electroencephalogram is now more readily available and cost effective as a monitoring tool than it was a decade ago; however, only a minority of intensivists have specialized training in neurophysiology with the recognition that its most appropriate

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implementation in the critically care setting will likely be in the context of training programs [14]. Although comprehensive EEG expertise falls into the realm of neurology, critical care trainees benefit from adequate EEG exposure and knowledge while caring for critically ill patients.

Using a neurophysiology expert, a multidisciplinary educational module of EEG interpretation had previously been shown to significantly improve the EEG knowledge in anesthesiology [15,16] and neurosurgery residents [17]. A significant acquisition of EEG knowledge, as measured by evaluation scores in a previous study, occurred after 10 EEG interpretations [16]. These results showed that 10 EEG interpretations were effective for increasing knowledge on the assessment tools and thus became the number of EEGs to be interpreted for this critical care education module to ascertain if this educational initiative would be beneficial for critical care trainees. The educational methods used by the module are adaptable to the particular needs of the various backgrounds of rotating trainees.

This aim of this study was to evaluate the effectiveness of a multidisciplinary curriculum for EEG instruction for critical care medicine fellows during a required month in the neurosurgical intensive care unit (NSICU).

2. Methods

The University of Kentucky Institutional Review Board and the Graduate Medical Education Committee approved this prospective study. All participants provided written consent.

Pulmonary critical care fellows were introduced to an EEG learning initiative developed by a neurophysiologist and a neurointensivist at the University of Kentucky during a 1-month NSICU rotation. The curriculum included the basics of monitoring, physiologic basis, and the relevant clinical applications (Table 1) of EEG. The fellows participated in didactics of EEG fundamentals and interpreted 10 EEGs with a neurophysiologist (1:1 faculty-to-fellow ratio) to reinforce basic key concepts as well as critical care and sleep disorder–related EEG areas of interest. The total time spent in this EEG learning module during the NSICU month was approximately 4 hours per fellow. The educational module of the fellow's NSICU rotation included seeing critically ill patients who were placed on cEEG video monitoring and/or patients undergoing routine EEGs. The fellows, with the neurophysiologist, were able to follow up these patients' EEGs in real time and as well as remotely, thus representing some of the relevant EEGs analyzed during the reading sessions.

Table 1
EEG curriculum and content of EEG assessment tools

EEG curriculum	Content of EEG assessment tools
EEG potential generation	✓
Terminology and electrode placement	✓
Fundamentals of frequency bands	✓
Common artifacts	✓
Normal adult EEG: -awake -sleep	✓
Abnormal EEG patterns	✓
• Slowing (focal and generalized slowing) burst suppression	EEG tracing interpretations including:
• Presence of epileptiform discharges (focal and generalized seizures)	• Normal state—awake and sleep
• Status epilepticus	• Artifacts/movement
• Prognostic indicators	• Epileptogenic activity
• Cerebral ischemia	• Epileptogenic potential
• Drug effects	• Encephalopathy
• Hypothermia	• Ischemia
	• Burst suppression
	• Drug effect

Participants completed the baseline evaluation tool before any EEG instruction and followed by another assessment when 10 EEG interpretations with the neurophysiologist were completed. Each evaluation tool contained 25 multiple-choice items, including appropriate EEG tracings. One point is assigned to each correct answer for a total maximum grading score of 25 points. Although similar in content, each evaluation tool consisted of unique questions specifically targeted to assess EEG knowledge, including its use and interpretation. The assessment tool question content is shown in Table 1. The assessment tools were primarily created by one of the investigators and then subsequently edited by the clinical neurophysiologist; the content was reviewed for validity by one investigator who had examination development training from the National Board of Medical Examiners. These evaluation tools have been shown to be reliable previously using Cronbach α[16].

All 9 pulmonary critical medicine fellows on the NSICU rotation consented to participate; none declined. Because there was one fellow per rotation, enrollment in the study was sequential. The NSICU rotation and study participation occurred during the second year of training for all but one fellow whose participation was during the third year.

Minimum sample size was calculated and estimated the minimum detectable difference to be 5 points from a total of 25 points (5/25 points, corresponding to 20% in a 100% scale) on the educational tool and the SD to be 3.000. Using a power of 0.800 and an α value of .050, the estimated sample size was 7. A total of 9 fellows were assessed.

The scoring of the evaluations was completed by an independent third party with the total number of correct answers representing the evaluation score. The investigators were blinded to the individuals' assessment scores. The scores on the evaluation tools were compared using one-way, repeated-measures analysis of variance followed by Student-Newman-Keuls post hoc test comparing both assessment scores.

3. Results

There were 9 pulmonary critical care fellows who provided written consent and completed the study. The results are shown in Fig. 1. The mean score increased from 7.56 ± 2.24 before the learning module to 16.67 ± 2.96 ($P < .001$) after the module. All participants increased their scores compared with baseline after the EEG learning module. To test for a normally distributed population, a normality test was performed using the Kolmogorov-Smirnov test and passed ($P = 1.000$). An equal variance test was performed by checking the variability about the group means and passed ($P > .999$).

4. Discussion

The EEG has several indications in critically ill patients with primary neurologic and nonneurologic disorders. The incidence of epileptic activity, particularly status epilepticus when presenting as nonconvulsive, is now being understood to be a more common occurrence in the critically ill patient. The potential impact of its early recognition and appropriate management on patient outcomes has contributed to an increased use of cEEG in the ICU [13]. Additional indications for EEG monitoring in the ICU include (1) as a diagnostic tool for unexplainable mental status alterations or coma, (2) as confirmation for specific patterns present with metabolic encephalopathies (eg, triphasic waves with hepatic encephalopathy), and (3) as a confirmatory test for brain death [18]. It can be used as a monitor for treatment end points and for measuring therapeutic efficacy for status epilepticus and intracranial hypertension. Its use as a prognostic tool is being increasingly investigated [19-21]. However, EEG has the inherent limitations of complex monitoring modalities, including time-sensitive interpretation and the recognition of artifacts.