

Short-term effectiveness of a condensed series of standard EEG lectures for adult neurology residents*

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ABSTRACT

Objective. To investigate (i) the short-term effectiveness of a series of traditional didactic EEG lectures for an adult neurology resident cohort and (ii) whether the educational benefit of such lectures correlates with residents' prior formal EEG exposure.

Methods. We evaluated the short-term effectiveness of traditional lectures by testing residents' EEG knowledge before and after a series of four EEG lectures given by epilepsy attending physicians. The EEG test consisted of both normal (27) and abnormal (10) EEG questions. Only residents who performed the test before (pre-test) and after (post-test) and attended at least two lectures were included. Residents were divided based on whether they had at least one EEG rotation during or prior to the study (Group A) or not (Group B).

Results. Twelve residents met the inclusion criteria: two PGY1 (postgraduate year 1), four PGY2, one PGY3, and five PGY4 residents. One of these residents did not complete the abnormal EEG section of the tests. The time interval between both tests ranged from 40 to 75 days. The overall score (mean±SEM) for the normal ($n=12$) EEG section was $47\pm6.1\%$ (pre-test) and $58\pm5.5\%$ (post-test) ($p=0.0168$). The overall score for the abnormal ($n=11$) EEG section was $48\pm7.2\%$ (pre-test) and $62\pm8.6\%$ (post-test) ($p=0.0396$). Group A ($n=6$) pre- and post-test scores were $53\pm6.7\%$ and $72\pm4.6\%$, respectively ($p=0.0008$). Group B ($n=5$) pre- and post-test scores were $42\pm11.4\%$ and $48\pm11.7\%$, respectively ($p=0.3777$).

Significance. A condensed series of four EEG lectures given by epilepsy attending physicians generated a statistically significant increase in EEG knowledge among adult neurology residents who already had some degree of formal in-residency EEG exposure. Standard EEG lectures may be an invaluable tool in resident EEG education. It would be advisable to ensure that residents undergo hands-on EEG exposure through formal rotations either prior to or during standard lectures in order to generate maximal educational benefits via this teaching avenue.

Key words: education, residency, EEG, epilepsy, neurology, clinical neurophysiology

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Electroencephalography (EEG) plays a central role in the care of patients with seizure and epilepsy. Accurate EEG interpretation, therefore, is mandatory for optimal care of this patient population. Since a major portion of those who read EEG are general neurologists without additional, post-residency training in clinical neurophysiology and/or epilepsy [1], ensuring successful neurology resident EEG education is of paramount importance. Evidence suggests, however, that an alarming portion of graduating adult neurology residents in the United States does not feel confident reading EEGs independently [2].

A recent survey-based study involving adult neurology program directors in the United States showed that EEG education barriers are pervasive and include insufficient EEG exposure and ineffective didactics [3]. Despite didactics being reported as ineffective, this study identified that the most utilized EEG teaching methods are didactic-based [3]. Herein, we investigated (i) the short-term effectiveness of a series of traditional didactic EEG lectures in an adult neurology resident cohort and (ii) whether the educational benefit of such lectures correlates with residents' prior formal EEG exposure.

Methods

We evaluated the short-term effectiveness of traditional EEG lectures by testing the EEG knowledge of a group of adult neurology residents with the use of a quiz before (pre-test) and after (post-test) a series of four lectures. Only those residents who underwent both pre- and post-tests and attended at least two of the four lectures were included. Moreover, we divided participants based on whether they had at least one EEG rotation during or prior to the study (Group A) or not (Group B). Each EEG rotation in our institution corresponds to a four-week period devoted to learning EEG. Notably, the EEG quiz as well as a portion of the data pertaining to participants included in this study were published previously [4].

Residents' EEG knowledge was measured with a quiz, which consisted of two parts: normal and abnormal EEG. These sections were composed of 27 and 10 EEG questions, respectively, all of which were obtained from the authors' personal collections and were deemed to be highly informative. Residents were given 30 minutes to complete the quiz, and it was scored by giving one point for each correct answer; neither partial nor negative points were given. A list of all the EEG features present in the quiz and the original test were previously published [4] and are summarized in *table 1*. The pre-test was completed immediately before the first lecture whereas the post-

▼ **Table 1.** List of EEG examples included in the EEG quiz.

Normal EEG section	Abnormal EEG section
Section 1 – awake/sleep states	1 Focal spike
1.1 Awake	2 Focal polymorphic slowing
1.2 Drowsy	3 Generalized spike-and-wave
1.3 Stage N1 sleep	4 Generalized polyspike-and-wave
1.4 Stage N2 sleep	5 Lateralized periodic discharges
1.5 Stage N3 sleep	6 Generalized periodic discharges with triphasic morphology
1.6 REM sleep	7 Lateralized rhythmic delta activity
Section 2 – normal variants	8 Right-sided attenuation due to a right subdural hematoma
2.1 Mu rhythm	9 Hypsarrhythmia
2.2 Lambda waves	10 Burst suppression
2.3 Breach rhythm	
2.4 Wicket waves	
2.5 6 Hz phantom spike-waves	
2.6 Posterior dominant rhythm	
Section 3 – sleep structures	
3.1 Positive occipital sharp transients	
3.2 Vertex waves	
3.3 K complexes	
3.4 Sleep spindles	
3.5 Sawtooth waves	
Section 4 – artifacts	
4.1 Ocular, blinking	
4.2 Ocular, fluttering	
4.3 Cardiac, pulse	
4.4 Cardiac, EKG	
4.5 Myogenic	
4.6 Sweat	
4.7 Electrode pop	
Section 5 – activation findings	
5.1 Photic driving	
5.2 Photoparoxysmal response	
5.3 Hyperventilation-induced slowing	

test was completed between 40 and 75 days after the pre-test. Residents did not receive their scores or the correct answers until the end of the study (*i.e.* after the post-test). Data are presented as mean±SEM, and normality condition was analyzed by the Shapiro-Wilk test. Two-tailed paired t-tests were used to compare pre- and post-test scores. A *p* value of less than 0.05 was considered to indicate statistical significance. Statistical analyses were performed using IBM (SPSS) Statistics Version 28.0 software.

▼ **Table 2.** Lectures' learning objectives.

Lecture topic	Learning objectives
Introduction to EEG and artifacts	Understand location of EEG electrodes Distinguish referential and bipolar montages and identify their advantages/disadvantages Gain familiarity with common EEG terminology Understand the important features of an EEG report and level of necessary details Describe features of EEG that distinguish cerebral activity from EEG artifacts Identify common EEG artifacts
Normal and abnormal EEG	Identify and describe characteristic EEG findings during wakefulness, drowsiness, and sleep Identify benign variants on EEG Identify common non-epileptiform EEG abnormalities Understand necessary features to include in describing non-epileptiform EEG abnormalities
Intensive care unit (ICU) EEG	Understand the ACNS ICU EEG terminology Define the ictal-interictal continuum and how it applies to clinical care Understand the challenges in interpreting ICU EEG and the clinical correlation of these patterns
Ictal and interictal EEG	Understand the features that define epileptiform activity Distinguish epileptiform discharges from other cerebral activity Identify ictal events and describe associated EEG changes

The series of four lectures focused on the following topics: introduction to EEG and artifacts, normal and abnormal EEG, intensive care unit EEG, and ictal and interictal EEG findings; each lasting, on average, 60 minutes. All lectures were live/face-to-face and given by clinical neurophysiology-trained attending physicians (Drs. Jay Gavvala and Atul Maheshwari) within eight days of the pre-test. The learning objectives of the lectures are listed in *table 2*. The study was approved by the Baylor College of Medicine Institutional Review Board (IRB) and was performed in August 2019. All data are available upon request.

Results

Twelve residents met the inclusion criteria and were, therefore, included in this study: two PGY1 (postgraduate year 1), four PGY2, one PGY3, and five PGY4 residents. One of these residents (PGY3) did not complete the abnormal EEG section of the pre- and post-test; therefore, this participant was not included in all analyses of the study. The time interval between the pre- and post-test ranged from 40 to 75 days, and six participants had not undergone any EEG rotation prior to or during the study. These data are summarized in *table 3*.

The overall pre-test scores (mean±SEM) for the normal ($n=12$) and abnormal ($n=11$) EEG sections of the test were $47\pm6.1\%$ and $48\pm7.2\%$, respectively. The overall post-test scores (mean±SEM) for the normal ($n=12$) and abnormal ($n=11$) sections were $58\pm5.5\%$

and $62\pm8.6\%$, respectively. There was a statically significant increase in overall score for both normal ($p=0.0168$) and abnormal ($p=0.0396$) EEG sections before and after the lecture series. These results are shown in *figure 1*.

We further analyzed pre- and post-test scores (collectively including both normal and abnormal EEG sections; *i.e.*, score = mean score for normal EEG section + mean score for abnormal EEG section/2) based on whether participants had (Group A) or had not (Group B) undergone EEG rotation(s) before or during the study (*figure 2*). One participant was excluded from this analysis because of a lack of data for the abnormal EEG sections of the test. Group A ($n=6$) pre- and post-test scores (mean±SEM) were $53\pm6.7\%$ and $72\pm4.6\%$, respectively, and this score increase reached statistical significance ($p=0.0008$). Group B ($n=5$) pre- and post-test scores (mean±SEM) were $42\pm11.4\%$ and $48\pm11.7\%$, respectively, however, this score increase did not reach statistical significance ($p=0.3777$).

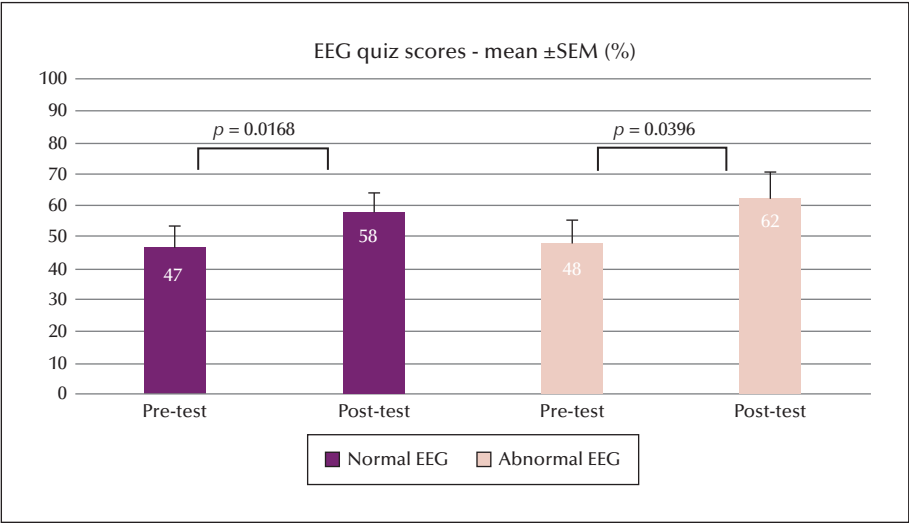
Discussion

Our study shows that a series of four EEG lectures given by epilepsy attending physicians over a period of less than two weeks targeted at a cohort of adult neurology residents generates a statistically significant increase in residents' measured EEG knowledge. Additionally, our results reveal that such a series of lectures is effective exclusively in residents who

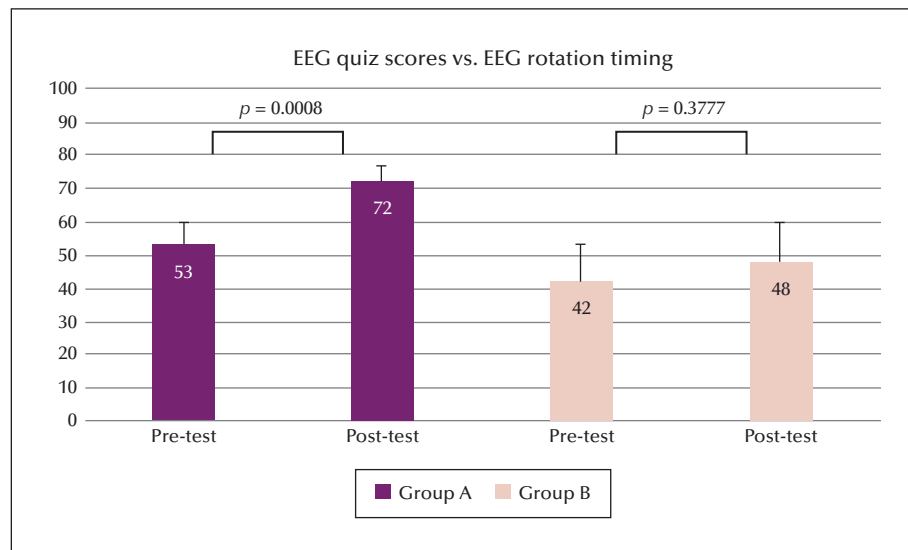
▼ Table 3. Summary of study data.

PGY	Normal EEG, pre-test score (%)	Abnormal EEG, pre-test score (%)	Normal EEG, post-test score (%)	Abnormal EEG, post-test score (%)	Time between pre- and post-test (days)	EEG rotation(s) during or prior to the study (n; timing)	Group
1	37	40	37	20	75	No	B
1	74	100	81	100	40	No	B
2	41	20	56	50	40	No	B
2	26	30	48	30	40	No	B
2	33	20	33	20	40	No	B
2	14	50	48	70	40	Yes: 1; during	A
3	30	N/A	37	N/A	75	No	N/A
4	67	60	74	80	40	Yes: 2; 15 and 17 months prior	A
4	37	50	67	70	40	Yes: 2; 2 and 6 months prior	A
4	78	60	70	100	40	Yes: 1; 9 months prior	A
4	52	30	48	70	75	Yes: 2; 6 and 16 months prior	A
4	70	70	93	70	75	Yes: 2; 8 and 22 months prior	A

PGY: postgraduate year; N/A: not available.



■ Figure 1. Residents' scores on the pre- and post-test stratified by normal EEG (n=12) and abnormal EEG (n=11) sections of the test. Paired t-test (two-tailed) was used to assess statistical significance.



■ **Figure 2.** Residents' scores on the pre- and post-test stratified according to EEG rotation(s) prior to or during the study (Group A; $n=6$) or no EEG rotation (Group B; $n=5$). Paired t-test (two-tailed) was used to assess statistical significance.

already have some degree of formal in-residency EEG exposure.

A better understanding of the benefits of various different EEG teaching methods is important in light of the high percentage of residents who do not feel confident reading EEG despite in-residency training [2, 4]. This issue was the impetus behind a survey involving adult neurology residency program directors in the United States focused on further defining the current state of residency EEG education [3]. Barriers to EEG education were reported by most program directors; the two most commonly mentioned were insufficient EEG exposure and ineffective didactics [3]. While increasing EEG exposure relies more on systematic changes to residency curricula, improving didactics requires a more in-depth characterization of the effectiveness of different EEG teaching methods – such as standard lectures.

Standard lectures have been reported as the most commonly used EEG teaching avenue in adult neurology residencies in the United States [3]. These lectures are most often delivered throughout the year (95%) and, less frequently, concentrated in a one to two-month protected course (30%) [3]. In our institution, the latter method has been the traditional way residents receive EEG education. From a resident standpoint, trainees in our institution have elected a combination of didactic lectures and reading EEGs with supervision as the most efficient way to teach EEG [4].

In addition to emphasizing the suboptimal overall resident EEG knowledge, which has been published

extensively [4-6], our results provide a better understanding of the effects of delivering a condensed series of four EEG lectures given by epilepsy attending physicians. First, we show that these lectures generated a statistically significant increase in residents' EEG knowledge – both related to normal ($47 \pm 6.1\%$ to $58 \pm 5.5\%$; $p=0.0168$) and abnormal ($48 \pm 7.2\%$ to $62 \pm 8.6\%$; $p=0.0396$) EEG – when tested one to two months thereafter. Upon subanalysis of these results, we identified an overall improvement in residents' EEG knowledge following lectures, primarily based on better post-test scores of those residents who already had at least some degree of formal in-residency EEG exposure ($53 \pm 6.7\%$ to $72 \pm 4.6\%$; $p=0.0008$) compared to those who did not have any prior EEG exposure ($42 \pm 11.4\%$ to $48 \pm 11.7\%$; $p=0.3777$).

Despite the relatively low number of participants in our study, which was a major limitation, our data suggest that delivering condensed EEG lectures by epilepsy attending physicians is effective for short-term knowledge retention particularly among adult neurology residents with some degree of prior formal EEG exposure during training. This observation, to the best of our knowledge, has not been reported in relation to resident EEG learning. However, neither the duration of in-residency EEG training (three or four months) nor the time since completion of training were shown to statistically affect residents' EEG interpretation skills [6]. Similarly, neither the presence or absence of epilepsy rotation nor its duration statistically affected adult neurology

residents' abilities to recognize seizures based on the EEG of critically ill patients [7].

The discrepancy in effectiveness of EEG lectures depending on whether residents had prior EEG exposure may be explained in light of a recently proposed multi-theory learning model [8]. This model comprises five phases in learning experience, including dissonance, refinement, organization, feedback, and consolidation. We hypothesize that standard EEG lectures would only introduce new facts/concepts (thereby demonstrating that learners have an incomplete existing knowledge; dissonance) in residents naïve to EEG. However, for those residents with prior EEG exposure, these lectures would also serve to refine and, to a certain extent, aid in organizing knowledge, as well as possibly allowing feedback (residents had the opportunity to ask questions and receive feedback during lectures). Consequently, lectures would provide greater educational benefit in the latter group because multiple phases within the learning process would be addressed.

Based on the medical education literature [9], we also suggest that teachers consider incorporating the principles of adult learning theory into formulating and delivering EEG lectures. Considerations include shortening lecture duration (given learners' limited attention spans), focusing on the highest-yield content, optimizing lecture organization, and ensuring that active learning strategies are involved.

Additional weaknesses in our study include a lack of information regarding residents' potential EEG knowledge acquired prior to the beginning of residency – for example, one of the PGY1 residents included in this study had been exposed to EEG prior to residency. Further, the pre- and post-tests included the same questions, which might have given residents an advantage if they had memorized the test questions. We tried to mitigate this bias by not giving residents their scores or the correct answers until the very end of the study. We acknowledge that the normal and abnormal EEG findings included in the test may not represent the knowledge an adult neurology resident must have prior to graduation. Moreover, we only assessed short-term knowledge, hence it is unclear whether residents retained the acquired knowledge longer after the intervention. Lastly, one should be cautious in extrapolating the success of our lectures since their effectiveness highly depends on the lecturers themselves and their ability to transmit knowledge [10].

In the pursuit of improving resident EEG education, we would like to highlight that a condensed series of standard lectures may still be an invaluable asset for teaching trainees how to read EEGs – especially those with at least some degree of EEG knowledge. Based on our results, it would be advisable to ensure that

residents undergo hands-on EEG exposure through formal rotations either prior to or during standard lectures in order to allow this teaching avenue to generate maximal educational benefits. Other methods, such as supervised EEG reading and e-learning programs – for example, those promoted by the International League Against Epilepsy (ILAE) [11] – should complement didactic-based education. Future studies should investigate the short- and long-term effectiveness of standard lectures in larger cohorts of residents as well as the effectiveness of formal EEG rotation(s) in isolation. ■

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TEST YOURSELF

(1) A condensed series of EEG lectures given to adult neurology residents generates a significant increase in trainees' short-term knowledge.

- A. True
- B. False

(2) A condensed series of EEG lectures seems to be effective in residents with at least some degree of prior formal in-residency EEG exposure.

- A. True
- B. False

Note: Reading the manuscript provides an answer to all questions. Correct answers may be accessed on the website, www.epilepticdisorders.com.
