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EEG education in neurology residency: background knowledge and focal challenges

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ABSTRACT – *Aims.* To assess the baseline EEG knowledge among adult neurology residents at our institution and their perspectives on EEG learning experience during residency.
Methods. We evaluated baseline EEG knowledge and resident perception of EEG education utilizing an EEG quiz and an online EEG survey, respectively. The EEG quiz was divided in two parts, composed of normal (*n*=27) and abnormal (*n*=10) EEG examples. The EEG survey focused on the importance of EEG, EEG milestones and EEG education.
Results. Twenty-one residents completed the EEG quiz; all 21 completed the normal EEG part whereas 19 of these 21 completed the abnormal EEG part. The overall score (mean±SEM) was 42±4.5% for the normal EEG part and 44±5.5% for the abnormal EEG part. The EEG survey was completed by 28 residents. Forty-three percent of the respondents reported not being able to read EEGs even with supervision. The most commonly reported education barriers were insufficient exposure, insufficient responsibility to read EEGs, and inability to link EEG learning to direct patient care.
Conclusion. On average, adult neurology residents were able to correctly identify less than half of normal and abnormal EEG findings. Almost half of residents reported not being able to read EEGs even with supervision.

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

Every neurologist should be fully capable of reading EEGs after successfully completing residency even without the benefit of any fellowship training (The Neurology Milestone Project, 2014). Nevertheless, more than half of all graduating adult neurology residents reported not feeling confident reading EEGs independently (Mahajan, 2019). Lack of EEG reading skills leads to EEG misinterpretation, which plays a large role in the high frequency of patients carrying a misdiagnosis of epilepsy (Smith, 1999). The negative impact provoked by epilepsy misdiagnosis on patients' lives, both from human and cost-related standpoints, is virtually universally undeniable.

In this study, we sought to (i) assess baseline EEG knowledge in the adult neurology residency cohort at our institution and (ii) survey this same

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cohort in an attempt to identify residents' perspectives on their EEG learning experience during residency.

Methods

We evaluated (i) baseline EEG knowledge and (ii) resident perception of EEG education utilizing an EEG quiz and an online EEG survey, respectively. The participants consisted of the adult neurology residency cohort at our institution. This study was approved by the Baylor College of Medicine Institutional Review Board (IRB) and was performed in August-September 2019. All data is available upon request.

The EEG quiz was divided in two parts, composed of normal (27) and abnormal (10) EEG examples (*table 1, supplementary figure 1*). Participants were asked to match the examples based on description. All EEG epochs were curated by board-certified epileptologists (AM, JC and JRG) and were deemed to represent high-yield EEG findings. Participants completed the EEG quiz during a 30-minute period and received one point for each correct answer; neither partial points nor negative points were given.

The online EEG survey consisted of 23 questions that focused on resident perception of EEG learning during residency. The survey was divided in three sections: importance of EEG, EEG milestones and EEG education (*supplementary figure 2*). The survey was conducted electronically, and links to the survey were distributed to all adult neurology residents. Participants were given the option to remain anonymous; however, they were systematically asked to provide their level of training.

Results

EEG quiz results

Twenty-one out of the 38 adult neurology residents completed the EEG quiz; all 21 residents (four PGY[postgraduate]1s, eight PGY2s, three PGY3s and six PGY4s) completed the normal EEG part whereas 19 (four PGY1s, seven PGY2s, two PGY3s and six PGY4s) of these 21 residents completed the abnormal EEG part. Two residents who completed the normal EEG part had technical issues preventing them from completing the abnormal EEG part.

The overall score (mean±SEM) for the normal EEG part was 42±4.5%. The score (mean±SEM) pertaining to each training level was 38±13% (PGY1), 33±5.7% (PGY2), 33±5.7% (PGY3) and 62±6.2% (PGY4). The overall score (mean±SEM) in the abnormal EEG part was 44±5.5%. The score (mean±SEM) pertaining to each training level was 48±18% (PGY1), 41±8% (PGY2), 15±15% (PGY3) and 55±5.6% (PGY4). The scores are summarized in *figure 1*.

In the normal EEG part, PGY4 scores (mean=62.3%, SD=15.1%) were higher in comparison to PGY1-3 scores (mean=34.3%, SD=16.9%) (p=0.0022). PGY3-4 scores (mean=52.7%, SD=19.4%) were higher in comparison to PGY1-2 scores (mean=34.5%, SD=18.6%) (p=0.0428). In the abnormal EEG part, similar trends were seen but these did not reach statistical significance. PGY4 scores (mean=55%, SD=13.8%) were higher in comparison to PGY1-3 scores (mean=39.2%, SD=26.6%) (p=0.1929). PGY3-4 scores (mean=45%, SD=23.3%) were similar to PGY1-2 scores (mean=43.6%, SD=25.8%) (p=0.9072). These analyses are summarized in *table 1*.

Table 1. Subgroup analysis of EEG quiz scores (mean; standard deviation [SD]; standard error of the mean [SEM]).

EEG quiz	PGY level	N	Mean (%)	SD (%)	SEM (%)	Unpaired t-test
Normal	PGY1-2	12	34.5	18.6	5.38	t(19)=2.17
	PGY3-4	9	52.7	19.4	6.47	p=0.0428
	PGY1-3	15	34.3	16.9	4.37	t(19)=3.53
	PGY4	6	62.3	15.1	6.15	p=0.0022
Abnormal	PGY1-2	11	43.6	25.8	7.8	t(17)=0.118
	PGY3-4	8	45	23.3	8.2	p=0.9072
	PGY1-3	13	39.2	26.6	7.4	t(17)=1.36
	PGY4	6	55	13.8	5.6	p=0.1929

PGY: postgraduate.

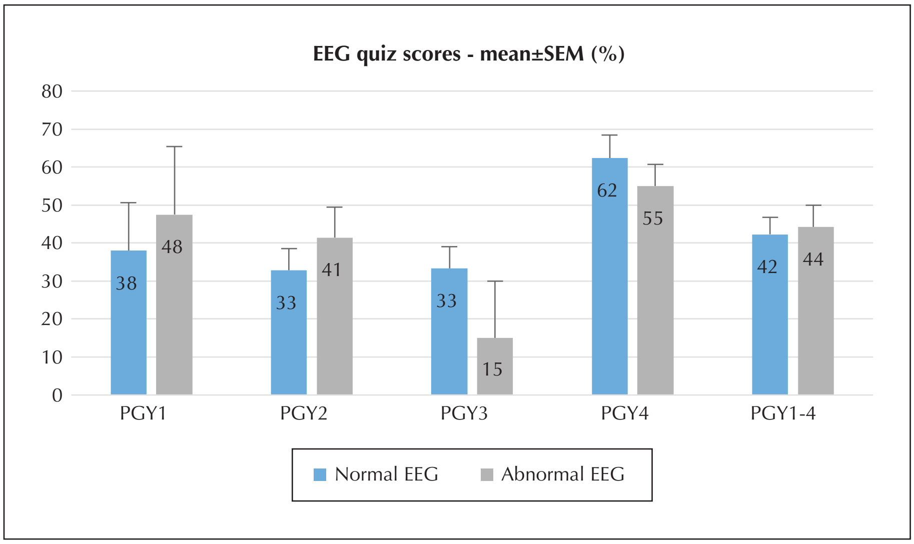

Figure 1. EEG quiz scores (mean and standard error of the mean [SEM]), as percentage, according to postgraduate year (PGY).

The most frequent incorrect questions were associated with identification of REM sleep, awake state, and pulse artifact. In the abnormal EEG part, the most frequent incorrect questions were associated with identification of focal spike, generalized polyspike-and-wave, and focal polymorphic slowing. This data is summarized in *table 2*.

Survey results

The survey was completed by 28 residents (74%). There were eight PGY1s, four PGY2s, six PGY3s and eight PGY4s; two respondents did not report their level of training.

Importance of EEG

Virtually all participants (96%) considered learning to read EEGs during neurology residency very important or extremely important. Similarly, the same percentage also disagreed that learning to read EEGs as residents becomes important only if one is pursuing a neurophysiology/epilepsy fellowship.

EEG milestones

This section was included in an effort to gauge residents' perceived EEG skills. Overall, almost half of the respondents (43%) reported not being able to read EEGs even with supervision. In terms of the ability to identify particular EEG findings in an independent fashion, 50% reported being able to comfortably identify awake and sleep states in adult patients and 14% in children, 36% felt they could recognize status epilepticus, 32% could recognize common abnormalities, 32% could recognize normal variants, and 25% could recognize common artifacts. Approximately one-fifth of residents (21%) reported being able to write an EEG report independently.

EEG education

The three most commonly reported barriers to EEG learning were insufficient exposure, insufficient responsibility to read EEGs during the EEG rotation and inability to link EEG learning to direct patient care. The most efficient ways to teach EEG were felt to be a combination of didactic lectures and reading EEGs with supervision. Residents reported the most effective measures to ensure competency in reading EEGs as the number of EEGs reviewed and the number of hours spent reviewing EEGs. However, there was significant variation in the reported minimum number of EEGs read and hours spent reading EEGs to achieve competency.

Discussion

Our EEG quiz results demonstrated that, on average, adult neurology residents were able to correctly identify less than half of normal (mean±SEM: 42±4.5%) and abnormal (mean±SEM: 44±5.5%) EEG findings. As expected, senior residents had higher scores compared to junior residents. This is likely due to progressive gains in confidence and skill throughout residency training, originating from both formal training (*e.g.*, EEG/epilepsy rotations and didactics) and clinical practice. In contrast to other studies assessing EEG knowledge in residents, we included PGY1s, who were completing their internal medicine

Table 2. List of EEG examples included in the EEG quiz and respective percentage of correct responses per question.

EEG: normal part	Correctly answered (*n*=21)	EEG: abnormal part	Correctly answered (*n*=19)
Section 1 – awake/sleep states		**1** Focal spike	21%
1.1 Awake	19%	**2** Focal polymorphic slowing	26%
1.2 Drowsy	24%	**3** Generalized spike-and-wave	58%
1.3 Stage N1 sleep	29%	**4** Generalized polyspike-and-wave	21%
1.4 Stage N2 sleep	29%	**5** Lateralized periodic discharges	32%
1.5 Stage N3 sleep	24%	**6** Generalized periodic discharges with triphasic morphology	58%
1.6 REM sleep	9.5%	**7** Lateralized rhythmic delta activity	42%
Section 2 – normal variants		**8** Right-sided attenuation due to a right subdural hematoma	53%
2.1 Mu rhythm	29%	**9** Hypsarrhythmia	63%
2.2 Lambda waves	52%	**10** Burst suppression	68%
2.3 Breach rhythm	48%		
2.4 Wicket waves	33%		
2.5 6-Hz phantom spike-waves	33%		
2.6 Posterior dominant rhythm	29%		
Section 3 – sleep structures			
3.1 Positive occipital sharp transients	43%		
3.2 Vertex waves	48%		
3.3 K complexes	62%		
3.4 Sleep spindles	62%		
3.5 Sawtooth waves	38%		
Section 4 - artifacts			
4.1 Ocular, blinking	57%		
4.2 Ocular, fluttering	57%		
4.3 Cardiac, pulse	19%		
4.4 Cardiac, EKG	48%		
4.5 Myogenic	57%		
4.6 Sweat	29%		
4.7 Electrode pop	71%		
Section 5 – activation findings			
5.1 Photic driving	48%		
5.2 Photoparoxysmal response	62%		
5.3 Hyperventilation-induced slowing	62%		

preliminary year before starting in neurology. PGY1s' scores therefore represent baseline EEG knowledge from medical school - unless the PGY1s included in our study had additional EEG training before, during, and/or after medical school. Our survey results showed that while the vast majority of respondents (96%) considered learning to read EEGs during residency training at least very important, less than half (43%) reported not being able to read EEGs even with supervision.

Our baseline EEG knowledge results are similar to those published in the literature. An EEG education study evaluated the performance of a group of 20 neurology residents (12 PGY3s and 8 PGY4s) before and after the implementation of an automated EEG teaching program. The EEG test contained 35 multiple-choice questions representing normal EEG, normal variants, slowing, epileptiform discharges, and seizures. The mean baseline EEG testing score was 42.7% (Weber, 2016). In a subsequent study involving

11 neurology residents, all of whom had completed three to four months of structured EEG training, baseline EEG testing scores ranged from 28% to 60% (mean score of 47%) (Dericioglu and Ozdemir, 2018).

Concerning resident perception associated with EEG education, a recent AAN survey showed that only 37.3% of graduating adult neurology residents felt confident about performing or interpreting EEG independently (Mahajan, 2019). In an additional survey-based study that involved 55 adult neurology residents from different programs, subjects were asked how confident they were, on a scale of 0 to 100%, in terms of their EEG skills. For graduating PGY4s, the median was 67% for interpreting common EEG abnormalities and creating a report and 60% for recognizing normal EEG variants (Daniello and Weber, 2018). The same study also identified that 95.6% of respondent residents felt that learning to read EEGs was important (Daniello and Weber, 2018).

Our study has weaknesses. This was a single-center study; as a result, our results may not be extrapolated to a national scale. Nonetheless, the overall EEG testing scores and survey data are concordant with the published literature. PGY3s were under-represented because this class is traditionally busy on consult rotations in our institution. We did not take into account whether participating residents already had exposure to EEG either prior to or during residency. Lastly, we could not subcategorize the survey results in accordance with the respondents' level of training due to the anonymous nature of the survey.

In conclusion, it appears that EEG learning in adult neurology residency training is suboptimal despite an overall interest in learning EEG from the residents' perspective. Optimizing EEG learning among residents is of paramount importance because general neurologists are expected to read EEGs and EEG misinterpretation has deleterious consequences to patients and health systems (Benbadis, 2007). In fact, according to the last report of the AAN member research subcommittee, EEG is the most common procedure performed by practicing neurologists (Adornato, 2011). Consequently, it is essential for neurology residents to be able to fully interpret EEGs upon graduation, as per the Neurology Milestone Project, published in 2014. In order to achieve this goal, however, we believe that EEG education delivered to neurology residents should be optimized.

Based on our results, insufficient EEG exposure is one of the most significant educational barriers. This curricular deficiency seems to be present on a national level – the average American neurology residency program offers only six weeks of EEG training (Schuh, 2009). Furthermore, our survey data pointed to insufficient responsibility to read EEGs and inability to link this knowledge to patient care as additional barriers. We believe that enhancing the EEG curricular component in light of these barriers should be pursued by all residency programs. Moreover, our residents reported that didactic lectures plus reading EEGs under supervision were the most effective way to teach EEG. Validation of EEG lecture-based didactics should be formally evaluated in order to assess for efficacy, while novel educational tools to enhance EEG exposure and feedback should also be explored and validated among neurology trainees. □

Supplementary data.

Supplementary figures are available on the www.epilepticdisorders.com website.

Disclosures.

FAN is a member of the Epileptic Disorders Editorial Board. AM, JC and JRG report no disclosures relevant to the manuscript. This work has been presented as an e-platform at the AAN 2020 Annual Meeting.

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TEST YOURSELF

(1) According to our study, what is/are the most commonly reported barrier(s) to EEG learning during residency?
A. Insufficient EEG exposure
B. Insufficient responsibility to read EEGs during EEG rotation(s)
C. Inability to link EEG learning to direct patient care
D. Inefficient EEG didactic lectures

(2) According to our study, what is/are the most often misidentified EEG finding(s)?
A. REM sleep
B. Awake state
C. Pulse artifact
D. Hypsarrhythmia

(3) According to our study, what is/are the most effective measure(s) to ensure competency in reading EEGs?
A. Number of EEGs reviewed
B. Number of hours spent reviewing EEGs
C. EEG written test
D. EEG oral examination

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