ORIGINAL RESEARCH

Electroencephalography in Clinical Practice: Neurology Professionals' Views on Optimal Standards of Care

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Purpose: Delivering optimal care to patients with seizures and epilepsy requires all EEGs to be interpreted accurately and reliably. This study investigated neurology professionals' opinions on the ideal standards for EEG in clinical care.

Methods: We developed an anonymous e-survey targeting practicing and trainee neurologists focused on participants' demographics, clinical practice characteristics, and views on optimal EEG standards of care—including whether an EEG certification test is needed and whether postresidency/fellowship training in EEG/epilepsy is necessary for neurologists who interpret outpatient/routine EEGs in practice. The survey was hosted by the Neurology Clinical Practice—Practice Current, and it was distributed online through the American Academy of Neurology, American Epilepsy Society, American Clinical Neurophysiology Society, and International League Against Epilepsy, and through social media.

Results: Two hundred eighty-three responses were included: 119 from EEG/epilepsy-trained neurologists, 83 from non-EEG/epilepsy-trained neurologists, 75 from trainees, and 6 from advanced care providers. Most participants (78%) agreed that "an objective certification test of ability to interpret EEGs is needed for all those who interpret EEGs in clinical practice." Most participants (71%) believed that outpatient/routine EEGs may be read only by neurologists with EEG/epilepsy training; this opinion was more prevalent among EEG/epilepsy-trained (83%) versus non-EEG/epilepsy-trained neurologists (55%).

Conclusions: Our neurology community should discuss the need to develop and implement a certification test of ability for all neurologists who wish to interpret EEGs in clinical practice. In addition, it is imperative to improve in-residency EEG education to ensure that neurology graduates achieve EEG competence before entering the workforce.

Key Words: EEG, Electroencephalography, Clinical practice, Neurophysiology, Epilepsy.

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EEG is the most common procedure performed by practicing neurologists in the United States, with approximately 60% reporting that they interpret EEG as part of their practice.[1] Similarly, a large portion of EEGs are interpreted by neurologists without postresidency EEG training in many European countries.[2] Learning EEG only during residency may not allow neurologists to achieve EEG competency before they start interpreting studies independently in clinical practice.[3–6] This is believed to be largely because of the well-documented challenges pertaining to in-residency EEG education.[2,7,8]

Subpar skill in EEG interpretation often leads to EEG misinterpretation, which is a major cause of epilepsy misdiagnosis.[9–14] To ensure that optimal care is delivered to patients with seizures and epilepsy and to maintain their safety, it is crucial to ensure that all EEG readers are competent in EEG. This study aimed to survey the opinions of neurology professionals as to the ideal use of EEG in real-world practice.

METHODS

We developed a 19-question online, anonymous survey (see **Supplemental Digital Content 1**, http://links.lww.com/JCNP/A309) that targeted practicing and trainee neurologists and advanced care providers (ACPs), and focused on participants' demographics, clinical practice characteristics, and opinions on optimal EEG standards of care. Survey questions were designed by four authors (F.A.N., R.K., N.R.K., D.Y.). Expert validation was subsequently conducted by consulting three authors (J.I.S., M.B.W., S.B.) and the Neurology Practice Current Editors, whose feedback on survey development and dissemination was incorporated. We included ACPs and practicing or trainee or practicing neurologists who reported spending at least 20% of their clinical time in the care of patients with neurologic conditions. The survey was hosted by Neurology Practice Current, which is a section of the American Academy of Neurology journal Neurology Clinical Practice, and remained open from December 2023 to May 2024. The survey was distributed through social media and through the American Academy of Neurology, Synapse, American Epilepsy

This work was conducted in collaboration with Neurology Clinical Practice—Practice Current. J. Sirven is chair of the American Academy of Neurology Education Committee.

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Society, American Clinical Neurophysiology Society, (Young Epilepsy Society [YES])-International League Against Epilepsy, and European Academy of Neurology. Data were collected and stored in the Neurology Clinical Practice platform. The data set was shared with the authors after the data collection was completed.

The American Academy of Neurology Practice Current Editorial Team submitted the study protocol to the Children's National Hospital Institutional Review Board, which determined the study to be exempt. The χ^2 test was used to perform group comparisons. Statistical significance was set at $P < 0.05$.

RESULTS

Two hundred eighty-three responses were included. Respondents comprised 119 EEG/epilepsy-trained neurologists, 83 non-EEG/epilepsy-trained neurologists, 75 trainees (including child and adult neurology residents and neurologists undergoing clinical fellowships), and 6 ACPs. The country of practice with the highest number of respondents was the United States (30%), where there was representation from 34 states. Survey data are summarized below and in Table 1.

Most participants (78%) agreed that "an objective certification test of ability to interpret EEGs is needed for all those who interpret EEGs in clinical practice." We analyzed responses given by EEG/epilepsy-trained neurologists and non-EEG/epilepsy-trained neurologists (Fig. 1). In the former group, 82% agreed with the statement above, while in the latter group, this figure was 71%. There was no significant difference in the opinions between these two groups ($P = 0.058$). Most trainees (80%) and ACPs (67%) also agreed that an objective certification test of ability is needed.

Most participants (71%) believed that outpatient (routine) EEGs (rEEG) may be read only by neurologists (general or epileptologists) with postresidency/fellowship training in EEG/epilepsy. Fifteen percent of respondents believed that rEEGs may be read only by neurologists without postresidency/fellowship training in EEG/epilepsy. These particular respondents comprised non-EEG/epilepsy-trained neurologists ($n = 21/83$), trainees ($n = 12/75$), EEG/epilepsy-trained neurologists ($n = 7/119$), and ACPs ($n = 2/6$). Fourteen percent believed that rEEGs may be read by neurologists with or without postresidency/fellowship training in EEG/epilepsy.

Group analysis of EEG/epilepsy-trained neurologists and non-EEG/epilepsy-trained neurologists is presented in Fig. 2. Most of both groups (83% and 55%, in the same order as listed above) believed that rEEGs may be read only by neurologists (general or epileptologists) with postresidency/fellowship training in EEG/epilepsy. There was a significant difference in the opinions from these two groups ($P = 0.001$). Most trainees (71%) and half of ACPs shared this belief.

TABLE 1. Summary of Survey Data

	Total (*n*; %)
Professional level ($n = 283$)	
EEG/epilepsy-trained neurologists	119; 42
Non-EEG/epilepsy-trained neurologists	83; 29
Trainees	75; 27
Advanced care providers	6; 2
Primary neurology practice ($n = 283$)	
General neurology	148; 52
Epilepsy	81; 29
Vascular neurology	15; 5
Multiple sclerosis	8; 3
Neuromuscular	6; 2
Movement disorders	5; 2
Neuro-oncology	3; 1
Neurology intensive care	1; <1
Neuropsychiatry/behavioral neurology	1; <1
Other	15; 5
Type of practice ($n = 283$)	
Academic practice	168; 59
Private practice	96; 34
Both	19; 7
Country of practice* ($n = 283$)	
United States†	84; 30
Peru	16; 6
Brazil	14; 5
India	13; 5
Canada	12; 4
Years in practice ($n = 283$)	
In training	45; 16
Less than 10 years	108; 38
10 or more years	130; 46
Patient population treated ($n = 283$)	
Adults	168; 59
Children	57; 20
Both	58; 20
Interpret EEGs in clinical practice ($n = 283$)	
Yes	212; 75
No	71; 25
Years interpreting EEG‡	
<2	59; 28
2–5	32; 15
>5 and <10	38; 18
10–20	40; 19
>20	43; 20
Types of EEGs interpreted‡	
Outpatient EEGs < ~2 hours	196; 92
Ambulatory EEGs ≥ 24 hours	95; 45
Inpatient EEGs < ~2 hours	146; 69
Inpatient, LTM EEGs	121; 57
EMU scalp EEGs	91; 43
EMU intracranial EEGs	45; 21

*Top five countries.
†There was representation of 34 states within the United States.
‡Only those participants who reported interpreting EEGs in their clinical practice ($n = 212/283$) responded to these two questions.
EMU, epilepsy monitoring unit; LTM, long-term monitoring.

DISCUSSION

Most surveyed professionals (78%) believe that an objective certification test should be required for all those who interpret EEGs in clinical practice. This opinion is held both by neurologists with (82%) and without (71%) EEG/epilepsy training. Furthermore, most professionals (71%) believe that

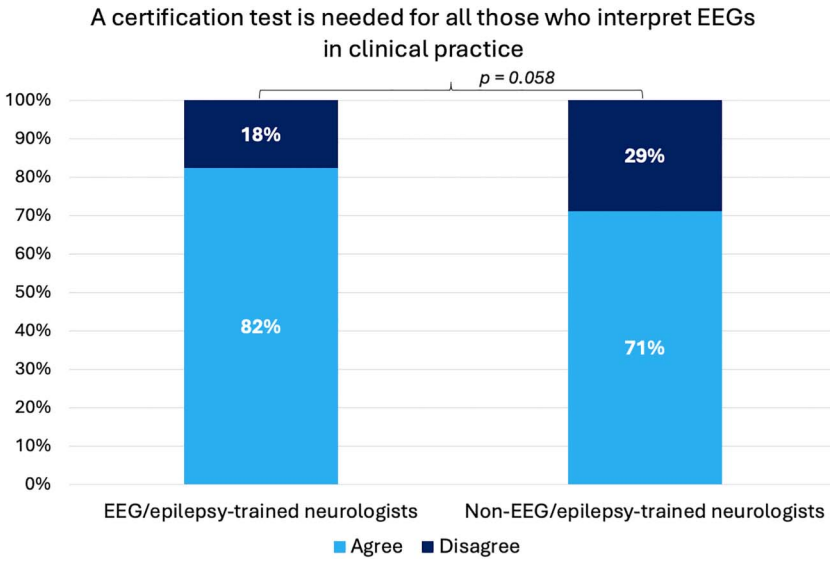

FIG. 1. Survey data pertaining to opinions as to the need for a certification test for all those who interpret EEGs in clinical practice stratified into two participant groups: EEG/epilepsy-trained neurologists ($n = 119$) and non-EEG/epilepsy-trained neurologists ($n = 83$). Note that we used a 5-point Likert scale ranging from strongly disagree to strongly agree. For the purposes of our analysis, we created two groups: agree (including strongly agree and somewhat agree) and disagree (including strongly disagree, somewhat disagree, and neutral).

rEEGs should be read only by neurologists with postresidency/fellowship training in EEG/epilepsy. The opinion is more common among neurologists with EEG/epilepsy training (83%) versus those without this additional training (55%).

Notably, there is not a requirement for a certification test among neurologists who wish to interpret EEGs in practice in many geographies—including the United States[1,11,15] and several European countries.[2] Moreover, the practice in these locations dictates that EEGs can be (and are) interpreted by neurologists without training in neurophysiology.

Indeed, a large portion of EEGs in the US clinical practice[1] are read by neurologists without postresidency/fellowship training in EEG/epilepsy. As far as neurophysiology, these professionals conceivably rely heavily on the EEG education received during residency training. This practice raises remarkable concerns because of two main reasons. First, in-residency EEG education is far from optimal.[2–8] Second, there is no certification test requirement for EEG readers. Consequently, it is not uncommon in practice that EEG studies are interpreted by noncompetent readers.

Subpar skill in EEG often translates into misinterpretation of graphoelements (namely, over-reading normal patterns as epileptiform[10,12–14]) and consequent epilepsy misdiagnosis. The effects of an epilepsy misdiagnosis are disconcerting. Patients are subject to stigma, employment and driving restrictions, unnecessary exposure to antiseizure medications, and the lack of treatment of the actual underlying etiology of paroxysmal events (e.g., cardiac arrhythmia, or neuropsychiatric pathology in cases of psychogenic nonepileptic spells). These diagnostic errors are often harmful and compromise patient safety. Furthermore, health care systems are adversely affected as well.[9] Notably, this issue has recently become even more critical given the increase in the number of EEGs performed—both "standard" and point-of-care studies—and resultant increase in the number of providers interpreting these studies.

Our study has limitations. First, because our surveys were anonymous, we are unable to confirm the profession of each

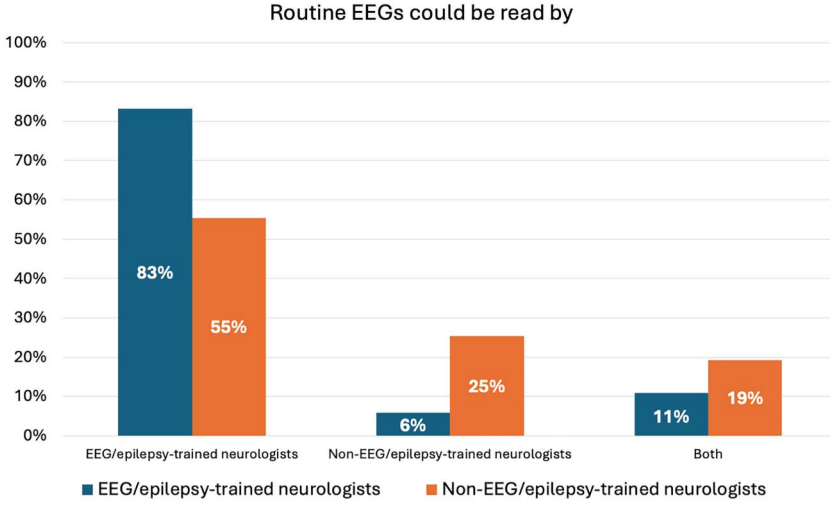

FIG. 2. Survey data pertaining to opinions as to who could interpret outpatient/routine EEGs in clinical practice stratified into two participant groups: EEG/epilepsy-trained neurologists ($n = 119$) and non-EEG/epilepsy-trained neurologists ($n = 83$).

participant. Second, there may have been a selection bias where those who participated were inherently more interested in EEG and its clinical practice. Third, our cohort was slightly skewed toward academic practitioners, and providers who treat predominantly adults. Fourth, almost half of the survey respondents consisted of EEG/epilepsy-trained neurologists thereby potentially biasing the opinions obtained in the survey. Fifth, because the survey was conducted electronically and disseminated online, we are unable to calculate the response rate as we cannot measure the number of eligible subjects who received the invitation to participate. Finally, even though our respondents were diverse, they were largely from the United States, thus potentially limiting the generalizability of our results.

We believe the first step toward improving EEG care is to ensure that neurology graduates achieve EEG competence before entering the workforce. This can be achieved by maximizing the quantity and enhancing the quality of in-residency EEG education. We propose that this education should be primarily focused on outpatient/routine EEGs[16,17] (vs. epilepsy monitoring unit or intensive care unit studies) because rEEGs are the most common type of studies in practice.

In addition, we suggest our neurology community discuss the need for an objective certification test of ability in EEG for all neurologists planning to interpret these studies in practice. We would envision such a test as one that mirrors real-world EEG interpretation and, as a result, is able to accurately measure a given candidate's competence. In our view, the ideal test would include several interactive EEGs (either short segments or full studies) covering the whole breadth of important EEG findings/patterns of varying levels of difficulty. In addition, the test would be grounded on a robust gold standard consisting of both expert consensus and an externally validated source (e.g., video-EEG data and long-term follow-up).

We hope our results can stimulate a discussion about avenues to ensure that every EEG is interpreted by a competent reader, only then can we ensure that the care delivered to patients with seizures and epilepsy is optimal.

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