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EPILEPSY (C. W. BAZIL, SECTION EDITOR)

Epilepsy Education: Recent Advances and Future Directions

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Abstract

Purpose of Review The goal of this review is to survey the current literature on education in epilepsy and provide the most up-to-date information for physicians involved in the training of future doctors on this topic. We intended to review what opportunities exist to enhance our current teaching practices that may not be well-known or widely used, but may be adapted to a broader audience.

Recent Findings Many new techniques adopting principles of education (e.g., retrieval practice and spaced learning) or new technologies (e.g., pre-recorded lectures, computer-enhanced modules, and simulation practice) have been trialled to enhance medical education in epilepsy with some success. Many of these techniques are currently adaptable to a wider audience or may soon be available.

Summary The use of these opportunities more broadly may allow expansion of educational research opportunities as well as enhancing our ability to pass on information. As the knowledge base in epilepsy continues to dramatically expand, we need to keep evaluating our teaching techniques to ensure we are able to pass along this knowledge to our future providers.

Keywords Epilepsy education · Graduate medical education · Technology in education

Introduction

The field of epilepsy is rapidly advancing, but, in general, education in the field has continued in the same apprentice model that it has always used. However, recent advances in technology have allowed the integration of new techniques into the standard curriculum. As these new mechanisms begin to be tested for outcomes and to better utilize core concepts of adult education, we hope we will be able to keep our teaching as current as our new techniques for diagnosis and management. In this review, we will discuss the current state of epilepsy education, the changing face of the medical education landscape more broadly, and what is coming in the future for epilepsy education.

This article is part of the Topical Collection on *Epilepsy*

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The Current Epilepsy Education Landscape

The Institute of Medicine released a report in 2012 detailing recommendations for epilepsy care across the spectrum [1]. One of the major recommendations was for increased education of health care providers, patients, and their families. It was emphasized that professional organizations should lead the way in promoting education about this devastating illness. As outlined below, since the publication of that report, many educational initiatives for physicians have blossomed, and there has been a significant innovation in epilepsy education.

Current training for physicians begins in the pre-clinical neuroscience courses of medical school and will likely include few lectures on epilepsy and its treatment. Additional exposure can come during a medical student's clinical years, although not all medical schools require neurology rotations [2]. If a student has a neurology rotation, their exposure to topics in epilepsy will depend largely on the cases they happen to see during the rotation, and the interests of their supervising physicians. Subsequently, if a physician chooses to pursue residency in neurology they will be expected, over the 3 years of neurologic training, to attain proficiency in diagnosing and treating common epilepsy disorders, and when to refer patients to a subspecialty epilepsy center [3]. Unfortunately, not all residents get the same exposure, and if outcomes for

attaining epilepsy milestones are similar to those for attaining EEG or EMG milestones, it is likely that several practicing neurologists may not feel as comfortable with epilepsy as the ACGME would expect [4]. How much education in epilepsy the residents actually receive will greatly depend on the program they attend, the cases they see, and the interests of their faculty. Resident physicians who are intensely interested in epilepsy as a field may continue to do an additional 1–2 years of fellowship training in epilepsy to get exposure to things they may not have seen during residency and to hone their skills with the more uncommon epilepsies and complicated treatments. The ACGME recently approved the accreditation of a fellowship in epilepsy, taking a step toward standardizing the exposure that fellowship training would provide.

It is known that misdiagnosis in epilepsy is common [5]. Overdiagnosis of epilepsy can lead to delays in appropriate care with patients who have psychogenic nonepileptic seizures often waiting more than 7 years before reaching an accurate diagnosis [6]. These misdiagnoses are often based in part on an overinterpreted EEG, arguably due to a lack of standard education [7]. Currently, no time dedicated to EEG or epilepsy education is mandated as a part of Neurology Graduate Education [8]. Recurrent surveys of program directors in neurology illustrate an average of 2 months of residency training being spent in either EEG or epilepsy wards [9, 10].

The educational landscape is changing because of the evolution of the structure of neurology training, and because of the explosion in knowledge and skills expected of a neurologist. As mentioned above, it has become much less common that a graduate of a neurology residency program in the USA would possess the experience and expertise to independently review and report on an EEG [11]. In addition, the explosion of continuous EEG recording for critically ill patients has dramatically changed the training experiences of modern neurology residents and has increased variability in the training experiences and the expectations of training outcomes between centers [4, 12]. Didactic education in both undergraduate and graduate medical education has become more fragmented because of work hours restrictions and increasing utilization of night-float and alternative scheduling approaches [13]. A multimodal, flexible, and adaptable approach to epilepsy education can allow us to ensure adequate training opportunities in epilepsy and EEG education, despite these challenges.

Changes in Approaches to Medical Education

Medical education as a whole is in the midst of a period of dramatic change, due to the explosion of medical knowledge, rapid advances in information technology, self-directed learning opportunities, and the evolving expectations of modern learners. A century after the publication of the Flexner Report, which had established the standard structural framework for medical education in the twentieth century, the Carnegie Foundation commissioned a new report, published in 2010, which proposed some fundamental changes in the approach to undergraduate and graduate medical education [14, 15]. While Flexner focused on a standardized structure to medical education (e.g., 2 years of pre-clinical education followed by 2 years of clinical training), the authors of the 2010 report suggest a focus on standardized outcomes, with individualization of the processes to achieve these outcomes. These recommendations were part of the wave of increased emphasis on competency-based medical education (CBME) in both graduate and undergraduate medical education [16, 17].

Shared Digital Tools

Considering both the shift in emphasis to CBME and the evolution of digital tools in learning, traditional approaches to didactic education have been challenged [18, 19]. Traditional lectures can be disengaging and dry, and in many institutions are poorly attended. A quick glance around the room of any lecture (from first-year medical school to international meetings) will reveal eyes fixed to screens rather than on the podium. In an age when learners can find high-quality video lectures online focusing on nearly every topic, it seems quaint and inefficient that medical schools and residency programs are producing their own versions of each lecture. As a result, Le and Prober have suggested that medical schools should work together to create a "common curricular component ecosystem" [20••]. Such a system would contain learning tools (video-based lectures, course materials, and other content) that could be shared between medical schools, and each school could adapt these tools to their individual environments and learning objectives. Less time would be needed for individual schools to create content, and more faculty time could be allocated for interaction with learners, thus enriching the educational experience.

Some of the infrastructure for such an "ecosystem" for epilepsy and EEG education already exists, through both open and for-profit online video portals, online books and journals, educational resources through the American Epilepsy Society, and open-access resources like MedEdPORTAL. For example, MedEdPORTAL has several peer-reviewed resources including EEG teaching modules and learning exercises, and simulation scenario that could be adapted by medical school faculty, nursing and technology educators, and residency and fellowship directors to support local educational efforts [21–24].

It is important to emphasize that technology and innovation should support a curriculum that is based on time-honored educational principles. Technology should not be

seen as an end in itself, but as a tool to augment a robust clinical training experience. Important consideration should be given to match technological choices with learning objectives, and with the educational needs of learners [25]. Some examples of how technological teaching tools have been integrated into the teaching environment for EEG and epilepsy are outlined in the next section below. Technological tools also allow for the collection of metadata, which can allow us to understand the learning process, and how learners engage with new information. For example, one of the authors of this review collected viewership metadata from a web-based EEG video lecture curriculum and analyzed patterns of audience retention [26•]. There were segments of the video lectures with "spikes" in audience retention, suggesting that learners were returning to these segments to rewatch and re-review. One of the largest "spikes" in audience retention was to a segment on polarity rules in EEG (Fig. 1). In separate qualitative research, polarity was identified by experts as a "threshold concept," a concept that was necessary to understand in order to progress to expertise in EEG interpretation [27]. In this way, learning technology can be useful not only as a teaching tool, but as a research tool that augments our understanding of how complicated concepts (including many of the concepts in epilepsy and EEG) are learned.

Competency-Based Assessment

Beyond teaching and curriculum design, the shift of emphasis to learning outcomes has drastically changed how we assess competence and readiness for independent practice. CBME puts greater emphasis on workplace-based assessments: determinations of a learner's abilities on the basis of direct observations in the clinical setting. While competencies and milestones often describe the characteristics of a learner that would allow him or her to perform a clinical task, a newer concept, the entrustable professional activity (EPA), focuses on the learner's performance of the task itself [28]. An example of an EPA in epilepsy could be: "Recognize and manage convulsive and nonconvulsive status epilepticus" [29]. An assessment of a learner's ability to perform this activity would be made on the basis of direct observation by trained neurologists in the clinical setting (or possibly in a simulation scenario). In such a situation, it may only be necessary for the instructor to determine the level of supervision the learner requires, and from this, specific competencies could be inferred. If an experienced epilepsy specialist has determined that a learner can independently manage status epilepticus, we can likely assume that the learner possesses the requisite (1) medical knowledge about epilepsy and seizure physiology, semiology, and clinical features; (2) patient care skills to stabilize and treat the seizures; (3) system-based practice habits to coordinate the care required for this complicated clinical situation; and (4) communication skills with team members, allied professionals, and family in a high-intensity setting. Thus, as an assessment tool, the EPA leverages the expertise and experience of frontline clinical teachers to ensure that competencies are being achieved, while potentially removing the burden of long checklists, arbitrary rating scales, and obscure terminology (e.g., "systems-based practice."). The "rule of multiples" posits that reliable determinations of competence require the observations of multiple assessors, in multiple settings, across multiple patient encounters [30].

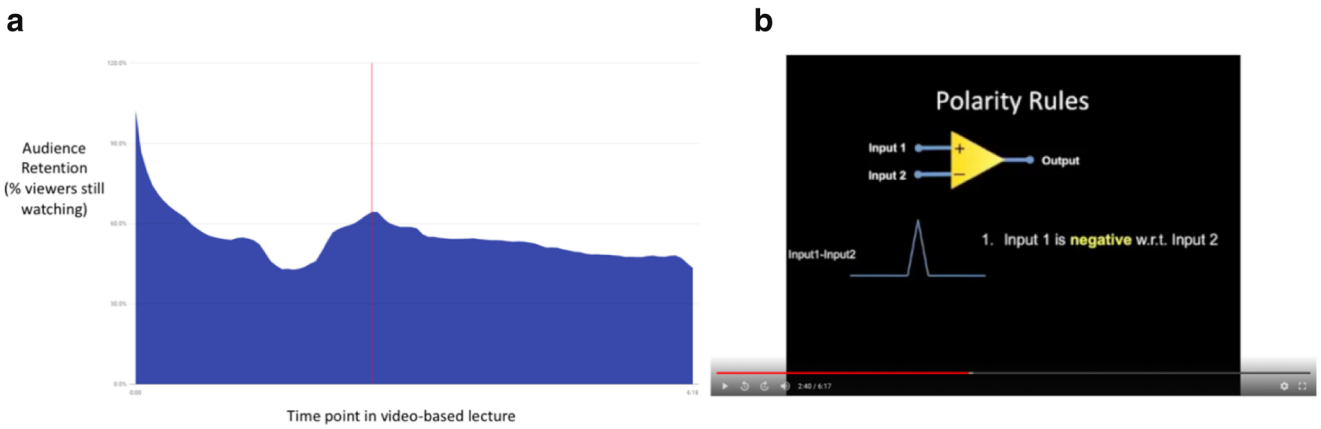

Fig. 1 Example of how audience retention analytics for video-based lectures can provide insight into learning. **a** Audience retention curve, showing the percentage of viewers who opened the video who are still watching at every time point. There is a spike in retention at approximately 2:40 in the video, suggesting that viewers returned to this point for re-watching. **b** Screenshot of the video-based lecture at the time of the spike in audience retention. This corresponds to a point in the video where polarity rules are first explained. This highlights that polarity rules may be a particularly important or difficult concept for some learners. (*Images were captured from YouTube on February 8, 2019; with permission from Dr. Jeremy J. Moeller,* https://www.youtube.com/watch?v=gpnGEHHVtRs&list=PLxaiR6teSdjoEZWaDWm28A9QjFN7eguAp&index=2)

Retrieval Practice and Test-Enhanced Learning

There have also been dramatic changes in our understanding of how we can design curricula to promote long-term retention of knowledge. There has been compelling research to show that repeated retrieval of information is likely more effective than studying in ensuring that information is retained over the long term [31•]. The process of repeated retrieval of information is known as retrieval practice, sometimes also referred to as test-enhanced learning. There have been several studies demonstrating the effectiveness of retrieval practice in neurology and epilepsy education, including undergraduate and continuing education [32–34]. This effect is likely optimized when learners are prompted to produce information (i.e., short answer questions are better than multiple-choice questions), when the questions are placed in the context of a clinical problem, and when feedback is provided [35]. This effect should be considered carefully when designing courses at every level, in order to maximize retention and transfer of information. Retrieval practice has been adopted as a study strategy by students. In one study at a large US medical school, the vast majority of students reported using board-style practice multiple-choice questions and/or spaced repetition ("flash card") software to prepare for the first step of the US Medical Licensing Examination (USMLE) [36]. The use of practice questions and some types of spaced repletion software programs were both independently associated with higher scores on the licensing examination. Scores also increased in proportion to the number of practice questions and flash cards used. This approach to learning is not only appropriate for test preparation, but has been shown to improve transfer: that is, the application of a newly learned concept in a different context. For example, in one study, medical students who participated in retrieval practice using written tests on various neurological topics (including seizures) performed better on a simulated patient examination than students who had simply studied the topic [33]. Retrieval practice is a powerful approach to promote knowledge retention and transfer, and the incorporation of frequent tests, flashcards, and other retrieval tools in epilepsy and EEG curricula could improve learning in meaningful ways.

Educational Innovations in Epilepsy and EEG

Table 1 contains an overview of approaches to medical education that have received significant attention in recent years, and how these approaches have been (or could be) applied in epilepsy and EEG education.

Advances in EEG Education

Although the bedrock for the education of physicians about epilepsy and EEG has continued to be through the apprenticeship model of residency and fellowship with one-on-one teaching supplemented by lectures, many technological innovations have begun to emerge as supplements to that education. As mentioned previously, pre-recorded online lectures have been used to supplement the resident and fellow learning experience in EEG interpretation [23, 37]. Residents are able to view these lectures on their own time and refer back to them as needed, allowing in-person time with the subspecialist to be devoted to clarifying concepts rather than relaying basic information.

In Kentucky, standardized EEG Education curricula were designed and shown to be effective at increasing test scores for anesthesia residents [38]. Pre-recorded audio lectures (podcasts) were effective to improve testing outcomes similarly to standard didactic lectures [39]. This "flipped classroom" model has been gaining traction broadly in the educational landscape and continues to become more widely utilized within epilepsy education. As a follow-up study, the use of a "flipped" approach resulted in increased scores on the EEG related portions of the standardized resident in-service training examination for anesthesia residents [40•].

Working off the flipped classroom model, the American Epilepsy Society has recently released an online fellowship curriculum consisting of brief pre-recorded videos covering a broad array of topics by experts within the field of epilepsy. The goal of these videos is also to encourage the use of the flipped classroom model where the trainee would spend time reviewing the videos independently and use time with their supervising epileptologists to clarify points of misunderstanding and to learn the nuances of the field. Although these lectures are open and free for anyone to use, they were only recently released in late 2018, so utilization and outcome data are not yet available.

Over the last few years, the EEG education at the Veterans Affairs Hospital in Boston shifted from a traditional one-on-one EEG review of an attending with a resident to the adoption of a new software program, the Modular Real-time EEG Education Guide (MR EEG) [41•]. This software allows residents to review pre-selected full-length EEGs and get immediate feedback on how their interpretations compare to those of the experts reviewing the studies (Fig. 2). Faculty are available throughout the day to clarify any points of confusion, and the software also has the ability to prompt the residents to review certain pre-recorded lectures if they are doing poorly interpreting particular parts of the EEG. This method of active learning of EEG showed significant improvement on assessments given before and after this training process. Anecdotally, this program has also greatly reduced the necessary faculty time required to teach basic EEG interpretation to these residents. The American Epilepsy Society is currently

Table 1 Educational approaches and strategies in epilepsy and EEG education

Educational Approach	Description	Current or potential applications to epilepsy and EEG education
Flipped classroom and video-based lectures	Learners are introduced to new concepts using materials such as web-based lectures, podcasts, and reading materials. Group time is spent applying newly learned concepts in order to enhance consolidation and transfer	EEG podcasts and video lectures [39, 57]. Flipped EEG curriculum [23]. Enduring educational materials developed by national or international organizations, such as the American Epilepsy Society
Interactive computer-based modules	Learners solve problems (such as interpreting an EEG) using an interactive computer-based teaching module, providing opportunities for immediate feedback.	MR EEG computer software [41•].
Simulation	Learners work through a clinical problem and apply skills in a simulated clinical setting. This provides opportunities for the practice of technical skills, direct observation of clinical skills, and immediate feedback.	Simulations of the management of status epilepticus [44••]. Interprofessional simulations to improve safety protocols in the epilepsy monitoring unit [45].
Retrieval practice	Learners repeatedly retrieve information (through flash cards, written tests, or other methods) at spaced intervals in order to enhance long-term retention and application of knowledge in novel situation (transfer).	Tests (multiple-choice, short answer, essays, simulation scenarios) as an adjunct to didactic presentations [33, 34]. Augmenting CME courses with repeated testing of attendees [32]. Encouragement of the use of question sets, self-assessment examinations, or flash cards as a study strategy [36].
Competency-based medical education	Emphasizing the attainment and demonstration of specific knowledge, skills and attitudes (competencies) to determine readiness for unsupervised practice.	The ACGME Milestones Project [3]. Development of entrustable professional activities or observable practice activities (EPAs/OPAs) as assessment tools [29].

working on setting up a similar system online that would be broadly available to trainees. Such a system could allow residents to study EEG interpretation at their own pace in-between any organized rotation they may have at their institution. There are many possible benefits to standardization in the process of learning EEG, and such a system would also be of great help to programs that may not have ready access to subspecialists in epilepsy to assist in the training of their residents. In addition, such a program would allow residents to space out their learning of this valuable skill, a practice which has been shown to increase long-term retention [42].

Simulation

Simulation has gained increasing prominence as a tool for both teaching and assessment, and emerging research has demonstrated its feasibility and utility in neurology and epilepsy. Simulation provides the opportunity for learners to engage in a structure fashion with clinical scenarios that occur uncommonly or unpredictably in the workplace, such as neurological emergencies [43]. For example, management of status epilepticus may be difficult to teach and reliably assess in the real-world setting, because of its unpredictability and the rapid pace of clinical changes. In a simulation center, learners would be able to engage with a case of status epilepticus, with the difficulty modified on the basis of their clinical training, and with an opportunity for standardized feedback and assessment. Simulation has been shown to improve mastery of a status epilepticus protocol in pediatrics residents, and an accompanying increase in self-determined comfort level in the management of children with status epilepticus [44••]. Interprofessional simulation training has been employed in an attempt to improve patient safety during acute events in the epilepsy monitoring unit, but while the simulation curriculum improved knowledge of seizure management, it has not yet been determined as to whether the curriculum had a meaningful effect on patient outcomes [45]. Further research is necessary to determine the range of roles that simulation might play in epilepsy education.

ICU EEG Nomenclature Teaching

Standardized training has also emerged in the realm of ICU EEG. Strong interrater reliability was shown after using a standardized set of teaching slides to teach the ACNS-approved standard ICU EEG terminology learners with a broad range of EEG experience [46]. It was subsequently shown that completion of that set of training slides increased interrater reliability in a group of experts [47]. This training curriculum is available online for public use through the critical care EEG consortium. There is an ongoing effort, supported by the American Board of Psychiatry and Neurology, to

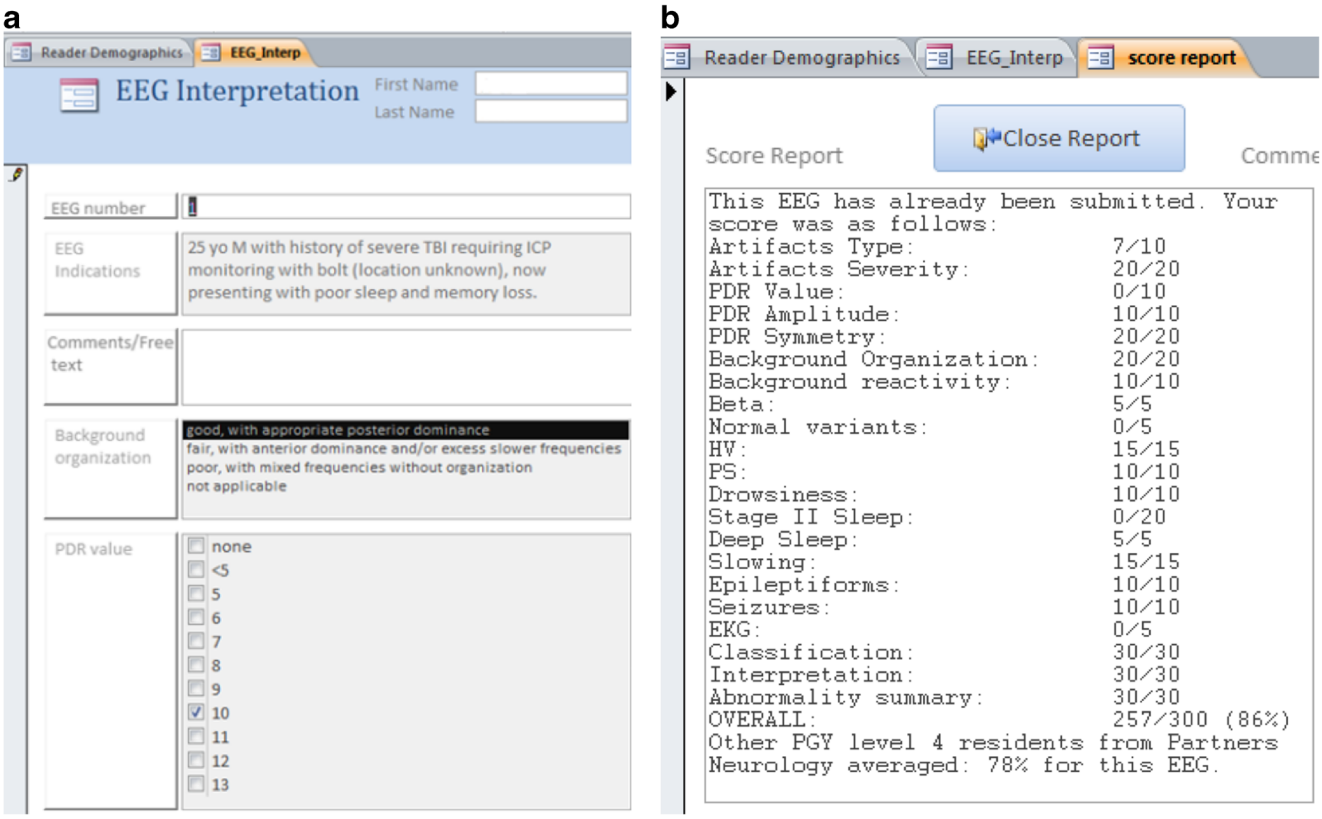

Fig. 2 Screenshots from the input and output screens of the Modular Real-time EEG Education Guide (MR EEG) currently used for EEG training of some residents. This system allows immediate detailed feedback on a resident's interpretation of a full-length EEG

create a more in-depth online platform to improve training in critical care EEG through the establishment of standardized training modules allowing consistent exposure to the varied content of ICU EEG to all trainees [48]. As the exposure of any given trainee within a program may be limited to what happens to be recording during their rotation platforms like this will enable trainees to expand their exposure and enhance their mastery of the topic.

Looking to the Future

The role of neurologists and epileptologists is likely to change in the coming years, as automation and quantitative methods become more advanced, particularly in EEG interpretation. One recent study demonstrated that a spike detection software tool performed similarly to humans in identifying focal epileptiform discharges on a set of 40 prolonged EEG recordings [49]. Another group has demonstrated that deep learning techniques can predict with over 80% accuracy whether EEG recordings are normal or abnormal [50]. While the level of accuracy and details is still not at the level required for clinical practice, the fact that there has been incremental improvement with each successive software innovation suggests that automated EEG interpretation is likely to emerge in the coming years and decades. Quantitative tools for EEG interpretation, including spike detectors and long-term trend analysis, have been in widespread practice for many years, and have multiple clinical and research applications [51]. EEG education should include a significant focus on current and future EEG software tools, so that future epileptologists and neurophysiologists are poised to adapt to their changing roles in EEG interpretation.

Software tools will also play an important role in clinical epilepsy. Prediction tools based on meta-analysis and clinical trials are easily accessible in the clinical setting and can provide instantaneous data to aid clinical decision-making [52–54]. Computer-aided decision analyses have raised questions about long-held beliefs about starting antiepileptic drugs after a first seizure. [55] These types of analyses and decision tools are likely to become more commonplace, and epilepsy education should also focus on equipping students, residents and fellows with the skills to find and use these tools in their practice.

Both education and clinical practice will continue to increase in complexity, and epilepsy educators will serve an important function in ensuring that our learners and educational programs keep pace with the changes. In our opinion, this means that neurology departments and epilepsy divisions should support and promote clinician-educators, and provide

them with the skills and opportunities to succeed in the competitive academic environment [56]. Evaluation of clinician-educators for promotion requires a broader interpretation of "impact," and national and international organizations can play an important role in providing opportunities for education, networking and mentorship of clinician-educators in epilepsy.

Conclusion

There have been tremendous advances in the clinical care of patients with epilepsy and similarly impressive advances in medical education, both of which provide opportunities for innovation in epilepsy and EEG education. We have outlined some recent innovations in epilepsy and EEG education and have provided some ideas for future advancement in educational programs. We look forward to an era of further collaboration between educators and institutions, so that we can ensure that epilepsy and EEG teaching and learning is composed of the best aspects of medical education as a whole.

Compliance with Ethical Standards

Conflict of Interest Daniel J. Weber and Jeremy J. Moeller each declare no potential conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- •• Of major importance

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