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Research paper

Neurology resident EEG training in Europe

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ABSTRACT

Objective: To detail current European EEG education practices and compare European and U.S. EEG teaching systems.
Methods: A 19-question online survey focused on EEG clinical practices and residency training was emailed to all 47 European Academy of Neurology Societies.
Results: Thirty-two (68 %) out of the 47 Societies completed the survey. In half of countries, general neurologists are either among the providers or the only providers who typically read EEGs. The number of weeks devoted to EEG learning required to graduate ranged from none to 26, and it was expected to be continuous in one country. In most countries (n = 17/32), trainees read >40 EEGs per EEG rotation, and the most commonly interpreted studies are routine and prolonged routine EEGs. Rotations involve clinic/outpatient (90 %), epilepsy monitoring unit/inpatient (60 %), or both (50 %). Roughly half of countries do not use objective measures to assess EEG competency. The most reported educational methods are teaching during EEG rotation and yearly didactics, and the most reported education barriers are insufficient didactics and insufficient EEG exposure.
Conclusions: We suggest neurology educators in Europe, especially in those countries where EEGs are read by general neurologists, consider ensuring that residency EEG learning is mandatory and establishing objective measures in teaching and evaluating competency.
Significance: Similar to the U.S., neurology resident EEG training in Europe is highly variable.

1. Introduction

Neurology residency training has been shown to be substantially variable across European countries. Differences include disparities in duration of residency training and programs' intrinsic structure such as the profile of mandatory external rotations (Kleineberg et al. 2020; Zis and Kuks 2016; Struhal et al. 2011). Particularly concerning clinical neurophysiology, it is either a separate field altogether or part of residency training. When integrated to residency training, teaching systems range from delivering brief theoretical courses to having an established minimum number of studies to be performed (Kleineberg et al. 2020). In-depth information related to current EEG teaching systems in Europe, however, is yet to be fully described. Here, we sought to (i) better understand current European EEG education practices by surveying European National Neurological Societies and (ii) compare European and U.S. EEG teaching systems.

2. Methods

We assessed European EEG education practices with a 19-question online survey (e-survey), which was adapted from a recent U.S. study (Nascimento and Gavvala 2021). Questions focused on demographics (n = 3), neurology residency training (n = 2), EEG training (n = 13), and clinical EEG reading practices (n = 1). The latter asked respondents to select profession and training profile of those providers who typically read EEG in clinical practice in their respective countries. This data was used to divide European countries in two groups: countries where general neurologists (without additional training in EEG or clinical neurophysiology) are either among the providers or the only providers who typically read EEGs (group 1), and countries where general neurologists (without additional training in EEG or clinical

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neurophysiology) are not among the providers who typically read EEGs (group 2).

The survey was hosted by Survey Monkey and emailed to all 47 Neurological Societies affiliated to the European Academy of Neurology (EAN) as per the Academy's website (ean.org/home/members/national-neurological-societies). Surveys were either completed or endorsed by these Societies thereby reflecting their official position. In Europe, neurology training is regulated and coordinated at a national level hence we collected data from National Neurological Societies. Prior to completion of the study, respondents were given the opportunity to review and, if necessary, edit the survey data linked with their respective countries.

We utilize the term "read" EEG for the exercise of interpreting these studies by trainees without officially reporting/signing off the EEG results. Data collection was performed from January to November 2021. Invitation and follow-up emails were sent during this time period. No financial compensation was offered to respondents. All data is available upon request. The study data was obtained from healthcare providers who volunteered to share EEG education practices related to their respective countries. Therefore, we did not seek ethical approval from an institutional review board or informed consents from survey respondents.

3. Results

3.1. Survey results

Thirty-two (68 %) out of the 47 European National Neurological Societies completed the survey and were therefore included in this study (Fig. 1 and Tables 1–3). In half of participating countries, general neurologists are either among the providers or the only providers who typically read EEGs (group 1, n = 16/32; Table 2), whereas, in the other half, general neurologists are not among the providers who typically read EEGs (group 2, n = 16/32; Table 3).

3.2. Neurology training

The total number of residents who graduate from adult neurology residency yearly varied significantly between countries (range 2.5–250; 1.0–14 per 1 million inhabitants (United States Census Bureau, 2021)) (Tables 2 and 3). This great variability reflects the fact that European countries significantly vary both in size and population. In Luxembourg, an average of 2.5 residents graduate in neurology per year, whereas in Germany and Italy, this number increases up to 250. Notably, in Cyprus, all residents undergo training abroad. Neurology training occurs in different settings depending on the respective countries: combined university and community hospitals (n = 20), university hospitals (n = 11), and community hospitals (n = 1).

3.3. EEG clinical practices

In most countries, only 0–20 % (n = 22/31) or 21–40 % (n = 9/31) of graduating residents pursue additional fellowship training in clinical neurophysiology (with EEG emphasis) or epilepsy. EEG clinical practices are highly variable among countries (Tables 2 and 3).

Fig. 1. Participating European countries (n = 32). Countries where general neurologists are either among the providers or the only providers who typically read EEGs (n = 16/32; group 1, green), and countries where general neurologists are not among the providers who typically read EEGs (n = 16/32; group 2, blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Survey respondent(s) per National Neurological Society.

Neurological Society	Survey respondent(s)
Armenia	Dr. Mariam Baklavajyan
Austria	Dr. Iris Unterberger
Azerbaijan	Dr. Shiraliyeva Rana
Belgium	Dr. Chantal Depondt
Bulgaria	Dr. Dessislava Bogdanova
Croatia	Dr. Tereza Gabelic
Cyprus	Dr. Georgios Kaponides
Denmark	Drs. Sandor Beniczky and Hatice Tankisi
France	Drs. Philippe Derambure and Sophie Dupont
Georgia	Drs. Sofia Kasradze and Marina Janelidze
Germany	Drs. Stefan Rampp, Susanne Knake, and Walter Paulus
Greece	Dr. Katerina Theodorou
Hungary	Dr. László Vécsei
Ireland	Dr. Janice Redmond
Italy	Drs. Francesco Brigo, Letizia Leocani, and Gabrielle Siciliano
Kazakhstan	Dr. Saltanat Kamenova
Kosovo	Dr. Afrim Blyta
Latvia	Dr. Santa Asmane
Lithuania	Dr. Ruta Mameniskiene
Luxembourg	Dr. Alexandre Bisdorff
Norway	Dr. Andrej Netland Khanevski
Poland	Dr. Urszula Fiszer
Portugal	Dr. Isabel dos Santos Luzeiro
Republic of Moldova	Dr. Vitalie Lisnic
Romania	Dr. Bogdan Popescu
Russia	Dr. Flora Rider
Slovakia	Dr. Zuzana Gdovinova
Spain	Drs. Jose Fernandez-Torre and Paula Martinez Agredano
Sweden	Drs. Erik Westhall and Johan Zelano
Switzerland	Drs. Aikaterini Galimanis, Andrea Rosetti, and Hans H. Jung
Turkey	Dr. Serefnur Ozturk
United Kingdom	Drs. Michalis Koutroumanidis, Joanne Lawrence, and Abby Wright-Parkes

3.4. EEG rotation characteristics

The number of weeks devoted to EEG learning required to graduate ranged from none to 26. Similarly, the mean number of EEG weeks completed per resident by graduation varied significantly. In Luxembourg, EEG learning is continuous throughout residency.

Residents read multiple types of EEG during training (as per responses from all but two Neurological Societies; n = 30/32): routine (100 %) and prolonged routine (40 %) EEGs, continuous EEGs including ICU EEGs (33 %), ambulatory EEGs (27 %), and epilepsy monitoring unit studies (23 %). During a typical EEG rotation, most residents read, on average, >40 EEGs (n = 17/32); in the remaining countries, the number of EEGs was 0–10 (n = 4/32), 11–20 (n = 1/32), 21–30 (n = 3/32), 31–40 (n = 4/32), and unanswered/not applicable (n = 3/32). Electroencephalography rotations involve clinic/outpatient (n = 27/30; 90 %), epilepsy monitoring unit/inpatient (n = 18/30; 60 %), or both (n = 15/30; 50 %) settings, and EEG rotations are completed by postgraduate year 3 s (PGY3s) (n = 17/30; 57 %), PGY4s (n = 16/30; 53 %), PGY2s (n = 15/30; 50 %), PGY1s (n = 7/30; 23 %), and PGY5s (n = 7/30; 23 %). Requirements for successfully completing an EEG rotation ranged from none to reading 800 EEGs and an oral examination. In roughly half of countries (n = 15/32), no objective measures are used to assess EEG competency. In the remaining countries, objective measures included a minimum number of EEGs read and different types of examinations. This data is summarized in Tables 2 And 3.

3.5. EEG education – Teaching methods, barriers, and solutions

Primary mechanisms of EEG education included: teaching during EEG rotation by fellows and/or attending physicians (n = 22/31; 71 %), didactics throughout the year given by residents, fellows, and/or attendings (n = 21/31; 68 %), teaching during epilepsy clinic (n = 14/31; 45 %), bedside teaching during inpatient rounds (n = 12/31; 39 %), and didactics in a 1–2-month protected course given by residents, fellows, and/or attendings (n = 4/31; 13 %). Absence of formal didactics was reported by 2 countries (n = 2/31; 6 %). Barriers to EEG teaching were reported by the majority (n = 25/32; 78 %) of Neurological Societies, whereas the remainder reported no barriers (n = 6/32; 19 %) or it was not applicable (n = 1/32; 3 %). Reported barriers included insufficient didactics (n = 13/32; 41 %) and insufficient EEG exposure (n = 12/32; 38 %). On evaluation of free text responses, Societies described the following select barriers: variability in EEG education among centers/programs (n = 2), "overstretched staff" (n = 1), "insufficient manpower" (n = 1), non-standardized training in continuous and video-EEG (n = 1), "lack of evidence-based approach to EEG among teaching personnel" (n = 1), and the fact that neurologists are not allowed to read EEG without a state EEG certificate (n = 1).

Possible solutions, proposed by 22 European Neurological Societies, included increasing resident EEG exposure (n = 5), improving EEG training/didactics (n = 3), improving coordination and rotations between different regions/centers (n = 2), implementing EEG education in the general curriculum (n = 2), increasing number of EEG experts in faculty (n = 2), standardizing EEG education (n = 2), establishing EEG training as mandatory (n = 1), educating EEG educators (n = 1), creating online resources (n = 2) or a centralized case-library with typical EEGs (n = 1), developing the educational system and formulating a special exam (n = 1), and "paying more attention to EEG education" (n = 1).

4. Discussion

Neurology resident EEG education practices are highly variable among European countries. The number of EEG weeks required to graduate residency ranges widely as well as requirements for successful completion of EEG rotations and resident EEG competency evaluation. Similarly, EEG clinical practices also vary significantly – for instance, general neurologists are either among the providers or the only providers who typically read EEGs in half of countries.

In European countries where general neurologists are either among the providers or the only providers who typically read EEGs (n = 16/32) (Table 2), residents are required to undergo at least 4 weeks of EEG training (range 4 to continuous training, in Luxembourg) except in Cyprus and France. In Germany, a minimum number of EEG weeks is not established. Moreover, in most countries (n = 12/16), residents read >40 EEGs during a typical rotation. Requirements for completion of an EEG rotation range from none to reading 400 EEGs. Almost one-third of European countries in this group (n = 5/16; 31 %) do not utilize objective measures to assess resident EEG competency.

In European countries where general neurologists are not among the providers who typically read EEGs (n = 16/32) (Table 3), the minimum number of EEG weeks required to graduate ranges from 1 (Poland) to 26 (Switzerland) except in Norway, Ireland, and the United Kingdom. In Norway, the minimum number of EEG weeks required to graduate ranges zero to 1, whereas in Ireland, this is not established. In the United Kingdom, clinical neurophysiology is a separate specialty thus requiring training outside neurology residency; in neurology residency, however, residents are exposed to the basics of EEG such as its technical aspects, uses and limitations, and basic interpretation skills. In Poland, there is a post-residency 4-month training course on EEG which is usually completed by neurologists although it can also be completed by neurology residents. In this group, the number of EEGs read in a typical rotation varies significantly: 0–10 (n = 4/16) to >40

Table 2
Summary of survey results – countries where general neurologists (without additional training in EEG or clinical neurophysiology) are either among the providers or the only providers who typically read EEGs.

Country	EEGs typically read by?	Graduating neurology residents yearly (n; per 1 million inhabitants*)	Number of EEG weeks required to graduate	Mean number of EEG weeks completed by graduation	Mean number of EEGs read during a typical EEG rotation	Requirements for EEG rotation completion	Objective measures for EEG competency assessment
Austria	A, B	Unanswered	12	16	>40	250 EEGs	Yes; 250 EEGs
Belgium	A, B, C, D, E	32 (2.7)	26	<26 (“highly variable”)	>40	250 EEGs	No
Croatia	A, C	20 (4.8)	8	8	31–40	EEG interpretation skills	Yes; EEG skills upon supervised reading
Cyprus	A, B, C	None (training done abroad)	N/A	N/A	Unanswered	None	Unanswered
France	A, B, D, E	90 (1.3)	None	N/A	31–40	Unestablished	No
Germany	A, B, C, D	250 (3.1)	Unestablished	3	>40	Unestablished	Yes; 500 EEGs with or without exam
Hungary	A, B	40 (4.1)	4	4	>40	EEG interpretation skills	Yes; 400 EEGs
Italy	A, B, C, D, E	250 (4)	16–24	8–12 (“highly variable”)	>40	Unestablished	Yes; 100 neurophysiological cases
Kazakhstan	A	155 (8.1)	4	4	21–30	Exam	Yes; unanswered
Kosovo	A, B, C, D	5–10 (2.6–5.3)	20	20	>40	Exam	Yes; unanswered
Latvia	A	8 (4.2)	4	4	>40	Attendance and evaluation by program director	No
Lithuania	A, B, C, D	8 (3.0)	4	4	>40	EEG interpretation skills, evaluation by supervisor	Yes; EEG skills
Luxembourg	A	2.5 (3.9)	Continuous training	N/A	>40	400 EEGs	No
Romania	A, C	50 (2.4)	5	5	>40	Evaluation by program director	No
Slovakia	A, C	30 (5.6)	4	4	>40	Evaluation by supervisor	Yes; 200 EEGs and exam
Turkey	A, B	150 (1.8)	8	8	>40	Independent EEG interpretation	Yes; 130–150 EEGs and exam

A, general neurologists (without additional training in EEG or clinical neurophysiology); B, neurologists with fellowship training in clinical neurophysiology; C, neurologists with fellowship training in epilepsy; D, neurologists with fellowship training in clinical neurophysiology and epilepsy; E, non-neurologists clinical neurophysiologists; N/A, not applicable; *, as per data extracted from https://www.census.gov/popclock/world (accessed in 2021).

Table 3
Summary of survey results – countries where general neurologists (without additional training in EEG or clinical neurophysiology) are not among the providers who typically read EEGs.

Country	EEGs typically read by?	Graduating neurology residents yearly (n; per 1 million inhabitants*)	Number of EEG weeks required to graduate	Mean number of EEG weeks completed by graduation	Mean number of EEGs read during a typical EEG rotation	Requirements for EEG rotation completion	Objective measures for EEG competency assessment
Armenia	B	42 (14)	4	4	31–40	Unanswered	Yes; measures unspecified
Azerbaijan	B	15 (1.5)	4	24	0–10	Unanswered	No
Bulgaria	D	100 (14)	4	4	0–10	Exam	No
Denmark	B, E	10 (1.7)	20	20	>40	Evaluation by supervisor	No
Georgia	D	9 (1.8)	6	2	11–20	General EEG knowledge	No
Greece	D	35 (3.3)	12	10–12	31–40	Unanswered	No
Ireland	E	5 (1.0)	Unestablished	N/A	N/A	Unestablished	No
Norway	E	29 (5.3)	0–1	0–1	0–10	None	No
Poland	B	100 (2.6)	1	1	>40	EEG interpretation skills	Yes; exam
Portugal	B, C, D, E	30 (2.9)	12	12	>40	Predetermined number of EEGs	Yes; EEG skills
Republic of Moldova	C, E	8 (2.4)	4	4	0–10	None	No
Russia	E	Unanswered	2	2	21–30	Exam	Yes; exam
Spain	C, E	45 (1.0)	4	4	>40	Attendance	No
Sweden	E	30 (2.9)	4	4	21–30	National and regional goals	No
Switzerland	B, C, D	37.5 (4.4)	26	26	>40	800 EEGs and oral exam	Yes; 800 EEGs and oral exam
United Kingdom	E	120 (1.8)	N/A	N/A	N/A	N/A	Yes; part of neurology exit exam

A, general neurologists (without additional training in EEG or clinical neurophysiology); B, neurologists with fellowship training in clinical neurophysiology; C, neurologists with fellowship training in epilepsy; D, neurologists with fellowship training in clinical neurophysiology and epilepsy; E, non-neurologists clinical neurophysiologists; N/A, not applicable; *, as per data extracted from https://www.census.gov/popclock/world (accessed in 2021).

Table 4
Electroencephalography (EEG) education comparison between Europe and the U.S.

	United States* [Nascimento and Gavvala 2021]	European countries** where general neurologists are either among the providers or the only providers who typically read EEGs (n=16/32)	European countries** where general neurologists *are not* among the providers who typically read EEGs (n=16/32)
EEG rotation(s) settings	Clinic/outpatient (70%) EMU/inpatient (91%)	Clinic/outpatient (90%) EMU/inpatient (60%) Both (50%)	
Typical PGY during EEG rotation(s)	PGY1 (2%) PGY2 (50%) PGY3 (41%) PGY4 (7%)	PGY1 (23%) PGY2 (50%) PGY3 (57%) PGY4 (53%) PGY5 (23%)	
Primary methods of EEG teaching	During EEG rotation (93%) Yearly didactics (95%) During epilepsy clinic (66%) Bedside/inpatient rounds (52%) 1-2-month didactics (30%) No formal didactics (0%)	During EEG rotation (71%) Yearly didactics (68%) During epilepsy clinic (45%) Bedside/inpatient rounds (39%) 1-2-month didactics (13%) No formal didactics (6%)	
Main EEG barriers	No barriers (41%) Insufficient EEG exposure (32%) Ineffective didactics (11%)	No barriers (19%) Insufficient EEG exposure (38%) Insufficient didactics (41%)	
Mean number of EEG weeks required to graduate	6.8	9.2 (n=13/16; 81%) Continuous training (n=1/16; 6.3%) Unestablished (n=1/16; 6.3%) N/A (n=1/16; 6.3%)	7.4 (n=14/16; 88%) Unestablished (n=1/16; 6.3%) N/A (n=1/16, 6.3%)
Mean number of EEGs read during a typical EEG rotation	0-10 (14%) 11-20 (20%) 21-30 (20%) 31-40 (11%) >40 (34%)	0-10 (0%) 11-20 (0%) 21-30 (6.3%) 31-40 (13%) >40 (75%) Unanswered (6.3%)	0-10 (25%) 11-20 (6.3%) 21-30 (13%) 31-40 (13%) >40 (31%) N/A (13%)
Use of objective measures to assess EEG competency	No (64%)	No (31%)	No (63%)

EMU, epilepsy monitoring; PGY, postgraduate year; ICU, intensive care unit; N/A, not applicable; *, survey respondents were residency program directors; **, survey respondents were National Neurological Societies.

(n = 5/16). Requirements to complete an EEG rotation also vary, and most countries (n = 10/16) do not use objective measures for EEG competency assessments.

Overall, European residents typically read routine (100 %) or prolonged routine (40 %) EEGs and continuous EEGs including ICU EEGs (33 %), and EEG rotations are usually completed by PGY2-4s. Further, rotations involve the outpatient (90 %) more frequently than the inpatient (60 %) setting, and both in half of countries. In more than two-thirds of European countries, a minority of residents (0–20 %) pursue further training in clinical neurophysiology/EEG or epilepsy. The most commonly reported methods of EEG teaching are teaching during EEG rotation (71 %) and didactics throughout the year (68 %). Most European countries (78 %) reported barriers to EEG education, which included insufficient didactics (41 %) and insufficient EEG exposure (38 %).

In terms of tangible neurology resident EEG rotation characteristics – namely EEG exposure (represented by mean number of EEG weeks required to graduate and mean number of EEGs read during a typical EEG rotation) and methods of competency assessment, our data suggests a trend favoring more rigorous EEG training in European countries where general neurologists are either among the providers or the only providers who typically read EEGs. We speculate that this discrepancy may be explained by the need to ensure that neurology graduates have the required skills to accurately interpret EEGs in clinical practice irrespective of undergoing additional, post-residency EEG-focused training.

In terms of tangible neurology resident EEG rotation characteristics in the U.S., the average number of 1-month EEG rotations required to graduate is 1.7 (range 0–4), most residents (55 %) read zero to 30 EEGs in a typical rotation, and most programs (64 %) do not utilize objective measures to assess resident EEG competency (Nascimento and Gavvala 2021). This data suggests that the American EEG education practices are more similar to those common to European countries where general neurologists are not among the providers who typically read EEGs. This observation is counterintuitive because, in the U.S., a large portion of EEGs are read by general neurologists (Adornato et al. 2011; Benbadis 2007). In fact, although the exact percentage of EEGs read by general neurologists is unknown, the most recent AAN practice report (Adornato et al. 2011) showed that EEG was the most commonly performed procedure (56.9 %) among a random sample of U.S. practicing neurologists.

In terms of the remaining EEG education measures studied, European countries and the U.S. are similar regarding primary methods of teaching and main barriers (Nascimento and Gavvala 2021). However, European and American systems differ in that, in the former, EEG rotations more often involve the outpatient setting versus the inpatient setting (Nascimento and Gavvala 2021). Moreover, European residents are typically PGY2-4s when undergoing EEG rotations, whereas in the U.S. residents are typically PGY2-3s (Nascimento and Gavvala 2021).

Lastly, a small portion of residents pursue further training in clinical neurophysiology/EEG or epilepsy in Europe (0–20 % of residents in most countries) and in the U.S. (approximately 20 % and 14 % of residents plan to pursue fellowship training in epilepsy and clinical neurophysiology, respectively (Mahajan et al. 2019)). Data comparison between Europe and the U.S. is summarized in Table 4.

Our study has limitations. First, we did not receive responses from all European National Neurological Societies. Second, we understand that EEG education practices may vary significantly within nations. Third, data comparison between European countries as well as with the U.S. should be done with caution given the inter-nation disparities related to neurology residency training. While in the U.S. neurology residency training lasts 48 months, in Europe it ranges from 12 to 72 months (median duration of 60 months) (Kleineberg et al. 2020). Fourth, our study was not designed to precisely estimate profession and training profile of providers who typically read EEGs in clinical practice.

We believe that understanding education systems is the first step toward improving resident EEG training. We suggest neurology educators in Europe consider utilizing the available European and U.S. EEG education data presented herein to continue to optimize their respective EEG education systems. We believe that, especially in countries where EEGs are interpreted by neurologists who do not undergo post-residency clinical neurophysiology training, neurology trainees should ideally undergo comprehensive and rigorous EEG training. In these scenarios, ensuring that residency EEG learning is part of the curricula as well as establishing clear and objective measures both in teaching and evaluating competency should be considered. Moreover, it would be reasonable to standardize these educational measures on an international level. Non-traditional teaching methods, such as e-learning programs developed by the International League Against Epilepsy (ILAE) (Beniczky et al. 2020; Nascimento et al. 2022), appear to be a promising educational resource to supplement resident EEG education.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Disclosure

FAN, JRG, HT, and SB report no disclosures relevant to the manuscript.

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Author contributions

F. Nascimento conceptualized and designed study, collected, analyzed and interpreted data, and drafted manuscript. J. Gavvala, H. Tankisi, and S. Beniczky conceptualized and designed study, analyzed and interpreted data, and reviewed manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cnp.2022.08.001.

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