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BRIEF COMMUNICATION

EEG Availability in the Intensive Care Setting: A Multicentre Study

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Although the role of continuous EEG (cEEG) in ICU is well established, the variability of access to EEG in ICUs across the world is poorly documented. It is likely that variation in EEG availability between ICUs will contribute to variability in management practices and may impact significantly on the outcome of patients with seizures and acute neurological disturbances. In this study, we surveyed the level of EEG availability in ICUs in different parts of the world to better understand the practical context in which studies of EEG in ICU should be interpreted.

A survey was formulated by a clinical neurophysiologist (JMcH), and two intensivists (LMacD and MH). This was distributed to intensivists using a Survey-Monkey link. The sample population was primarily identified by direct personal messaging to Twitter followers of European Society of Paediatric and Neonatal Intensive Care (ESPNIC) and European Society of Intensive Care Medicine (ESICM) who self-identified as 'Intensivist', 'Consultant Intensivist' and/or 'ICU consultant'. This was augmented by direct contact with intensivists from European and other centres internationally. The questionnaire quantified access to EEG testing and specialist interpretation and included a site-identifying question to avoid inclusion of duplicate responses. CEEG was defined as recordings of > 3 h. Recordings of < 3 h were classified as routine EEG.

Fisher's exact test was used to compare 4 different categories of EEG availability, with 4 levels of perceived cEEG-need and 3 categories of ICU bed number; a p value of 0.05 was chosen for statistical significance.

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Sample Population

A total of 170 specialists from 21 countries were contacted; 65 respondents from 17 countries completed the survey, representing a 38% response rate. Four survey responses were duplicates; these were excluded. The remaining surveys represented 61 distinct institutions from 17 countries for analysis (Fig. 1).

Forty-four surveyed centres (72%) were adult only ICUs; 15 (25%) were paediatric intensive care units (PICUs); and 2 (3%) were both. Thirty-five (57%) had fewer than 20 beds, 19 (31%) had 20–40 beds, and 7 (12%) had more than 40 beds. Of the 61 units, 25 (41%) were general, 8 (13%) were specialist, 6 (10%) were both, and 22 (35%) did not specify. The majority of countries were classified as High Income (Gross National Income [GNI] per capita of $12,376 or more); 6 were Upper Middle Income or less (GNI per capita < $12,376) as per World Bank Economic Classification Fiscal Year 2020 [1].

Availability of EEG Recording

Availability of EEG recording is summarized by region in Table 1. Nine (15%) units had no access to any EEG service, and 19 (31%) had access to routine EEG recordings only. Fourteen (23%) units had access to day time only cEEG recording up to 12 h. Only 19 (31%) had access to overnight cEEG recording > 12 h duration. Bigger units had a greater degree of EEG availability: of the units with < 20 beds, *40% had access to cEEG; as compared to 63% of units with 20–40 beds, and 100% of units with > 40 beds* ($p = 0.009$). Of the 14 respondents from specialist units, 7 had routine EEG access; 3 had continuous EEG up to 12 h; 4 had > than 12 h and overnight recording.

Frequency of Need for cEEG in Clinical Practice

Intensivists were asked how often cEEG was indicated to answer clinical questions in their unit. There were 58 respondents to this question. Three units (5%) said that

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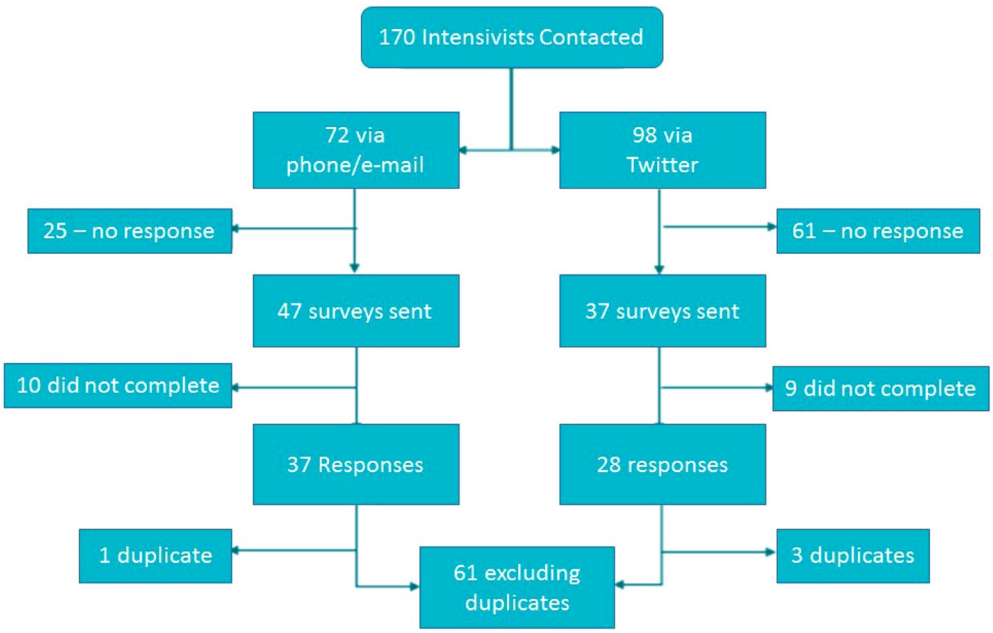

Fig. 1 Summary of sample population surveyed

Table 1. Availability of EEG recording by region

ICU Location by Region	ICUs contacted	ICUs responded	Duplicates (excluded from analysis)	No access, *n* (%)	<3 h EEG, *n* (%)	Daytime only cEEG <12 h, *n* (%)	Overnight cEEG, *n* (%)
UK/Ireland	60	33	1	4 (12)	14 (44)	6 (19)	8 (25)
Continental Europe	34	7	0	1 (14)	3 (43)	1 (14)	2 (29)
Asia	8	6	1	0 (0)	1 (20)	2 (40)	2 (40)
North America	27	6	1	0 (0)	0 (0)	0 (0)	5 (100)
Central/South America	8	4	0	1 (25)	1 (25)	2 (50)	0 (0)
Australia	13	5	0	3 (60)	0 (0)	0 (0)	2 (40)
Africa/Middle East	12	4	1	0 (0)	0 (0)	3 (100)	0 (0)
Unknown Location	8	0	–	–	–	–	–
Total	170	65	4	9 (15)	19 (31)	14 (23)	19 (31)

cEEG was necessary most days in their clinical practice; 12 (21%) had requirement for cEEG once per week; 16 (28%) once per month; and 27 units (46%) less than once per month. Units with higher bed numbers had a higher perceived frequency of cEEG need ($p = 0.038$).

Amplitude Integrated EEG (aEEG)

Thirty-nine per cent of 61 responding ICUs described familiarity with aEEG. Fourteen (23%) units used aEEG in their practice; 5 in adult patients only; 5 in paediatric patients only; and 3 in both children and neonates. One additional unit reported recent acquisition of an aEEG monitor and was early in the process of familiarization with its use. Most of these units were centres in which overnight cEEG was also available.

Availability of Registered EEG Technicians

Figure 2 summarizes the availability of both EEG technicians and specialist EEG interpreters in the 61 surveyed ICUs. In the 19 units where overnight cEEG recordings were available, access to registered EEG technicians was midweek office hours (Monday to Friday 9 a.m.–5 p.m.) in 7 units, Monday to Friday extended hours in 1 unit, every day (day-time only) in 3 units and 24/7 in 7 units. Of these 7 units with 24/7 access, 4 were American, 2 were English, and one was Dutch. One unit stated that

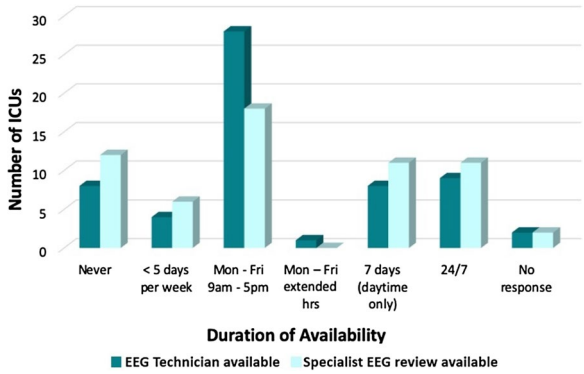

Fig. 2 Availability of EEG technicians and specialist EEG interpretation

registered technicians were not available for EEG recording and that nurses had been trained in EEG set up.

Specialist reporting of EEG in the 19 units with overnight cEEG was available Monday–Friday (9.a.m.–5 p.m. only) in 5 units; 5 units had 7-day access, daytime only; 24/7 specialist reporting was available in 8 units; and 1 unit reported no specialist reporting. We did not gather information on the frequency of review or formal reporting of cEEG recordings.

In this study of 61 centres, we have demonstrated that the majority does not have access to overnight EEG monitoring, whilst a substantial minority has no EEG access at all. This has implications for the generalizability of findings from studies of cEEG in ICU. This is the first study that reports on the availability of EEG in ICU in an international context. It is also novel in its effort to quantify the component personnel resources which underpin cEEG provision.

A previous survey of 151 ICUs in the USA found 86% of 97 responding centres had on-call resources for 24/7 cEEG monitoring, the majority carrying out cEEG for 24–48 h in comatose patients [2]. A similarly high level of cEEG access was evident from all 4 of the responding US centres in our study. Outside of North America, our data show that there is considerable variation in EEG access in Ireland, the UK and in Australia. Variation is also evident in the scores drawn from respondents of centres from other European and non-European countries. Such variation is likely to reflect differences in funding and different models of healthcare.

The provision of 24/7 cEEG access in ICU is costly in terms of technology, infrastructure and personnel. In some centres, specialist EEG-readers were available in the absence of on-call EEG technical staff; in other units, the opposite was seen; in one centre, it was reported that nursing staff had been trained in EEG application. Sanchez et al. reported that review and reporting of cEEG took place no more than twice per 24 h of study in 56% of hospitals surveyed, highlighting that overnight recording is not the same as continuous monitoring [3]. The frequency of cEEG review was not specifically addressed in our questionnaire which is one limitation of the study.

It is clear that availability of EEG resources shapes patterns of utilization. In one study, it was reported that 18% of intensivists would opt for more cEEG access in situations of unlimited resources [2]. This contrasts sharply with 74% of our respondents who expressed that cEEG was necessary not more than once per month in their ICU. In some centres, decisions not to implement cEEG monitoring are made based on the perceived lack of evidence rather than a lack of resources [4]. Reported seizure prevalence rates are higher in ICUs where cEEG is available and decisions regarding seizure management are informed directly by EEG in these settings [5]. Elsewhere, clinical management practices adapt in the absence of cEEG. This was evident in the recent report from our 24-bed paediatric ICU, in which a seizure detection rate of 17% was observed in the absence of 24/7 cEEG resources, but rates of empirical AED use were high [6].

We acknowledge a number of methodological limitations. Twitter was used as a primary tool to identify the sample population. Clearly not all European Intensivists use social media or are followers of either the ESPNIC or ESICM leading to an element of sampling bias. Furthermore, we accept that centres with no EEG access were perhaps less likely to respond to our questionnaire, which would lead to the results being a gross over-estimate of true EEG availability worldwide. Larger centres have more EEG access than smaller units, and this may be a more influential determinant of EEG availability than the nationality of the ICU.

We conclude that ICU access to EEG is variable within and between developed countries. The variability would appear to influence management practices in relation to critically ill patients with seizures and acute neurological disturbance. The results of on-going multicentre research should help to determine how such variation may contribute to variations in outcome [7]. It is possible that adjuncts such as aEEG may have some role in identifying patients who are most likely to benefit from more comprehensive EEG utilization. Guidelines for the use of cEEG need to be flexible and to take account of the reality of EEG resource limitation.

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Author Contributions
LM was involved in data collection and drafting of the manuscript. MH was involved in crafting the questionnaire used in the study. JCM was involved in planning of the study and final write-up of the manuscript.

Conflicts of interest
The authors declare that they have no conflicts of interest.

Ethical Approval/Informed Consent
The study was carried out with the approval of the Ethics Board of CHI-Crumlin.

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References

1. Bank W. *World Bank Economic Classification Fiscal Year 2020*. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.
2. Gavvala J, Abend N, LaRoche S, et al. Continuous EEG monitoring: a survey of neurophysiologists and neurointensivists. Epilepsia. 2014;55(11):1864–71.
3. Sanchez SM, Carpenter J, Chapman KE, et al. Pediatric ICU EEG monitoring- current resources and practice in the United States and Canada. J Clin Neurophysiol. 2013;30(2):156–60.
4. Hilkman DMW, van Mook W, Mess WH, van Kranen-Mastenbroek V. The use of continuous eeg monitoring in intensive care units in The Netherlands: a national survey. Neurocrit Care. 2018;29(2):195–202.
5. Kilbride RD, Costello DJ, Chiappa KH. How seizure detection by continuous EEG monitoring affects the prescribing of antiepileptic medications. Arch Neurol. 2009;66(6):723–8.
6. MacDarby L, Healy M, Curley GF, McHugh JC. EEG in the pediatric intensive care unit—an Irish experience. J Clin Neurophysiol. 2019. https://doi.org/10.1097/WNP.0000000000000673.
7. Rossetti AO, Rabinstein AA, Oddo M. Neurological prognostication of outcome in patients in coma after cardiac arrest. Lancet Neurol. 2016;15(6):597–609.