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Utilization of quantitative electroencephalogram in China: an online questionnaire survey

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Abstract

Background: Quantitative electroencephalogram (QEEG) is a tool that uses a computer to analyze brain activity monitored by electroencephalogram (EEG) according to measurements such as frequency, amplitude, and slope. The purpose of this study was to understand the current situation of QEEG utilization in China and further compare the situations among different regions and different levels of hospitals.

Methods: An online questionnaire comprising 14 questions was designed. Statistical description and analysis were made for the results of the questionnaire survey.

Results: A total of 158 people from 134 medical institutions participated in the survey. The participants came from 21 provinces, accounting for 61.76% (21/34) of the 34 provincial administrative regions in China. The Eastern China region accounted for 66.42% (89/134) of all the medical institutions that participated in this survey. Among the institutions surveyed, QEEG was routinely used in only 23.88% (32/134) of them. Among the medical institutions in which QEEG was routinely used, 87.50% (28/32) of them were 3A-grade hospitals. Among the institutions with routine use of QEEG, 56.25% (18/32) were affiliated hospitals of medical schools. There was a significant difference in the utilization of QEEG between the 3A-grade and non-3A-grade hospitals ($P=0.040$) and between the hospitals affiliated to medical schools and those non-affiliated to medical schools ($P=0.020$).

Conclusions: The utilization of QEEG is still limited in China. There are differences in the use of QEEG among different hospitals and regions.

Keywords: Quantitative electroencephalogram, Continuous electroencephalogram, Questionnaire online, Seizure detection

Background

Quantitative electroencephalogram (QEEG) is a tool that compresses long-term EEG and presents it as a trend, which can be used to assist in the analysis of a large amount of raw EEG data. Commonly used technical methods of QEEG include frequency-domain analysis, time-domain analysis, trend characteristics, topographic map drawing, etc. [1]. Since the introduction and utilization of QEEG in the 1980s, the technology of QEEG has been developed in China [2].

Clinically, seizures and EEG paroxysmal abnormalities are mostly random in epilepsy and other paroxysmal diseases, so it is not easy to capture abnormal signals in a standard EEG recording. Long-term EEG can monitor the EEG activity in real-time, record EEG signal changes in detail, and help in the diagnosis and differential diagnosis of epilepsy and other diseases. While long-term EEG is extensively used in China, it faces problems of a shortage of professionals, heavy workload, and low

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efficiency, making it hard to meet the growing clinical needs [3]. If EEG reading is too fast, some information would be missing; but if reading is too slow, it would be time-consuming and labor-intensive. The utilization of QEEG can reduce the technical workload and improve the EEG reading efficiency [4].

QEEG can analyze primary EEG data, and compress and integrate the data according to different measures such as frequency, amplitude, and slope, thereby improving the effectiveness and accuracy in detecting abnormal information. The huge burden of data analysis can be shared by the utilization of QEEG [5]. However, QEEG also has shortcomings. The most common problem is that it cannot effectively distinguish abnormal discharges from artifacts, such as the high false-alarm rate caused by motion artifacts [6]. Also, QEEG is not sensitive to transient and slowly evolving seizures, which leads to misdiagnosis, resulting in a high false-positive rate and false-negative rate [5]. Although the validity and reliability of QEEG are currently controversial [5], there are still many studies showing that QEEG is valuable for assessing traumatic brain injury, learning disabilities, attention deficit disorder, alcoholism, depression, etc. [7]. In particular, QEEG is widely used in epileptic seizure monitoring and intensive care unit (ICU) long-term EEG monitoring [5].

In 2016, a national survey on the daily utilization of QEEG in Canada showed that at least 70% of the Canadian population had access to QEEG services through academic medical institutions for adults and children [8]. Other researchers investigated the status of clinical utilization of QEEG in critically ill patients in the United States. In this survey, 76.29% of neurophysiologists used QEEG in clinical practice [5]. These surveys show that QEEG has been extensively used in developed countries such as Canada and the United States, covering most of the population. In China, with the development of the economy and medical advances, QEEG has been gradually promoted since the 1980s. For example, the use of EEG in some hospitals has expanded from standard EEG to brain electrical activity mapping, dynamic EEG, and other technologies [2]. However, the general utilization of QEEG in China is not well known.

There is an increased demand for the use of QEEG and the broadening of its application field. In this study, we set out to determine the current status of QEEG use in China.

Methods

In this cross-sectional observational study, the survey was designed with reference to the study of *The state of everyday QEEG use in Canada: A national technologist survey* [8], under the approval of the authors. The questionnaire was modified and designed by an epileptologist from the First Affiliated Hospital of Soochow University to comprise 14 items (Table 1), including single-choice, multiple-choice, yes/no choice, and open-ended questions, containing additional information such as hospital level, department of the hospital, and brain electrical activity mapping. The survey was conducted voluntarily and anonymously and was distributed and collected through WeChat in the form of an online questionnaire survey. The personal information of the surveyed person was not collected, nor was the specific information of the investigated organization disclosed. Epileptologists, neurologists, EEG technicians, neurosurgeons, and ICU physicians engaged in EEG (for adults and children) in various regions of China were invited to participate in the online questionnaire survey through the WeChat platform. This study was approved by the Ethics Committee of the First Affiliated Hospital of Soochow University.

Inclusion criteria of participants: medical professionals engaged in EEG-related examinations and diagnosis who accepted the questionnaire survey; professionals from different medical institutions; or professionals from different departments of the same medical institution.

Exclusion criteria: duplicate entries from the same department in the same medical institution; or incomplete surveys.

In particular, brain electrical activity mapping, which is widely used in the mainland of China, is subject to many interference factors and has limited clinical application value, thus it was not considered as QEEG.

Statistical analysis

All statistical analyses were performed with the SPSS Statistics 19.0 software. Data were analyzed with Pearson's chi-square test and chi-square test with continuity correction. A double-sided P value < 0.05 was considered as statistically significant.

Results

A total of 158 people completed the survey, of whom 148 participants from 134 hospitals met the inclusion criteria. The 148 participants were from 21 of 34 provincial administrative regions in China. Most of the hospitals involved in the survey were located in Jiangsu Province (Fig. 1). Among the medical institutions in the survey, only 23.88% (32/134) could provide QEEG service (Table 2). According to the Chinese hospital hierarchy, hospitals can be rated as three grades, and each grade can be divided into three levels, namely A, B, and C. Among the 32 institutions with the utilization of QEEG, the 3A-grade hospitals accounted for 87.50% (28/32). There was a significant difference in the

Table 1 Survey questions and response options

Questions	Response options
1. Hospital name	Manual input
2. Hospital level	The 3A-grade; the 3B-grade; the 2A-grade; the 2B-grade; the 1A-grade
3. Department	Neurology; Neurology Intensive Care Unit; Neurology Brain Function Unit; the EEG Unit; Neurosurgery; Intensive Care Unit; Others
4. Service crowd	Children; Adult; Children and adult
5. Software of EEG	Nicolet; Nihon Kohden; Cadwell; Natus; EBNeuro; Harmonie; Philip EGI; Domestic EEGs of China
6. The duration of scalp EEG monitoring	About 20–30 min; About 2–3 h; About 12 h; About 24 h; About 1–5 days; or Longer
7. Does your institution use QEEG	Yes or No
8. Software of QEEG	Nicolet; Nihon Kohden; Natus; EBNeuro; Persyst; Others
9. The way to analyze QEEG	Real-time data processing and analysis; Retrospective data processing and analysis
10.Clinical indications for QEEG utilization	Quantitative and trend analysis of long-term EEG of epilepsy monitoring unit; Analysis of brain function in intensive care unit; Scientific research; Automatic seizure detection; Ischemia detection; Others
11.Items of QEEG	Spectrogram; Amplitude-integrated EEG; Automatic seizure detection; Automatic detection of spikes; Burst suppression ratio; Artifact detection; Rhythmicity spectrogram; Asymmetry index; Frequency domain analysis; Compressed spectral array; Fast Fourier transformation spectrogram; Time domain analysis; Power by frequency band; Peak envelope; Alpha-delta ratio; Time–frequency domain analysis; Rhythmicity by channel; Others
12. The duration of raw EEG on a page for QEEG	About 10–30 min; About 30–60 min; About 1–4 h; About 4–8 h; More than 8 h; Others
13. Does your institution use the brain electrical activity mapping	Yes or No
14. The duration of raw EEG on a page for the brain electrical activity mapping	About 1–10 s; About 10–60 s; More than 60 s; Others or any choice of time

QEEG: quantitative electroencephalogram

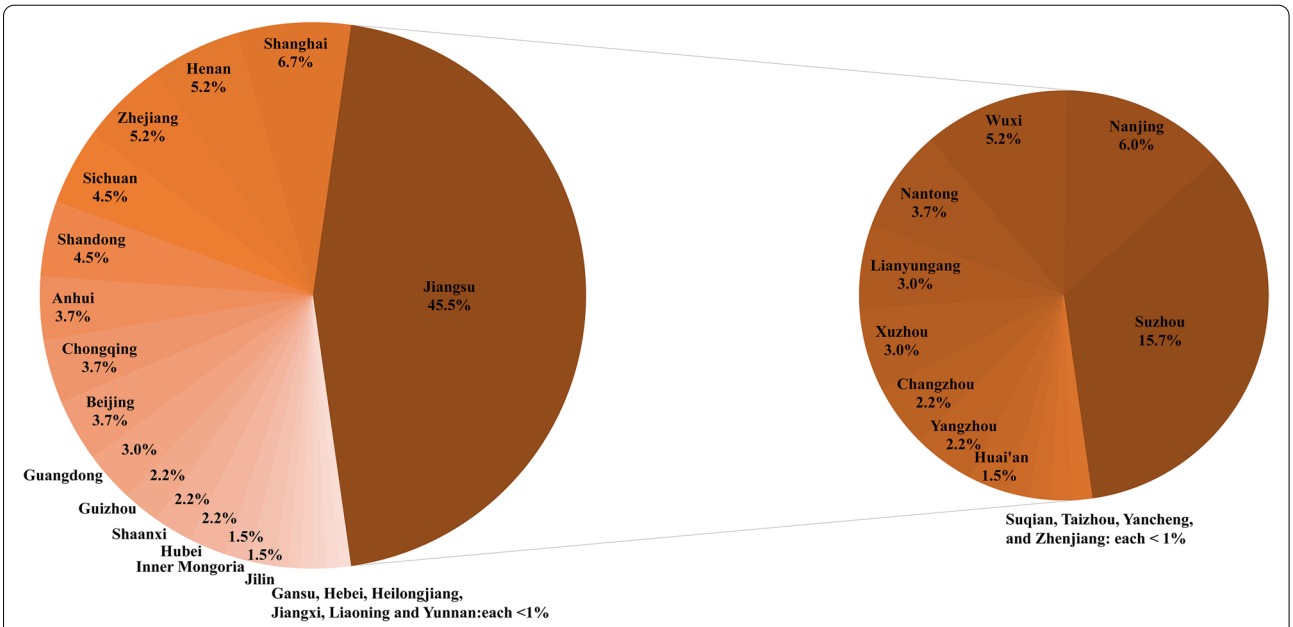

Fig. 1 Distribution of hospitals covered in this survey in China and Jiangsu Province. The figure on the left shows the distribution of hospitals participating in the survey in various regions of China, and hospitals in prefecture-level cities of the Jiangsu Province are shown in the figure on the right. The ratio of the hospitals participating in the survey in each region to the total hospitals participating in the survey is shown in the sector represented by each region

Table 2 Utilization of quantitative electroencephalogram (QEEG) in hospitals

	Hospitals (*n*)	Percentages (%)
Hospitals included	134	
3A-grade hospitals	96	71.64 (96/134)
Non-3A-grade hospitals	38	28.36 (38/134)
Hospitals affiliated to medical schools	52	38.81 (52/134)
Non-affiliated hospitals	82	61.19 (82/134)
Hospitals with routine use of QEEG	32	23.88 (32/134)
3A-grade hospitals	28	87.50 (28/32)
Non-3A-grade hospitals	4	12.50 (4/32)
Hospitals affiliated to medical schools	18	56.25 (18/32)
Non-affiliated hospitals	14	43.75 (14/32)
QEEG not used	102	76.12 (102/134)

There was a significant difference in the utilization of QEEG between the 3A-grade and non-3A-grade hospitals ($P=0.040$) and between the hospitals affiliated to medical schools and those non-affiliated to medical schools ($P=0.020$)

utilization of QEEG between the 3A-grade and non-3A-grade hospitals ($P=0.040$). There was also a significant difference in the utilization of QEEG between hospitals affiliated to medical schools and those not affiliated to medical schools ($P=0.020$).

According to geography and administrative regions, China can be divided into seven regions, namely, North China, Northeast China, East China, Central China, South China, Southwest China, and Northwest China. Twenty-two out of 32 (68.75%) medical institutions that used QEEG were located in East China. Most of the surveyed institutions could provide EEG examinations for both adults and children (62.69%, 84/134), while 28.36% (38/134) and 8.96% (12/134) provide EEG only to adults and children, respectively. In 17 of 31 (a participant skipped this item, therefore 31 instead of 32) institutions (54.84%), QEEG was applied for both real-time and retrospective data analysis. The most-selected application purposes (Fig. 2) included "quantitative and trend analysis of long-term EEG of the epilepsy-monitoring unit" (90.63%, 29/32), "analysis of brain function in intensive care unit" (59.38%, 19/32), and "for scientific research" (53.13%, 17/32). The most-selected items of QEEG (Fig. 3) included "Spectrogram" (68.75%, 22/32), "Amplitude-Integrated EEG" (53.13%, 17/32) and "Automatic seizure detection" (53.13%, 17/32).

The most commonly used softwares for QEEG were Nicolet (62.50%, 20/32), Nihon Kohden (34.38%, 11/32), EBNeuro (15.63%, 5/32), and Persyst (3.13%, 1/32). The durations of scalp EEG monitoring commonly used in various institutions were "about 20–30 min" (77.61%, 104/134), "about 24 h" (70.90%, 95/134), "about 2–3 h" (49.25%, 66/134), "about 12 h" (41.79%, 56/134), and "about 1–5 days, or longer" (22.39%, 30/134).

Eighty-seven (64.93%, 87/134) hospitals had utilization of brain electrical activity mapping. The time of each

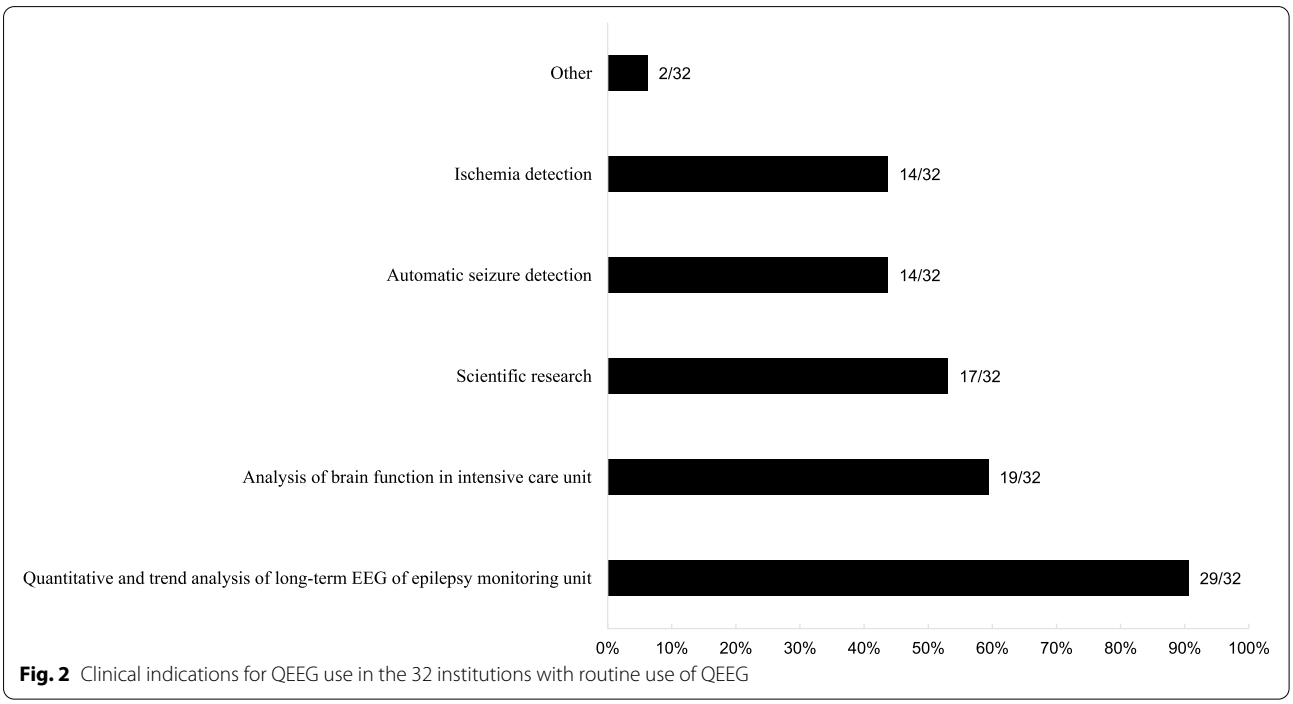

Fig. 2 Clinical indications for QEEG use in the 32 institutions with routine use of QEEG

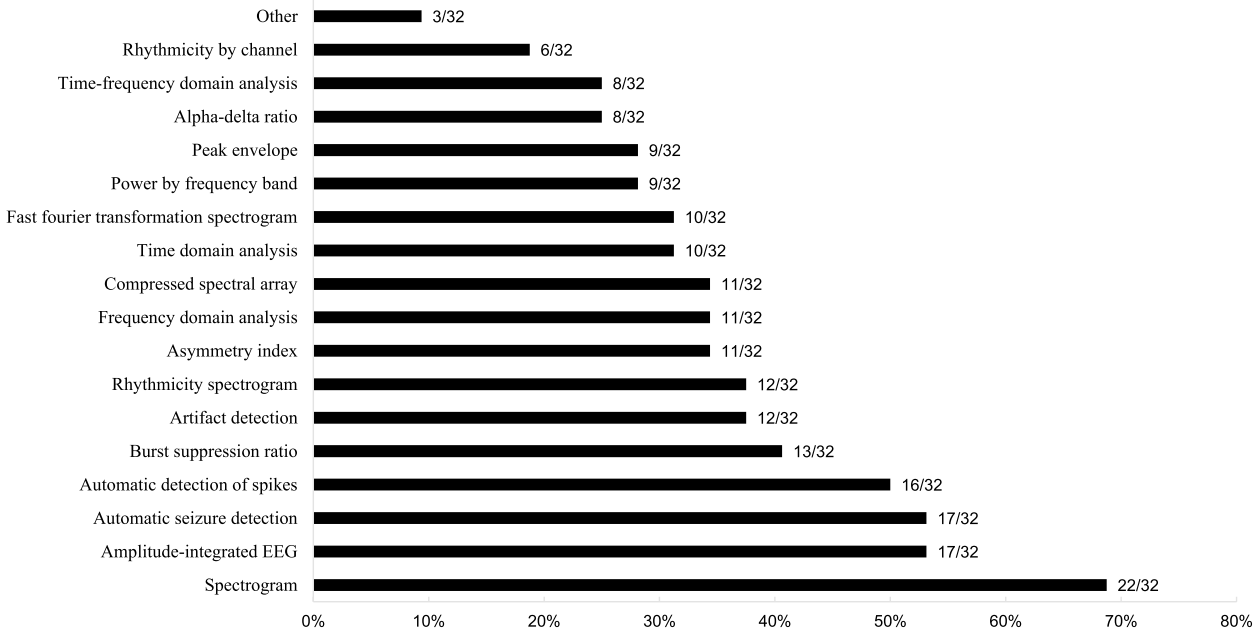

Fig. 3 Items of QEEG in the 32 institutions with routine use of QEEG

brain electrical activity mapping to display the original EEG was mostly "about 1–10 s" (43.68%, 38/87) and "about 10–60 s" (37.93%, 33/87).

Discussion

In this study, 158 professional and technical personnel from 134 medical institutions in 21 provinces in China participated in the survey. The results showed that 32 institutions had routine use of QEEG, accounting for only 23.88% of the institutions surveyed. According to the total population by region, about 81.79% of the Chinese population can access QEEG services through local medical institutions [9]. However, as this survey did not cover all regions of China and due to the large population of China, currently QEEG cannot be considered as widely available in China.

This study was carried out in the way of online survey among EEG professionals in some medical institutions. Participants were mostly from Departments of Neurology (64.19%, 95/148), Electroencephalography (18.92%, 28/148), and ICU (4.05%, 6/148). No scientific research institutions were involved. The medical institutions covered 4 of the top 10 (40%) profession-comprehensive hospitals [10], and 15 of top 50 (30%) hospitals [11].

The content of the questionnaire in this survey was designed with reference to the surveys carried out in relevant institutions in Canada [8] and the United States [5] to investigate the utilization of QEEG in these countries. Our results show that QEEG was used in 23.88% (32/134) of the surveyed institutions. This rate was much smaller, though the sample size in the Canadian survey was smaller than that in our study [8]. The US survey focused on the use of QEEG in ICU [5]. In this survey, a large number of participants (158 participants in total) were involved, who were mostly from in higher-level general hospitals, such as the 3A-grade hospitals (71.64%, 96/134), and were in various departments. Therefore, our result suggests that QEEG is not widely used in China, compared to Canada and the United States.

Another finding in this survey was that 54.84% (17/31) of institutions apply QEEG to both real-time and retrospective data processing and analysis. Real-time data processing and analysis are mostly used for ICU monitoring or epileptic seizure detection [12]. For example, QEEG can be used to monitor many brain-related clinical indications in critically ill patients, including seizure detection, burst suppression, and detection of delayed cerebral ischemia [13]. The retrospective data processing and analysis helps to reduce the workload of manual EEG reading [14].

The top three application purposes were “quantitative and trend analysis of long-term EEG of epilepsy monitoring unit”, “analysis of brain function in ICU”, and “for scientific research use”. The data proved that many medical institutions in China apply QEEG for monitoring seizures. QEEG recognizes epileptic seizures faster and shortens the time for analysis. Numerous studies have shown that QEEG has been extensively used to

identify seizure onset, ictal and postictal durations, and seizure types [6]. The abnormal changes of EEG during the interictal phase can be used for differential diagnosis from other non-epileptic seizure diseases [15]. Meanwhile, with the wide utilization of long-term EEG, the heavy workload of data analysis has promoted the utilization of QEEG in epilepsy monitoring units. The most involved QEEG items include spectrogram, amplitude-integrated EEG, and automatic seizure detection and analysis. The spectrogram can provide accurate information on EEG frequency. Spectrogram is usually a general term for a type of QEEG, which includes Asymmetric Index, Fast Fourier Transform Spectrogram, and Rhythmicity Spectrogram [6]. The automatic analysis of epileptic seizures can effectively reduce the time of manual reading and improve the sensitivity of seizure detection, especially for generalized seizures [6]. Amplitude-integration EEG is the integration of amplitude of EEG, which can increase the resolution and measurement accuracy of low-amplitude components. It is mainly used for the judgment and prognostic evaluation of brain injury [16], brain function monitoring for critically ill patients [17], and the continuous evaluation of brain functions of newborns [18].

The brain electrical activity mapping displays the spatial distribution of power spectrum values at each independent electrode on the scalp surface in the form of a two-dimensional power spectrum topographic map [19]. Brain electrical activity mapping is mostly used for the diagnosis of cerebrovascular diseases, epilepsy, brain tumors, and other diseases [20]. The advantage of brain topography is that it can clearly and intuitively display the lesion, with high sensitivity, non-invasiveness, and low price. Therefore, it is used clinically in many medical institutions in China. However, the brain electrical activity mapping cannot identify artifacts, and the duration of EEG that it can calculate is short. Therefore, brain electrical activity mapping can only be used for auxiliary diagnosis, which limits its wide use. Therefore, in this study, it was not included in the category of QEEG.

There are several limitations in this study. This was a cross-sectional study, the sampling method of this survey was indeed insufficient, and there were selection deviations. The number of medical institutions covered in this survey was limited, especially in remote and undeveloped areas of China. The department distribution of the respondents was unreasonable, as most of them were from the Department of Neurology.

Conclusions

In summary, the utilization of QEEG is still limited in China. There are differences in the status of QEEG use among different hospitals and regions. This disparity may be due to the following reasons. First, the utilization of QEEG requires higher-level hardware facilities and related softwares for data analysis and processing. However, most of these softwares are developed and supplied by foreign companies, which limits their availability among Chinese technicians. Second, this problem is unlikely to be solved in a short time, resulting in the limited use of QEEG in China.

More efforts are needed to advance the development of this field, thereby pushing forward QEEG use in EEG practitioners in China.

Abbreviations

QEEG: Quantitative electroencephalogram; EEG: Electroencephalogram; ICU: Intensive care unit.

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Authors' contributions

JL wrote the manuscript and prepared figures and tables. XH revised the manuscript. XH, SP, YL, and XZ distributed questionnaires and collected the data. The author(s) read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The name of the ethics committee that approved the study and the committee's reference number: the Ethics Committee of the First Affiliated Hospital of Soochow University; (2022 [146]). Due to the noninterventional nature of the study, informed consent was not required. We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this article is consistent with those guidelines.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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References

1. Riviello JJ Jr. Digital trend analysis in the pediatric and neonatal intensive care units. J Clin Neurophysiol. 2013;30(2):143–55.
2. Qiyao W. Theory and application of quantitative electroencephalogram. J Clin Electroencephalogr. 1996;5(1):3–7.
3. Kubota Y, Nakamoto H, Egawa S, Kawamata T. Continuous EEG monitoring in ICU. J Intensive Care. 2018;6:39.
4. Haider HA, Esteller R, Hahn CD, Westover MB, Halford JJ, Lee JW, et al. Sensitivity of quantitative EEG for seizure identification in the intensive care unit. Neurology. 2016;87(9):935–44.

5. Swisher CB, Sinha SR. Utilization of quantitative EEG trends for critical care continuous EEG monitoring: a survey of neurophysiologists. J Clin Neurophysiol. 2016;33(6):538–44.
6. Goenka A, Boro A, Yozawitz E. Comparative sensitivity of quantitative EEG (QEEG) spectrograms for detecting seizure subtypes. Seizure. 2018;55:70–5.
7. Nuwer M. Assessment of digital EEG, quantitative EEG, and EEG brain mapping: report of the American Academy of Neurology and the American Clinical Neurophysiology Society. Neurology. 1997;49(1):277–92.
8. Ng MC, Gillis K. The state of everyday quantitative EEG use in Canada: A national technologist survey. Seizure. 2017;49:5–7.
9. Tabulation on the 2010 population census of The People's Republic of China. National Bureau of Statistics of The People's Republic of China. 2010. http://www.stats.gov.cn/tjsj/pcsj/rkpc/6rp/indexch.htm; [accessed 20 March 2021].
10. The ranking of profession-comprehensive-best hospitals in China. Institute of Hospital Management, Fudan University. 2019. http://rank.cn-healthcare.com/rank/profession-comprehensive-best/17/2019; [accessed 20 March 2021].
11. The ranking of general-best hospitals in China. Institute of Hospital Management, Fudan University. 2019. http://rank.cn-healthcare.com/rank/general-best; [accessed 20 March 2021].
12. Kang JH, Sherill GC, Sinha SR, Swisher CB. A Trial of real-time electrographic seizure detection by Neuro-ICU nurses using a panel of quantitative EEG trends. Neurocrit Care. 2019;31(2):312–20.
13. Claassen J, Hirsch LJ, Kreiter KT, Du EY, Connolly ES, Emerson RG, et al. Quantitative continuous EEG for detecting delayed cerebral ischemia in patients with poor-grade subarachnoid hemorrhage. Clin Neurophysiol. 2004;115(12):2699–710.
14. Moura LM, Shafi MM, Ng M, Pati S, Cash SS, Cole AJ, et al. Spectrogram screening of adult EEGs is sensitive and efficient. Neurology. 2014;83(1):56–64.
15. Feyissa AM, Tatum WO. Adult EEG. Handb Clin Neurol. 2019;160:103–24.
16. Shah NA, Wusthoff CJ. How to use: amplitude-integrated EEG (aEEG). Arch Dis Child Educ Pract Ed. 2015;100(2):75–81.
17. Dong X, Shao H, Yang Y, Qin L, Guo Z, Zhang H, et al. Early evaluation of patients with amplitude-integrated electroencephalogram on brain function prognosis after cardiopulmonary cerebral resuscitation. Zhonghua wei zhong bing ji jiu yi xue. 2017;29(10):887–92.
18. Hellstrom-Westas L, Rosen I. Continuous brain-function monitoring: state of the art in clinical practice. Semin Fetal Neonatal Med. 2006;11(6):503–11.
19. Duffy FH. Topographic display of evoked potentials: clinical applications of brain electrical activity mapping (BEAM). Ann N Y Acad Sci. 1982;388:183–96.
20. Persson A, Hjorth B. EEG topogram--an aid in describing EEG to the clinician. Electroencephalogr Clin Neurophysiol. 1983;56(5):399–405.