Research Article

Nepal Journal of Neuroscience 2025;22(1): 6-13

Current Practices and the Future of Continuous EEG Monitoring in Indian ICUs: Insights from a National Survey

Sachin[1], Archana Verma[2], Sharukh Khan[3], Madhav Suri[4]

[1,2]Department of Neurology, All India Institute of Medical Sciences (AIIMS), Munshiganj, Dalmau Road, Raebareli (U.P.) 229405, India

[3,4] Suri Neurology Clinic and Education Center, New Delhi, India

Date of Submission: 16th December 2024 Date of Acceptance: 08th May 2025 Date of Publication: 15th May 2025

Abstract

Introduction: Continuous electroencephalography (cEEG) is essential for detecting non-convulsive seizures, status epilepticus, and tracking brain activity in critically ill patients. However, its utilization in Indian intensive care units (ICUs) varies. The purpose of this study is to evaluate current cEEG procedures, identify implementation challenges, and investigate the role of remote monitoring in improving patient care in intensive care units.

Materials and Methods: In September 2024, a national survey was undertaken in Indian hospitals to assess cEEG prevalence and practices. The poll, which was circulated using Google Forms, was aimed at neurologists, neurophysiologists, intensivists, and EEG technicians. It included 20 questions about hospital characteristics, cEEG availability, use, clinical applications, and barriers. To compare public and private hospitals, data were examined using descriptive statistics and Chi-square/Fisher's exact tests.

Results: There were 76 answers, with 63% of ICUs employing cEEG. Private hospitals received 50% of the responses, followed by government hospitals with 38%. Non-convulsive seizures (29%) and status epilepticus (29%) were the predominant reasons for cEEG. Barriers to adoption included a lack of skilled personnel (32%), as well as high expenses (14%). Remote EEG monitoring was employed in 37% of ICUs; however it faced problems such as unstable internet and staff opposition. Despite these challenges, 49% of respondents reported better patient outcomes using cEEG.

Conclusion: Although cEEG use is increasing in major Indian institutions, problems remain. Remote monitoring could reduce obstacles and improve access, but consistent training and national guidelines are required to increase cEEG implementation in Indian ICUs.

Key words: EEG, ICU, non-convulsive seizures, remote monitoring, barriers

Introduction

Continuous electroencephalography, or cEEG, is an essential monitoring tool for brain activity in critically ill patients [1].It is useful in detecting conditions that standard EEGs may not identify, including non-convulsive seizures (NCS) and non-convulsive status epilepticus (NCSE). In the intensive care units, cEEG offers real-time, continuous monitoring of subtle neurological changes that may be indicative of life-threatening conditions. In addition to diagnosing NCS and NCSE, cEEG is also used to monitor cerebral ischemia, continuously monitor the level of sedation, assess the severity of encephalopathy, and monitor the effectiveness of seizure management therapies [2,3]. The use of continuous EEG (cEEG) in intensive care units (ICUs) is recommended by international guidelines, such as those from the Neurocritical Care Society (NCS) and the American Clinical Neurophysiology Society (ACNS), especially for critically ill patients who have refractory status epilepticus or unexplained changes in consciousness[4].

However, the use of cEEG in India is still limited. The situation is worse in resource-constrained settings, such as smaller hospitals, where trained personnel and advanced monitoring equipment are often unavailable. Although cEEG has become standard practice in ICUs across North America and Europe5,barriers such as staff shortages, lack of infrastructure, and inadequate awareness hinder its widespread adoption in India.

Neurological diseases such as epilepsy, stroke, and traumatic brain injury are becoming more common in India, highlighting the critical need to reduce this gap. To address this, a national survey was performed to assess current practices, difficulties, and prospects for using cEEG in Indian ICUs. This study aims to provide a comprehensive understanding of the organisational, operational, and technical variables influencing cEEG adoption, as well as to investigate the potential of remote monitoring solutions to reduce resource limitations. The findings will help to

Access this article online

Website: https://www.nepjol.info/index.php/NJN

DOI: https://10.3126/njn.v22i1.72688

HOW TO CITE
Sachin, Khan S, Suri M, Verma A. Title: Current Practices and the Future of Continuous EEG Monitoring in Indian ICUs: Insights from a National Survey.NJNS. 2025;22(1):6-13

Address for correspondence:
Mr. SACHIN, R.EEG.T./CPSGT, M. Sc. (Neuro) , EEG Technologist
Department of Neurology All India Institute of Medical Science Raebareli
Uttar Pradesh - 229405
Email: Sachin.eeg96@gmail.com

Copyright © 2023 Nepalese Society of Neurosurgeons (NESON)
ISSN: 1813-1948 (Print), 1813-1956 (Online)

This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License.

shape future clinical guidelines and policy recommendations, resulting in larger deployment of cEEG monitoring in Indian ICUs and improved critical care delivery.

Methods

Survey Design and Distribution

A national survey was conducted in the months of September 2024 to assess the current practices, challenges, and potential of cEEG monitoring in ICUs across the country. This study utilized a web-based survey designed using Google Forms that was disseminated across a comprehensive network of hospitals and healthcare professionals. Surveys were shared with key stakeholders through electronic mail, while professional social media sites, WhatsApp groups, LinkedIn, and Facebook forums of neurology and critical care experts served as vehicles for sharing the survey. After email reminders for participation and utilization of social media platforms, an adequate response to the survey questionnaires was garnered over the eight-week data collection period.

Survey Questionnaire

The survey included 20 structured questions divided into five key sections

1.Hospital and Respondent Information: This section gathered information about the hospital's features (e.g., size, kind, ICU capacity) and the respondent's professional background (e.g., speciality, years of experience, and cEEG training).

2.Availability and Use of cEEG Monitoring: Questions addressed the availability and frequency of cEEG use, clinical conditions monitored (e.g., non-convulsive seizures, encephalopathy, cerebral ischaemia), and review methods.

3.Challenges and Barriers to Implementation: This section looked at issues like a lack of qualified workers, equipment expenses, and understanding of clinical utility.

4.Review and Reporting Practices: The questions focused on how cEEG traces were evaluated and how promptly anomalies were reported.

5.Future Directions and Needs: This part investigated the feasibility of remote EEG monitoring (tele-EEG) and the accompanying challenges.

Reliability and Validity

The survey tool was developed based on a review of the literature and input from experts in neurology, neurophysiology, and critical care. To ensure clarity and content validity, it was pre-tested with 10 healthcare professionals (including neurologists, ICU physicians, and EEG technologists). Feedback from this pilot group was used to refine question wording and structure.

Data Collection and Analysis

The survey was conducted from September to October 2024. All the responses were de-identified and grouped according to hospital type: public or private, and presence of an ICU. Descriptive statistics in terms of frequency counts and percentages were used for categorical variables. Differences between public and private hospitals were tested using Chi-square tests or Fisher's exact tests where appropriate. The p-value was set at <0.05 for statistical significance.

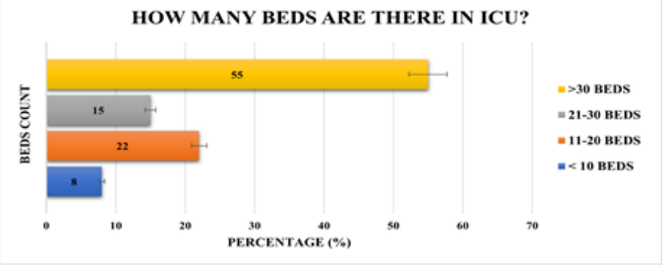
Result

ICU Type of Hospital

The Type of hospital mentioned in the survey was listed as follows with its percentage are Government/public hospital (38%), Private Hospital (50%), Teaching/Tertiary care hospital (10%), Trust Hospital (1%), Company hospital (1%). We can find that Private hospital working individuals had been actively participating in this survey.

Beds available in the ICU

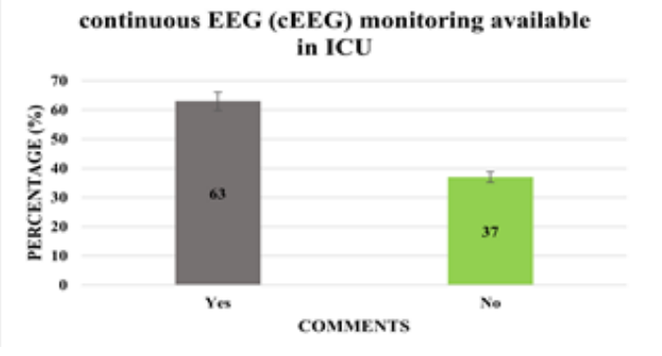
The Beds available in the ICU mentioned on the survey is < 10 beds is about 8%, 11-20 beds is about 22%, 21-30 beds is about 15%, >30 beds is about 55%. We found out that this survey was been attended by Larger Scale hospitals. For detailed results see Graph 1.



Graph 1: Beds available in the ICU

Intensive Care Unit Professionals Role & cEEG in available in ICU

The Job Roles in ICU mentioned are Neurologist (18%), Intensivist (5.5%), ICU Nurse (5.5%), EEG Technician (71%). We have found that the largest population that participated in this survey was EEG Technician (71%). The continuous EEG (cEEG) monitoring available in ICU with its percentage for Yes it is 63% and for No it is 37%. We can find that survey participants work the majority in Continuous EEG (cEEG) (63%). For detailed results see Graph 2.



Graph 2: continuous EEG (cEEG) monitoring available in ICU

Plans to implement cEEG

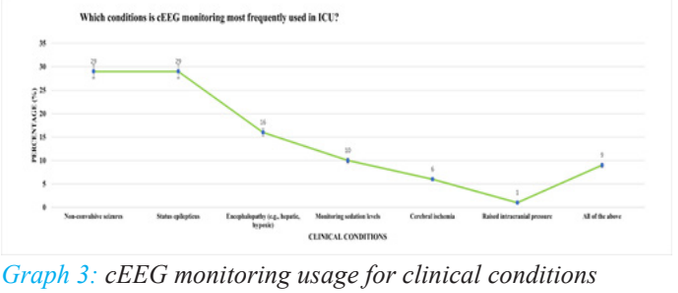
The Plans to implement cEEG when it is not available was taken in the survey and the percentage of comments are Not Sure is about 57%, No Plans to implement is about 7%, Yes, but no specific timeline is about 13%, Yes, within the next year is about 23%. This study stated that many working hospitals are not sure to implement in future because they don't have cEEG monitor in their hospital (57%).

cEEG usage

How often the cEEG monitoring used in ICU was conducted in the survey and it's percentage was found to be if Regularly it is 30%, Occasionally it is 34%, Rarely it is 19% and when it is Not used it is 17%. We can find that cEEG usage is occasionally done in most of the hospitals which has been evaluated in this survey (34%).

Clinical conditions in which cEEG monitoring employed

There are certain Clinical conditions in which cEEG monitoring is employed has been evaluated from the survey are Non-convulsive seizures is 29%, Status epilepticus is 29%, Encephalopathy (e.g., hepatic, hypoxic) is 16%, Monitoring sedation levels is 10%, Cerebral ischemia is 6%, Raised intracranial pressure is 1% and for All of the above it is 9%. From the above finding we can find that cEEG has been more frequently used for Non-convulsive seizures and status epileptics (29%) than other neurological conditions as per our survey. For detailed results see Graph 3.



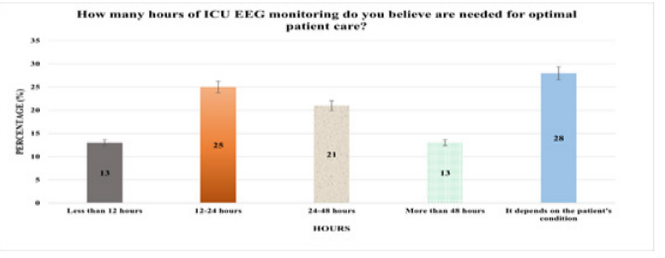
Graph 3: cEEG monitoring usage for clinical conditions

cEEG results review

How often the cEEG results are reviewed by a specialist has been investigated in this survey was mentioned if Multiple times a day it is 45%, Once a day it is 14%, Every 2-3 days it is 8%, Only when clinically indicated it is 17% and for None it is 16%. We find that cEEG was reviewed by a specialist is multiple times a day (45%) from this survey.

EEG monitoring required for optimal patient care

The Hours required for optimal patient care in ICU EEG monitoring evaluated from the survey is for < 12 hours it is 13%, 12-24 hours it is 25%, 24-48 hours it is 21%, >48 hours it is 13% and depending on the patient's condition it is 28%. Survey results clearly states that Hours required for optimal patient care in ICU EEG monitoring mainly depends on the patient's condition (28%). For detailed results see Graph 4.



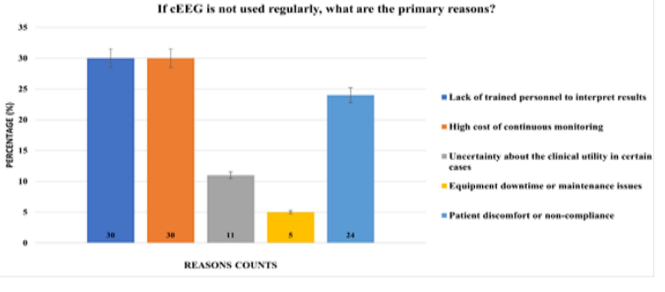
Graph 4 :Hours required for ICU EEG monitoring

Challenges involved in implementing cEEG

There are certain Challenges involved in implementing cEEG which is stated in the survey are Lack of trained personnel which is 32%, High cost of equipment is 14%, Limited availability of equipment is 20%, Difficulty in continuous review and interpretation is 13% and for the Lack of clinical awareness of its benefits is 21%. We find that the main challenge in implementing cEEG is the lack of trained personnel (32%) to monitor the cEEG than any other Challenging conditions given in the survey.

Primary reasons involved in not using cEEG

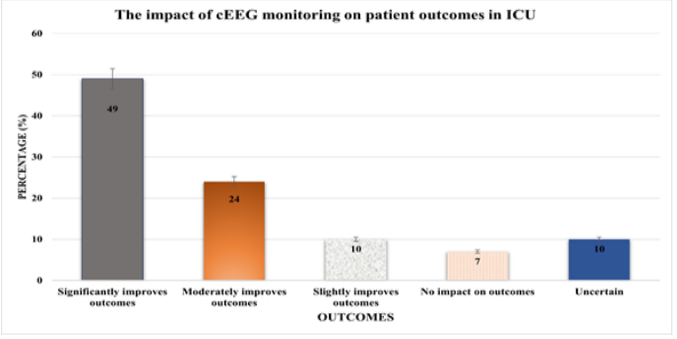
There are few Primary reasons which is involved in not using the cEEG evaluated from the survey are due to Lack of trained personnel to interpret results which is 30%, High cost of continuous monitoring is 30%, Uncertainty about the clinical utility in certain cases is 11%, Equipment downtime or maintenance issues is 5%, Patient discomfort or non-compliance is 24%. Lack of trained personnel to interpret results and High cost of continuous monitoring (30%) have been reported as the primary reason for not using cEEG in a regular basis. For detailed results see Graph 5.



Graph 5: If cEEG is not used regularly, what are the primary reasons?

Impact of cEEG monitoring on patient outcome

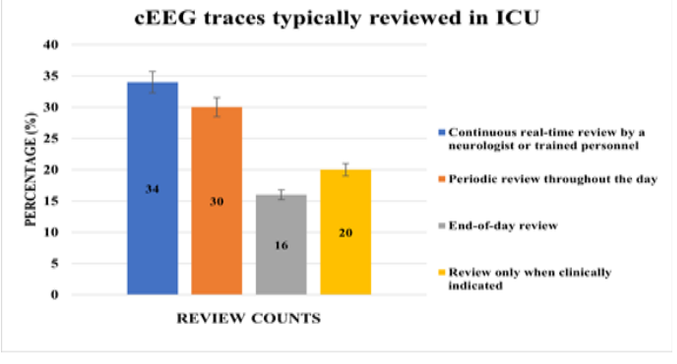
The impact of cEEG monitoring on patient outcome from the survey data involves Significantly improves outcomes which is 49%, Moderately improves outcomes is 24%, Slightly improves outcomes is 10%, No impact on outcomes is 7% and in Uncertain it is 10%. The impact of cEEG monitoring on patient outcome is evaluated as there is increase in number of significantly improves outcomes which is 49% when compared to any other cause mentioned in the survey. For detailed results see Graph 6.



Graph 6: The impact of cEEG monitoring on patient outcomes in ICU

cEEG traces reviewed

The cEEG traces reviewed in ICU stated from the survey data includes Continuous real-time review by a neurologist or trained personnel which is 34%, Periodic review throughout the day is 30%, End-of-day review is 16%, Review only when clinically indicated is 20%. This survey shows that Continuous real-time review by a neurologist or trained personnel (34%) in the cEEG traces is typically reviewed in the ICU. For detailed results see Graph 7.



Graph 7: cEEG traces typically reviewed in ICU

Significant abnormalities in cEEG

There are some of the Significant abnormalities in cEEG reported to the attending physician within certain time evaluated from the survey data includes Immediately (within minutes) which is 33%, Within an hour is 21%, Within a few hours is 16%, At the next scheduled review is 30%. Immediately (within minutes) (33%) is evaluated from the survey data as it is reported to the attending physician quickly for the significant abnormalities in cEEG results.

Continuous EEG interpretation

The remote EEG monitoring (tele-EEG) utilised in ICU for continuous EEG interpretation is questioned in the survey with its data analysed for Yes it is 37% and for No it is 63%. No (63%) remote EEG monitoring utilised in the ICU for continuous EEG interpretation was given as a result of this study.

Recordings of Remote EEG monitoring reviewed by an off-site specialist

How often the Recordings of Remote EEG monitoring reviewed by an off-site specialist is interpreted from the survey data includes In real-time it is 24%, Multiple times a day it is 21%, Once a day it is 16%, Only when clinically indicated it is 39%.

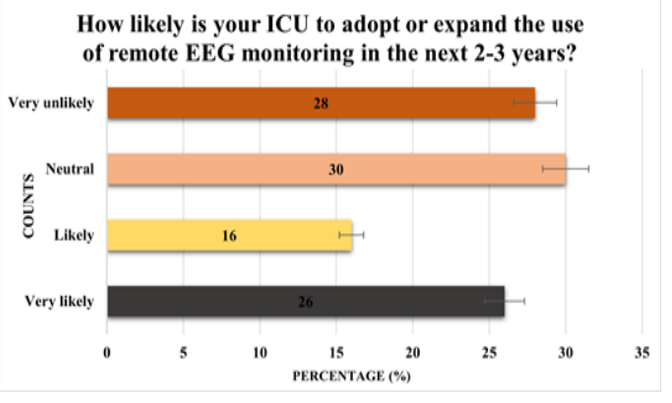
The remote EEG monitoring is used only when clinically indicated (39%) is the interpreted data recordings reviewed by an off-site specialist given as result of this survey.

Challenges in implementing remote EEG monitoring

The main challenges involved in implementing remote EEG monitoring on ICU includes Lack of reliable internet connectivity which is 30%, Concerns about data security and patient privacy is 16%, High cost of tele-EEG services is 26% and for the Resistance from local staff or specialists is 28% which is interpreted from the survey data. The main challenge in implementing remote EEG monitoring on ICU is lack of reliable internet connectivity (30%) according to the survey.

Adopting or expanding the usage of remote EEG monitoring

How likely is your ICU to get adopted or expanded for the use of remote EEG monitoring in the next 2-3 years is questioned in the survey data with interpretations includes Very likely is 26%, Likely is 16%, Neutral is 30%, Very unlikely is 28%. Neutral (30%) is interpreted from the survey data of adopting or expanding the use of remote EEG monitoring in the next 2-3 years.



Graph 8: How likely is your ICU to adopt or expand the use of remote EEG monitoring in the next 2-3 years?

Role of Healthcare professionals to be involved for connecting the EEG electrodes

The primarily responsible Healthcare professionals for connecting the EEG electrodes in the ICU was questioned in the survey and interpreted which includes EEG Technician is 80%, ICU Nurse is 7%, Neurologist is 5% and for Resident/Junior Doctor is 8%. EEG Technician (80%) is primarily responsible for connecting the EEG electrodes in the ICU which is interpreted as the result from the survey.

Discussion

According to the findings of this nationwide survey of cEEG practices in various types of Indian hospitals, ICU cEEG is used in nearly all Indian universities and most teaching hospitals, but is rarely used in general hospitals. This gap reflects an uneven distribution of resources and expertise, with better-equipped tertiary and teaching hospitals being more likely to implement advanced technologies such as cEEG. The higher prevalence of cEEG in institutions with more than 30 ICU beds emphasizes the importance of infrastructure and resource

availability in enabling its use[6,7]. Additionally, the study demonstrates that, similar to the United States, ICU cEEG use is increasing in India. A study by Ney et al. and Abend et al. done in the USA showed that increases in the use of cEEG occur mainly in university and teaching hospitals6. This is because generally, university and teaching hospitals adopt the newest techniques for patient care and research. It is surprising that even general hospitals, despite being smaller and looking after fewer cEEG-eligible patients, have had modest increases in cEEG usage. Even the best Indian hospitals often monitor less than 10-20 ICU patients per month using continuous EEG.

While cEEG adoption is still in its early stages, it is clear that with adequate resources, training, and technological advancements, it has the potential to become a cornerstone of neurocritical care in India.

4.1 Current Applications of cEEG in Indian ICUs

According to the survey results, continuous EEG (cEEG) monitoring is most commonly used in Indian ICUs to watch high-risk patients, particularly those with changed mental status as a result of convulsive seizures, traumatic brain injury (TBI), or intracerebral hemorrhage (ICH). These findings are consistent with international norms, in which cEEG is regarded critical for detecting nonconvulsive seizures (NCS) in patients with unexplained coma or encephalopathy[8]. However, its application to various disorders such as ischemic stroke, central nervous system (CNS) infections, and metabolic encephalopathy differs per institution, owing to a lack of precise clinical standards. This variation may possibly be due to geographical variances in the perceived risk of seizures in these situations. While some studies have suggested that CNS diseases such as meningitis or encephalitis might cause seizure activity similar to ICH, the lack of clear recommendations for these circumstances limits the general use of cEEG in these patient populations[9].

Patil et al. emphasise that cEEG is critical in the ICU for real-time brain monitoring, seizure identification, and therapy modification. Although cEEG increases sensitivity in the identification of NCSE and reduces ICU duration of stay, constraints such as interpretation skills and standardisation remain. Improvements in automated analysis and well-defined guidelines will enhance its clinical application[10].

Manjari et al. demonstrate the critical relevance of EEG in diagnosing NCSE, particularly among ICU patients with confused altered mental status for no apparent reason. Their findings suggest that EEG is required for detecting NCSE because overt clinical symptoms are absent in numerous critically ill patients. NCSE requires extended EEG monitoring, and cEEG is substantially more sensitive than normal EEG, with a 2.5 to 3-fold higher detection rate among critically sick patients. In resource-constrained contexts, a single-hour standard EEG may help to guide the need for continuous monitoring, and the 2HELPS2B seizure risk prediction score can also be utilised to help determine whether cEEG is required[11] .

Haranath et al. (2021) highlight the possibility, especially in low-resource settings where access to specialised neurocritical care is limited. Remote neuroconsultations were successfully delivered to 56 patients in 23 ICUs over a 16-month period, demonstrating telemedicine's ability to fill a gap in neurocritical care. The research emphasises the role of tele-EEG and remote EEG reading in aiding timely diagnosis and intervention in critically ill neurological patients. The adoption of portable EEG devices with real-time remote analysis has the potential to improve seizure diagnosis and treatment, particularly in hospitals without on-site neurophysiologists[12].

4.2 Issues with Monitoring Duration and Resources

The time of monitoring is a key barrier to the deployment of continuous EEG monitoring in Indian intensive care units. Although guidelines normally require 48 hours of monitoring for patients with changed mental status to reliably detect nonconvulsive seizures, many institutions restrict cEEG to 24 hours due to resource constraints[13]. This limitation is consistent with developments in developing countries, where limited resources and concerns about cost-effectiveness affect therapeutic decisions. Despite these limitations, many doctors believe that extended monitoring is essential for accurate seizure detection. To overcome this difficulty, it may need designing more efficient protocols for targeting the highest-risk patients, including risk classification models and optimizing resource usage[14].

4.3 Technical Expertise and Personnel Challenges

A significant impediment to the widespread adoption of cEEG in Indian ICUs is a lack of skilled people, such as EEG technologists and neurophysiologists, who can offer continuous EEG monitoring and interpretation. Resource-constrained institutions, particularly smaller hospitals, frequently struggle to maintain a 24-hour crew, which is critical for monitoring patients at risk of NCS. The findings from the survey show that, while there is a rising awareness of the need for skilled professionals, the availability of such experts remains restricted[15].

To close this gap, training activities for clinicians and technicians can help improve the knowledge and skills required for cEEG monitoring. Task-shifting, in which nurses and technicians are educated to execute basic cEEG operations, could be a viable alternative to lessen the need for specialized personnel. Furthermore, the adoption of ambulatory ICU EEG monitoring may ease some of these issues. With the ability to remotely monitor patients, ambulatory EEG systems can lessen the need for on-site expertise by providing real-time, actionable data that can be examined by specialists even when they are not present in the ICU. This not only makes cEEG more accessible, but it also assures that patients receive continuous monitoring without overburdening the existing staff.

4.4 Application and Maintenance of EEG Electrodes

Another problem that ICUs encounter is applying and maintaining EEG electrodes in critically ill patients, particularly those with head traumas or surgical scars. Simplified electrode systems, such as headset-type devices or reduced-montage setups, can be more practical due to their ease of application and maintenance[16]. Recent research, such as that of Caricato et al. (2020) and Herta et al. (2017), has shown that these systems are sensitive, dependable, and can be deployed fast, minimizing the time required on electrode setup[17].

In Indian ICUs, where rapid patient turnover and time-sensitive care are widespread, the adoption of MRI-compatible electrodes or elastic electrode caps can simplify the electrode application process, improving workflow efficiency and patient comfort[18]. These advances can lessen the risk of skin irritation while also improving the overall quality of EEG data gathered.

4.3 Duration and Interpretation of cEEG Data

The ideal period for cEEG recordings is still debatable. While extended recordings are frequently required to detect nonconvulsive seizures, they also pose issues like as data overload and the requirement for ongoing observation. According to the report, many institutions are now restricting cEEG monitoring to 24 to 48 hours due to resource restrictions. Anadure et al. identify portable EEG as a promising bedside tool for NCSE diagnosis in comatose ICU patients, detecting NCSE in 11.8% of instances. Antiepileptic treatment corrected EEG abnormalities, with positive effects in a few patients[19]. Although portable EEG is useful, 24-48 hour EEG with remote monitoring is required for better NCSE detection and management. However, a sizable proportion of practitioners understand the value of prolonged monitoring, implying that increasing monitoring time may provide better clinical benefit when resources are available.

In the Indian setting, research have demonstrated the utility of portable EEG in identifying NCSE among comatose ICU patients. Anadure et al. found that portable EEG helped detect NCSE in 11.8% of comatose patients, allowing for prompt antiepileptic medication administration. This method is especially useful in situations when continuous EEG monitoring may not be practicable[20].

Telemedicine and remote monitoring systems have the ability to alleviate this issue[21]. By integrating ambulatory ICU EEG, cEEG data can be transferred in real time to a centralized platform for ongoing evaluation by professionals. This remote access reduces the need for on-site expertise around the clock and allows for rapid, accurate interpretation, especially in places where 24-hour neurophysiological support is absent. The capacity to monitor and interpret EEG data in real time via remote platforms dramatically increases the possibility of early seizure diagnosis, which improves patient outcomes by allowing for timely interventions[22].

4.5 The Role of Technologists and Standardized Protocols

The survey revealed significant variation in the sorts of people involved in continuous EEG interpretation. Although some facilities have neurophysiologists or intensivists to interpret, they are generally limited resources, particularly during overnight shifts. Some centers employ EEG technicians for continuous monitoring, which varies between Indian intensive care units. This heterogeneity emphasizes the significance of well-defined protocols for distinguishing duties and responsibilities between technologists and physicians in continuous EEG monitoring.

A systematic review by Verma et al. underscores the need for building nursing skills in EEG to enhance patient care and outcomes, stressing the need for formal education and hands-on facilities in the Indian scenario[23]. The American Clinical Neurophysiology Society consensus statement details the qualifications and roles of cEEG staff, which can be a useful guide to establishing similar guidelines adapted to the Indian healthcare system[24]. Standardizing personnel duties may promote speedy and accurate seizure detection while also encouraging a more collaborative approach to patient treatment[6].

4.6 Limitations in Monitoring Beyond Seizure Detection

In neurocritical care settings, continuous EEG is mostly utilized to detect seizures; however, the survey found that it has little relevance for monitoring other critical brain events such burst suppression, vasospasm, or increased intracranial pressure (ICP). Although some institutions have started using cEEG to monitor patients with excessive ICP, this practice is not common, and the adoption of cEEG has been hampered by the lack of compelling evidence for its wider use in these settings[17]. Additional investigation is required to examine the possible applications of cEEG in monitoring other vital brain processes, such as vasospasm and ICP, especially in neurocritical care environments.

Recent Indian research have underlined the rising relevance of cEEG in seizure detection. Gupta et al. (2022) conducted a study in a tertiary care centre in North India and discovered that cEEG can detect early signs of cerebral ischaemia in ICU patients post-subarachnoid haemorrhage, indicating its potential in vasospasm monitoring[25].

By facilitating more thorough monitoring of neurological processes, cEEG monitoring scope expansion may enhance patient outcomes.

4.7 Technological Innovations and Future Directions

Technological improvements will be more important in enhancing the future of continuous EEG monitoring in Indian ICUs. The most promising approach is to employ artificial intelligence to identify seizures automatically[26]. AI has the potential to greatly accelerate and increase the sensitivity and specificity of seizure identification, particularly in cases where visual analysis may be impractical. Another realistic alternative is to employ cloud-based platforms for remote EEG analysis to solve resource constraints. The former allows for real-time EEG interpretation by professionals who are not in the ICU, which helps alleviate personnel shortages[27]. Furthermore, public-private partnerships with research institutions will aid in the development and application of such technology in Indian ICUs. In that circumstance, cEEG monitoring may be available in smaller hospitals and rural areas.

4.8 Policy and Training Recommendations

To address the issues raised in this survey, it is critical to create national guidelines and policies that standardize continuous EEG techniques across Indian ICUs. These guidelines should address a variety of topics, including the qualifications of individuals participating in monitoring and interpretation, the ideal monitoring length for different patient groups, and best practices for electrode insertion and maintenance. Furthermore, training programs that improve the competence of ICU personnel—technologists, nurses, and intensivists—in operating and interpreting continuous EEG are critical for closing existing

knowledge gaps. Setting up national registries to gather and evaluate cEEG data could potentially provide useful insights into its clinical utility and help guide future policy decisions28. Additionally, Indian EEG technicians frequently follow the American Clinical Neurophysiology Society's (ACNS) recommendations for critical care EEG procedures and bring a wealth of practical knowledge to the table. In addition to improving these technicians' abilities, encouraging them to obtain international qualifications like ABRET's Registered EEG Technologist (R. EEG T.) certificate would also raise the standard and uniformity of care given in intensive care units29. Additionally, the effectiveness and precision of cEEG interpretation may be enhanced by integrating quantitative EEG (qEEG) technologies, which help non-specialists detect seizures30,31.

4.9 Future Directions: The Role of remote or tele-EEG

Continuous EEG monitoring in Indian ICUs is of immense potential, especially when technical advances that address existing resource constraints are taken into consideration. However, the term "ambulatory EEG" is classically used in an outpatient setting and usually involves mobile, home-based monitoring for a patient who is not critically ill. In the context of ICUs, it would be more accurate to refer to this as remote or tele-EEG monitoring, which means the real-time evaluation of EEG data from off-site locations32.

This monitors a critical bedridden patient continuously without being confined to one place under the monitoring of a neurophysiologist. These systems enable specialists to monitor patients in various ICUs and contribute to the convenience and efficiency of workflow, meaning that neurological emergencies are addressed as early as possible. Automated seizure detection algorithms add further sensitivity and specificity to the detection of seizures, thereby allowing timely interventions33.

Moreover, remote monitoring has several benefits in resource-scarce environments. It decreases the requirement for specialized on-site personnel and exploits cloud-based platforms, thus expanding access to cEEG services, reducing ICU congestion, and lowering overall healthcare costs. These advances could revolutionize critical care delivery and improve patient outcomes, making cEEG more accessible across India, even in the rural underserved regions.

Conclusion

In conclusion, cEEG monitoring has the potential to revolutionize the way critically ill patients are managed in Indian ICUs, especially those who are at high risk for NCS and other neurological abnormalities. Where resource constraints and a shortage of trained personnel remain significant barriers, remote ICU EEG monitoring systems offer the promise of an alternative. These systems facilitate the remote, real-time evaluation of EEG data by reducing the continuous on-site expertise needed, thereby improving seizure detection efficacy and accuracy.

With continued progress in technological breakthroughs, for example, through automated seizure detection algorithms and the use of cloud-based platforms, along with increased awareness of the utility of cEEG, its more wide-scale use has the potential for better patient outcomes, optimizing resource utilization and increasing access to critical care within both urban and rural health contexts.

Declarations of interest

None.

Acknowledgement

Nil.

Funding

Nil.

Conflict of interest

The authors declare no conflict of interest regarding the publication of this manuscript. All authors have contributed significantly to the study and approved the final version for submission

References

1. Ney JP, van der Goes DN, Nuwer MR, Nelson L, Eccher MA. Continuous and routine EEG in intensive care: utilization and outcomes, United States 2005-2009. Neurology. 2013;81(23):2002-2008. doi:10.1212/01.wnl.0000436948.93399.2a
2. Bitar R, Khan UM, Rosenthal ES. Utility and rationale for continuous EEG monitoring: a primer for the general intensivist. Crit Care Lond Engl. 2024;28(1):244. doi:10.1186/s13054-024-04986-0
3. Önder H, Temoçin F. Periodic Discharges in Herpes Encephalitis Presenting with Non-convulsive Status Epilepticus: A Detailed Demonstration of the Temporal Correlation Between EEG and Neurologic Status. Turk J Neurol. 2020;25(4):253-257. doi:10.4274/tnd.2019.38455
4. Friedman D, Claassen J, Hirsch LJ. Continuous electroencephalogram monitoring in the intensive care unit. Anesth Analg. 2009;109(2):506-523. doi:10.1213/ane.0b013e3181a9d8b5
5. Koffman L, Rincon F, Gomes J, et al. Continuous Electroencephalographic Monitoring in the Intensive Care Unit: A Cross-Sectional Study. J Intensive Care Med. 2020;35(11):1235-1240. doi:10.1177/0885066619849889
6. Gavvala J, Abend N, LaRoche S, et al. Continuous EEG monitoring: a survey of neurophysiologists and neurointensivists. Epilepsia. 2014;55(11):1864-1871. doi:10.1111/epi.12809
7. Hilkman DMW, van Mook WNKA, Mess WH, van Kranen-Mastenbroek VHJM. The Use of Continuous EEG Monitoring in Intensive Care Units in The Netherlands: A National Survey. Neurocrit Care. 2018;29(2):195-202. doi:10.1007/s12028-018-0525-9
8. Leitinger M, Beniczky S, Rohracher A, et al. Salzburg Consensus Criteria for Non-Convulsive Status Epilepticus--approach to clinical application. Epilepsy Behav EB. 2015;49:158-163. doi:10.1016/j.yebeh.2015.05.007
9. Karki B, Shrestha PS, Shrestha N, Shilpakar O, Acharya SP, Neupane A. Prevalence of non-convulsive seizures

and electroencephalographic abnormalities in critically ill patients-A retrospective observational study. Epilepsia Open. 2024;9(1):325-332. doi:10.1002/epi4.12876
10. Patil A, Vooturi S, Jayalakshmi S. Continuous EEG Monitoring in Intensive Care Unit. Int J Epilepsy. 2019;05:62-67. doi:10.1055/s-0039-1693079
11. Tripathi M, Parihar J. Non-Convulsive Status Epilepticus in Critically Ill Patients. Neurol India. 2021;69(2):360. doi:10.4103/0028-3886.314548
12. Haranath SP, Ganapathy K, Kesavarapu SR, Kuragayala SD. eNeuroIntensive Care in India: The Need of the Hour. Neurol India. 2021;69(2):245. doi:10.4103/0028-3886.314591
13. Gaspard N. ACNS Critical Care EEG Terminology: Value, Limitations, and Perspectives. J Clin Neurophysiol Off Publ Am Electroencephalogr Soc. 2015;32(6):452-455. doi:10.1097/WNP.0000000000000228
14. Schramm P, Luczak J, Engelhard K, El Shazly J, Juenemann M, Tschernatsch M. Continuous electroencephalography in a mixed non-neurological intensive care population, an observational study. J Crit Care. 2017;39:62-65. doi:10.1016/j.jcrc.2017.01.015
15. White DM, Van Cott AC. EEG artifacts in the intensive care unit setting. Am J Electroneurodiagnostic Technol. 2010;50(1):8-25. doi:10.1080/1086508x.2010.11079750
16. Hirsch LJ, Fong MWK, Leitinger M, et al. American Clinical Neurophysiology Society's Standardized Critical Care EEG Terminology: 2021 Version. J Clin Neurophysiol Off Publ Am Electroencephalogr Soc. 2021;38(1):1-29. doi:10.1097/WNP.0000000000000806
17. Alghamdi W, Hazazi A, Alabdulqader R, et al. Continuous Electroencephalographic Monitoring in Adult ICU Challenges and Potential Solutions: A Scoping Review. SVOA Neurol. 2024;5(5):183-192. doi:10.58624/SVOANE.2024.05.0149
18. Mirsattari SM, Lee DH, Jones D, Bihari F, Ives JR. MRI compatible EEG electrode system for routine use in the epilepsy monitoring unit and intensive care unit. Clin Neurophysiol Off J Int Fed Clin Neurophysiol. 2004;115(9):2175-2180. doi:10.1016/j.clinph.2004.04.011
19. Anadure RK, Goel J, Saxena R, Gupta S, Vidhale T. A study on the clinical and electrographic profile of Nonconvulsive Status Epilepticus (NCSE) in comatose ICU patients using portable electroencephalography (EEG). Med J Armed Forces India. 2023;79(3):292-299. doi:10.1016/j.mjafi.2021.06.027
20. Amerineni R, Sun H, Lee H, et al. Using electronic health data to explore effectiveness of ICU EEG and anti-seizure treatment. Ann Clin Transl Neurol. 2021;8(12):2270-2279. doi:10.1002/acn3.51478
21. Sethi NK, Rapaport BS, Solomon GE. An audit of continuous EEG monitoring in the neurological-neurosurgical intensive care unit. J Clin Neurophysiol Off Publ Am Electroencephalogr Soc. 2014;31(5):416-417. doi:10.1097/WNP.0000000000000072
22. Sewell L, Abbas A, Kane N. Introduction to interpretation of the EEG in intensive care. BJA Educ. 2019;19(3):74-82. doi:10.1016/j.bjae.2018.11.002
23. Verma A, Sachin, Mishra A, Kumar A. A Comprehensive Review of EEG Education for Nurses: Addressing Knowledge Gaps and Exploring Future Opportunities. Int J Nurs Midwifery Res E-ISSN 2455-9318. 2024;11(1):21-28.
24. Herman ST, Abend NS, Bleck TP, et al. Consensus statement on continuous EEG in critically ill adults and children, part II: personnel, technical specifications, and clinical practice. J Clin Neurophysiol Off Publ Am Electroencephalogr Soc. 2015;32(2):96-108. doi:10.1097/WNP.0000000000000165
25. Gupta N, Baang HY, Barrett W, et al. Reducing seizure to needle times in nonconvulsive status epilepticus with multifaceted quality improvement initiatives. Epilepsy Res. 2023;190:107085. doi:10.1016/j.eplepsyres.2023.107085
26. Authors, Madakadze C, McGill SC. Artificial Intelligence–Enhanced Rapid Response Electroencephalography for the Identification of Nonconvulsive Seizure: CADTH Horizon Scan. Canadian Agency for Drugs and Technologies in Health; 2023. Accessed December 14, 2024. http://www.ncbi.nlm.nih.gov/books/NBK599853/
27. Egawa S, Hifumi T, Nakamoto H, Kuroda Y, Kubota Y. Diagnostic Reliability of Headset-Type Continuous Video EEG Monitoring for Detection of ICU Patterns and NCSE in Patients with Altered Mental Status with Unknown Etiology. Neurocrit Care. 2020;32(1):217-225. doi:10.1007/s12028-019-00863-9
28. Pan Y, Laohathai C, Weber DJ. The effectiveness of neurology resident EEG training for seizure recognition in critically ill patients. Epilepsy Behav Rep. 2021;15:100408. doi:10.1016/j.ebr.2020.100408
29. ABRET Neurodiagnostic Credentialing and Accreditation. Neurodiagnostic J. 2024;64(4):260-265. doi:10.1080/21646821.2024.2415858
30. Benedetti GM, Guerriero RM, Press CA. Review of Noninvasive Neuromonitoring Modalities in Children II: EEG, qEEG. Neurocrit Care. 2023;39(3):618-638. doi:10.1007/s12028-023-01686-5
31. Haider HA, Esteller R, Hahn CD, et al. Sensitivity of quantitative EEG for seizure identification in the intensive care unit. Neurology. 2016;87(9):935-944. doi:10.1212/WNL.0000000000003034
32. Murphey DK, Anderson ER. The Past, Present, and Future of Tele-EEG. Semin Neurol. 2022;42(1):31-38. doi:10.1055/s-0041-1742242
33. Limotai C, Jirasakuldej S, Wongwiangiunt S, et al. Efficacy of delivery of care with Tele-continuous EEG in critically ill patients: a multicenter randomized controlled trial (Tele-cRCT study) study. Crit Care Lond Engl. 2025;29(1):15. doi:10.1186/s13054-024-05246-x