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Review Article

Continuous Electroencephalographic Monitoring in Adult ICU Challenges and Potential Solutions: A Scoping Review

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Abstract

Background: Continuous electroencephalographic (cEEG) monitoring is continuous monitoring of brain activity that is often used in the intensive care unit (ICU). Recently, the usage of cEEG has grown in many institutions as it detects non-convulsive seizures better than routine EEG (rEEG). However, due to the aggressive environment of ICU, the application and the prolonged recording is challenging. The objectives of this scoping review are to evaluate the common challenges faced during cEEG in adult ICU and proper solutions for optimal implementation.

Methods: A scoping review was conducted using Arksey and O'Malley framework. The included articles contain "continuous EEG in ICU settings" in their titles, written in English, and published between 2010 and 2022. That was by searching the databases: PubMed, Google Scholar, and Summon.

Results: 14 articles were included as they meet the criteria of this review. (28.57 %) of the included studies mentioned the challenges regarding staff, (42.85 %) addressed the challenges of electrode application and the alternative techniques in ICU, and (42.85%) discussed the difficulties in interpretation and duration of the recording.

Conclusion: Continuous EEG is increasingly recognized as valuable mean of monitoring cerebral function, but it is faced with numerous challenges: the difficult environment of ICU and the type of critical patient admitted requiring the optimal electrode application and maintenance, minimizing artifacts and adequate duration of recording to detect abnormalities, and sufficiently trained personnel including ICU staff, technologist and neurophysiologist to provide the optimal patient care as it is the main goal.

***Keywords:** Continuous EEG, Challenges, ICU Settings, Solutions*

1. Introduction

Continuous electroencephalographic (cEEG) is the uninterrupted assessment of cortical activity used in intensive care unit (ICU). CEEG detects seizure activity and non-convulsive status epilepticus more efficiently than routine EEG (rEEG; 20 minutes) and is gaining increasing popularity (Swisher et al., 2015; Caricato et al., 2020).

CEEG is most commonly used to detect non-convulsive seizures (NCS) and non-convulsive status epilepticus (NCSE) in critically ill patients presenting with persistently abnormal mental status after generalized convulsive status epilepticus (GCSE), as it has been reported that 48 percent of cases with NCS and 14 percent of cases with NCSE were recorded during 24 hours of cEEG after GCSE. (DeLorenzo et al., 1998).

Acute brain injuries with altered mental status, such as traumatic brain injury (TBI), subarachnoid hemorrhage (SAH), and intracerebral hemorrhage (ICH) are also significant indications. (Claassen et al., 2004). Also, in unexplained coma or alteration of mental status without known acute brain injury 8-10% were reported to have NCS without prior clinical seizures (Herman et al., 2015).

In addition to NCS and NCSE, cEEG has been utilized to detect seizures in many neurological, medical, and surgical conditions, including CNS infections 10-33%, recent neurosurgical procedures 23%, brain tumors 23-37%, acute is chemic stroke 6-27% and hypoxia ischemic injuries 59% (Herman et al., 2015). CEEG is used as well for the assessment of clinical behavior with simultaneous video recording to determine whether a clinical behavior is correlated to electrographic seizures. Nevertheless, cEEG can be used to rule out seizures in critically ill patients who have abnormal movements or other clinical episodes that happen on a regular basis, raising the possibility of over-investigation and the administration of completely unnecessary anti-seizure medicines.

Approximately 30% of institutions conduct 11-20 cEEG studies per month, 30% perform 21-40 per month, and nearly 25% undertake >40 per month. In comparison to the previous year, 43% of institutions reported an increase in the number of cEEGs performed in a month. When cEEG is needed, 82% said they almost always use it. (Hilkman et al., 2018). However, cEEG is highly prone to artifacts, especially in the ICU hostile environment which makes recording and interpretation more challenging (Gavvala et al., 2014).

It is now clear that cEEG surpasses routine video EEG (20-30 min) in detecting seizures. (Claassen et al., 2004) reported that the seizures rate increases up to 95% after 48 hours of recording, whereas routine video-EEG seizures detection rate is 50% after 1 hour of recording and does not capture a large proportion of non-convulsive seizures. For this reason, cEEG is becoming expansively employed in ICUs.

For optimal utilization of cEEG and to decrease incidents of false positive and false negative seizures detection, several technical aspects must be considered for obtaining accurate interpretation of recordings. These include minimal electrodes requirements, adequate number of trained cEEG personnel available 24/7, and the interpretation of massive data. The present study aims to address the most common challenges that interfere with efficient recordings of cEEG in adult ICU settings by searching the literature to bring forward alternative strategies based on the current evidence to improve the outcomes and shorten ICU and hospital length of stay.

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2. Methods

This scoping review is conducted to map the common difficulties in performing cEEG in ICU settings and state the available solution. The approach of this research follows the Arksey and O'Malley (2005) framework, which involves the following five steps: identifying the research questions, identifying relevant studies, selecting the studies, charting the data, and summarizing and reporting results.

Stage 1: Identifying the Research Questions:

The question that guided this review is "what are the common challenges in performing continuous EEG (cEEG) in adult ICU settings and how to overcome them?"

Stage 2: Identifying Relevant Studies

The articles were selected by using electronic databases which are PubMed, Google Scholar, and Summon that contain 'continuous EEG in ICU settings' in their title, were written in English, and published between 2010 and 2022. After reading the abstract of each article, we determined if it contains any information about challenges faced in cEEG in adult ICU settings. Based on the selected articles, the most common challenges and their best available solutions were identified. All articles included representing critical illness in adult ICU settings undergoing continuous EEG. Excluded articles were non-English, pediatric and neonate populations and unrelated articles that do not answer our question.

Table 1. Key search items.

Condition 1	Condition 2	Condition 3
Search operator **Continuous EEG**	*AND* **ICU settings**	*AND* **Challenges**

Stage 3: study selection

All the researchers did electronic and manual searches by screening titles and abstracts of all articles for eligibility in the following databases: PubMed, Google scholar, and summon. Reviews, meta-analyses, case reports, conference papers, posters, and animal studies were filtered out. Additionally, duplicate articles were removed from each database that was searched with the help of Zotero software. Then each full-text article was reviewed to identify relevant studies based on the inclusion and exclusion criteria (Table 2).

Table 2. Inclusion/Exclusion criteria.

Inclusion criteria	Exclusion criteria
Human research	Animal research
Adult	Paediatrics and neonates
After 2010	Before 2010
English articles	Non-English
Primary sources	Secondary sources (reviews, books…etc)
ICU settings	Non-ICU settings (outpatient department, emergency …etc)
Continues EEG	Routine EEG
Discussed challenges	Not addressing challenges

Stage 4: charting the data

Extracted data table for cEEG in adult ICU settings was developed to summarize the results of studies. Covers the title, authors, year of publication, aim/purpose, study design and the number of participants (If applicable), and key findings related to the study.

Stage 5: Collating and summarizing data

The aim of this scoping review is to address common difficulties in performing cEEG in the adult ICU settings and present alternative techniques found in the literature to improve the recording.

3. Results

3.1 Included studies

After initial searching based on title and key words 540, 33200, and 5805 records were identified from PubMed, Google Scholar, and Summon respectively. Using different filters; year of publication between 2010-2022, human research, English research, primary sources; original/journal article, case studies, and reports. In addition to, searching only by title. 514, 33184, and 5791 records were removed from PubMed, Google Scholar, and Summon respectively. After further screening, 8 related records were found in the references of excluded reviews. The total number of records was 64. With the help of Zotero software, 19 duplicates were removed and the total number of records after duplicate removed was 45. Records were screened to further exclude articles that do not meet the inclusion criteria table1. 31 articles were excluded as they were; secondary resources, articles addressing routine EEG and not cEEG, pediatric/neonate studies, and articles that are not answering research question as they discuss conditions monitored and diagnosed by cEEG in ICU but did not address any challenges with the utilization of cEEG or possible solutions to overcome cEEG difficulties. Eventually, 14 articles were included in this scoping review. (Figure 1) illustrate the details of search process and results.

3.2 Study characteristics

14 studies were found on cEEG challenges in adult ICU, and possible approach for better utilization and difficulties minimization.

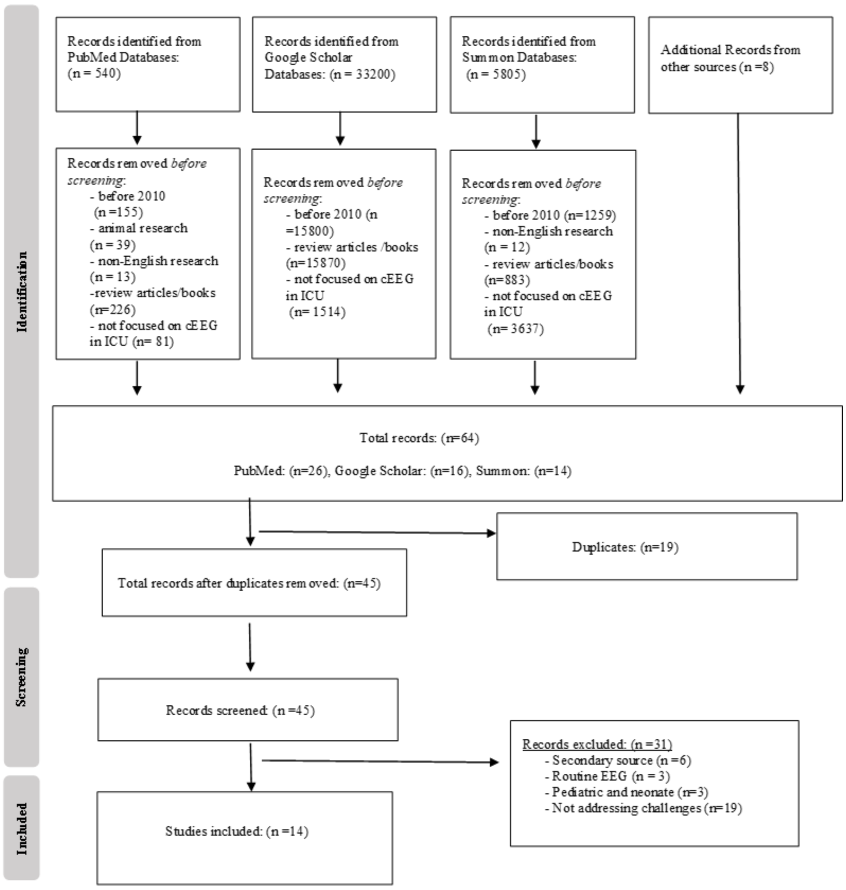

Figure 1: Process Flowchart of Articles Screening

3.3 Findings

Various challenges in cEEG in adult ICU were found after the critical reviewing of the 14 included articles. According to literature, the most common difficulties faced during cEEG in adult ICU were the lack of technical expertise/personnel, electrodes application, record duration and interpretation of massive data.

3.3.1 Technical expertise / personnel challenges

From the included studies there were four studies (28.57 %) addressing challenges related to staff. Koffman et al., (2020) reported a huge gap in the knowledge among intensivists about cEEG, and lack of cEEG sources.

Gavvala et al., (2014) surveyed neurointensivits and neurophysiologists from 97 institutions in United States, which resulted in inadequate EEG technologists available 24/7 and inadequate neurophysiologists. Sethi, Rapaport and Solomon, (2014) examined all cEEG monitoring studies from 2005-2011 in neurological-neurosurgical intensive care unit (NSICU), disclosed that there were deficiencies with EEG services that forced hiring new technicians.

Moreover, Kolls et al., (2014) reported that, behind the limited use of continuous video EEG (cvEEG) is the requirement of high trained certified technologists to apply electrodes, and the high cost of implementation.

3.3.2 Electrode application challenges

Six studies out of 14 (42.85 %) mentioned the most encountered challenges regarding electrode application in ICU settings. Lybeck et al., (2020) mentioned a simplified technique of cEEG electrode application by using four electrodes (F3, P3, F4, P4) with a ground in Fz and a reference in Cz. Herta et al., (2017) investigated the reduced electrodes techniques on pattern detection and sensitivity.

Egawa et al., (2020) introduced a new easy to use technology with rapid initiation known as Headset-type continuous video EEG monitoring (HS-cv EEG) that involves eight electrodes: left temporal, left central, left frontal, O1, right temporal, right central, right frontal, and O2.

Caricato et al., (2020) evaluated the use of simplified system (CerebAir®, Nihon-Kohden) in the ICU that consist of headset 8 wireless electrodes. The study concluded that the use of EEG helmet CerebAir® was easier and faster to position and result in a good quality EEG recording. Schultz, 2012; Kolls et al., (2014) addressed the demand of frequent use of the MRI in the ICU settings and that MRI compatible conductive plastic electrodes are easy to use and improve the quality of care.

3.3.3 Records duration and interpretation challenges

Six articles out of 14 (42.85%) discussed the concern of appropriate duration of recording and facilitation of interpretation. Swisher et al., (2015) suggested that to overcome the massive data, early detection of abnormalities can aid in determining the appropriate duration of recording. Additionally, Tu et al., (2017) highlighted the importance of cEEG experts in the interpretation by inter-reader agreement (IRA) method.

Table 3. Data extraction.

Title	Authors	Year	Aim/purpose	Study design/ number of participants	Key findings related to the study
“Continuous EEG in ICU: Not a Luxury After All”	“Bermeo-Ovalle et al.”	2021	To evaluate if cEEG is linked to lower mortality when compared to regular EEG.	Multi-center study	The importance of cEEG in critically ill adults, leads to increased seizure detection.
“Continuous Electroencephalographic Monitoring in the Intensive Care Unit: A Cross-Sectional Study”	“Lauren Koffman et al.”	2020	Determining the use of cEEG with a sample of ICU physicians.	Cross-sectional study. N=417	There is an evident gap in knowledge among intensivists in the protocols for the cEEG.
“Continuous EEG monitoring by a new simplified wireless headset in intensive care unit”	“Anselmo Caricato et al.”	2020	To evaluate the feasibility of this EEG headset for cEEG monitoring.	Single-center study Study-group =20 Control-group=20	This simplified EEG system could be feasible even if the EEG technician was not present.

Table to be continued..

"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"	"Satoshi Egawa et al."	2020	To examine the accuracy of head-set continuous video EEG monitoring in detecting abnormal EEG patterns.	N=50 patient, prospective observation and retrospective examination.	The use of HS-cv EEG monitoring demonstrated high reliability for the detection of abnormal EEG patterns.
"Bedside interpretation of simplified continuous EEG after cardiac arrest"	"Anna Lybeck1 et al."	2020	This study assesses the ability to interpret a Simplified cEEG recording by ICU physicians.	Observational study.	Using a simplified 4 electrodes montage has shown high sensitivity in detecting seizure activity.
"Comparative sensitivity of quantitative EEG (QEEG) spectrograms for detecting seizure subtypes"	"Ajay Goenka* et al."	2018	To assess the sensitivity of Persyst version 12 QEEG spectrograms in detection.	A retrospective analysis N= 58	According to the findings, Persyst QEEG spectrograms can greatly improve seizure detection sensitivity.
"Reduced electrode arrays for the automated detection of rhythmic and periodic patterns in the effect intensive care unit: Frequently tried, frequently failed?"	"J.Herta et al."	2017	To investigate the effect of systematic electrode reduction from a common 10-20 EEG.	Prospective multi-center study	Overall high to moderate sensitivity and specificity in detecting EEG patterns.
"Diagnostic accuracy between readers for identifying electrographic seizures in critically ill adults"	"Bin Tu et al."	2017	Determination of the annotation of electrographic seizure.	Single-center study N=50	The use of human experts in detecting seizures in ICU is moderately sensitive but highly specific.
"Sensitivity of quantitative EEG for seizure identification in the intensive care unit"	"Hiba A. Haider et al."	2016	To evaluate the sensitivity of QEEG for electrographic seizure identification in ICU.	Multi-center study	A panel of QEEG trends can be used by experts to shorten EEG review time for seizure identification.
"Baseline EEG Pattern on Continuous ICU EEG Monitoring and Incidence of Seizures"	"Christa B. Swisher et al."	2015	The probability of cEEG of detecting a non-convulsive seizure.	N=243 patients, Retrospective study	CEEG duration of recording determined according to the initial 30 min.
"Continuous EEG monitoring: A survey of neurophysiologists and neuro intensivists"	"Jay Gavvala et al."	2014	The research was carried out in order to recognize the current utilization of cEEG monitoring for adults in the United States.	N=137 Survey study	Technical considerations include insufficient numbers of EEG technologists available 24/7.
"An Audit of Continuous EEG Monitoring in the Neurological – Neurosurgical Intensive Care Unit"	"Nitin K. Sethi et al."	2014	To examine the cEEG monitoring for technical and staffing considerations.	Audit study N=203	CEEG requires repeated connection and disconnection of the patients which rise the burden of services and staffing.
"Integration of EEG Lead Placement Templates into Traditional Technologist-Based Staffing Models Reduces Costs in Continuous Video-EEG Monitoring Service."	"Kolls et al."	2014	To determine the utilization of cvEEG in a 10/20 lead application utilizing a template system.	Decision tree modeling.	A template was introduced for non-technologists such as nursing, respiratory therapists, or nursing assistants for easier application.
"Technical Tips: MRI Compatible EEG Electrodes: Advantages, Disadvantages, and Financial Feasibility in a Clinical Setting"	"Schultz et al."	2012	Evaluation of the advantages and disadvantages of MRI compatibility electrodes.	Survey study N=54	The use of -MRI compatible electrodes in cEEG can improve patient care due to less skin breakdown.

4. Discussions

As it is an expandingly used technology, cEEG comes with several challenges. The most common difficulties faced are inadequate expert personnel, difficulty in electrodes applications, and challenges in the duration and interpretation of cEEG data.

4.1 Technical expertise/personnel challenges

Behind the success of health care departments is the presence of knowledgeable expertise who know their roles and dedicate themselves to the sake of patient care. Unfortunately, one of the major drawbacks in cEEG implementation in ICU is the 24/7 hours availability of expertise and continuous video EEG (cvEEG) which demand a high cost of implementation, as well as knowledge of its protocols and availability (Kolls et al., 2014).

Several more authors addressed this challenge, Koffman et al., (2020) conducted a study showed that there was a lack of understanding of cEEG infrastructure among intensivists as well as the cEEG protocols. Likewise, Sethi et al. (2014) addressed the high requirements for cEEG and the heavy workload on both technologists and neurophysiologists attending of fellow on-call. In a survey conducted in 2012, to evaluate the current practice of cEEG, the lack of personnel including EEG technologists and neurophysiologists was reported in 15%, and 4% of the respondents respectively (Egawa et al. 2020). Moreover, Gavvala et al. (2014), reported limitations in resources acting as a barrier in the implementation of cEEG at most institutions.

A suggested solutions for these challenges include educational effort as it is essential for practitioners to be aware of cEEG indications - especially for non-neuroscience intensivists, ICU teams and residents - and to initiate new cEEG studies between 7 am and 10 pm, to permit review time to be three times a day and more frequently in cases of more active EEG studies (Sethi, 2014). Furthermore, when seizure frequency is greater than six per day, repeated routine EEG every six hours has been observed to potentially match the performance of cEEG in seizure detection. (Bermeo-Ovalle, 2021).

4.2 Electrode application challenges

According to the American Society of Clinical Neurophysiology, standard cEEG recording requires the application of minimum 16 electrodes using the 10–20 International System. However, the ICU settings propose challenges such as head injuries and surgical scars that limit the full electrodes application and frequent electrodes disconnections. Caricato et al., (2020) evaluated the use of a simplified system (CerebAir®, Nihon-Kohden) in the ICU that consists of eight fixed wireless electrodes headset.

Furthermore, Lybeck et al., (2020) conducted a simplified cEEG with only four electrodes (F3, P3, F4, P4) with a reference in Cz, and ground in Fz. Egawa et al., (2020) Headset-type continuous video EEG monitoring has been developed as a novel easy-to-use technique (HS-cv EEG monitoring; AE-120A EEG headset, Nihon Kohden). It has eight electrodes: left frontal, left central, left temporal, O1, right frontal, right central, right temporal, and O2. All these techniques were easier and faster to position compared to standard 10-20 system with a high to moderate reliability in detecting EEG abnormal patterns.

In a further study, Herta et al., (2017) investigated the effectiveness of reducing electrodes number on pattern detection sensitivity and specificity, by reviewing recorded cEEG in four different variations (hairline, vertex, forehead, and behind the ear montages). The result showed high detection sensitivity (84.99 - 93.39%) and specificity (90.05 - 95.6%) in all patterns. Overall, the best result in detecting burst suppression were hairline and vertex montages. While the forehead and behind the ear montages have an advantage in detecting ictal patterns.

Many patients in the ICU require frequent imaging leading to disconnection and reapplication of electrodes. Schultz, (2012) assessed the use of MRI-compatible electrodes which are conductive plastic electrodes with the advantage of reducing the repeated application that could result in skin irritation and breakdown. Kolls et al., (2014) presented the use of a "template" consisting of an elastic imaging compatible cap with color-coded holes that provides a guide for the proper locations of electrodes placement. Correspondingly, both MRI-compatible techniques improve the technologists' productivity, and are easy for non-technologists.

4.3 Records duration and interpretation challenges

The ideal duration of cEEG is not fully standardized in the literature. Swisher et al., (2015) categorized patients based on the initial 30-minute EEG background pattern into a low-risk group and a high-risk group to develop seizures which helps in early detection of seizure based on the baseline EEG pattern rather than unnecessary prolonged recording to reduces the consumption of resources and minimize the huge amount of data.

Asymmetric background generalized periodic discharges (GPDs) with triphasic shape, generalized slowness, and normal background were seen in the low-risk group. Seizures, burst suppression, GPDs, lateralized periodic discharges (LPDs), and focal epileptiform discharges are all symptoms of the high-risk group. The seizures were detected within 48 hours in patients with focal epileptiform discharges, within 72 hours in patients with LPDs, after 72 hours for burst suppression, and after 4 days of recording for GPDs. Furthermore, based on the first hour of EEG recording, Bermeo-Ovalle, (2021) developed the 2HELPS2B model to predict the tendency of subsequent seizures by assigning points to six different variables: (1 point) for bilateral independent parodic discharges, lateralized periodic discharges, lateralized rhythmic delta activity, history of recent seizure, periodic or rhythmic pattern > 2 Hz, sporadic epileptiform discharges, and superimposed rhythmic or sharp activity, and (2 points) for brief rhythmic discharges. a total of 6 points predicts a high risk of seizures up to 95%. Score of >2 or if seizures were previously encountered, extending the recording for at least 24 hours is highly recommended.

Additionally, Lybeck et al.,(2020) presented a 5-ranked order scale, based on the American Clinical Neurophysiology Society standardized EEG terminology, to facilitate interpretation based on 5 categories background assessed by the best 30 minutes of recording and classified into; (1)continuous normal voltage background (>20 μV) with suppressed background <10%, (2) continuous low voltage background (10-20 μV) with suppressed background <10%, (3) discontinuous and suppressed background (< 10 μV, 10%-49%), (4) burst-suppression (< 10 μV, 50%-99%), (5) suppression with extremely low-voltage background (< 10 μV, 100%). Epileptiform discharges assessed by the worst 30 minutes of recording and classified into; (A) absence of discharges or sporadic epileptiform discharges, (B) plenty of discharges equal or more than 0.1 Hz, (C) more than 1Hz discharges appearing continuously indicate status epilepticus, (D) unequivocal electrographic seizure more or equal 10 seconds consummate decisive seizures, (E) unequivocal electrographic status epilepticus constituting more than 50% of the 30-minutes recording.

Tu et al., (2017) suggested inter-reader agreement (IRA) between at least five experts in the interpretation of electrographic seizures.

Quantitative EEG (QEEG) is a mathematically visual representation of raw EEG in a compressed display to minimize massive data. Haider et al., (2016) demonstrated that a panel of QEEG trend can shorten cEEG review time and detect seizures with a reasonable sensitivity and a low false-positive rate when used by expert EEG reviewers. Moreover, Goenka, Boro and Yozawitz, (2018), suggested Persyst Magic Marker package to identify seizure onset, ictal, and postictal period of deferent types of seizure. The study investigated 5 spectrograms: asymmetry relative, Fast Fourier Transform (FFT), Rhythmicity, Amplitude-integrated EEG (aEEG), and seizure detector spectrogram. Different types of seizures can be best detected with different spectrograms, for example, focal seizures are best detected with asymmetry spectrograms, whereas focal with secondary generalized are best detected with FFT spectrogram.

Conclusion

The use and effectiveness of cEEG monitoring in ICU is indeed indisputable for many indications. Yet, its adoption is bounded by the various challenges faced in ICU hostile environment. The most common challenges addressed in current literature are lack of technical expertise/personnel, electrodes maintenance and application, also the challenge of optimal duration of recording and interpretation of massive data. Alternative strategies to improve the current situation were discussed.

A solution to the lack of personnel is repeated standard EEG every six hours that could match the performance of cEEG. Implementing a limited hours for the initiation of new cEEG study will reduce the workload on both technologists and neurophysiologists attending or fellow on call and help with the unavailability of the cEEG service 24/7. Educational efforts about the cEEG protocols, availability and indications are imperative specifically for the ICU team.

The use of MRI compatible conductive plastic electrodes, Headset-type continuous video EEG monitoring and EEG helmet CerebAir® systems. In addition, the categorization of patients based on the initial 30-minute EEG background pattern, the use of 2HELPS2B model to predict the probability of subsequent seizures based on the first hour of EEG recording to find the optimal recording duration and the use of 5-ranked order scale according to the American Clinical Neurophysiology Society standardized EEG terminology to facilitate the interpretation.

Study Limitations

The studies included in this scoping review were only in English and published in 2010-2022. Moreover, only the adult population was investigated, which may result in exclusion of significant findings.

Gap in the Current Studies

There is a lack of studies addressing the challenges of artifacts in cEEG in adult ICU, and there are inadequate studies measuring the effectiveness of the proposed alternative strategies. In addition, until now there is no clear consensus on these challenges of cEEG in adult ICU that implement the addressed solutions.

Future Recommendation

Future studies should be focused on investigating technical aspects of cEEG in ICU and its optimal implementation. Finally, establishing a standard guideline for challenges and their optimal solutions is highly recommended for maximizing patient care.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Bermeo-Ovalle, A. (2021) 'Continuous EEG in ICU: Not a Luxury After All', Epilepsy Currents, 21(1), pp. 21–23. doi: 10.1177/1535759720973987.
2. Caricato, A. et al. (2020) 'Continuous EEG monitoring by a new simplified wireless headset in intensive care unit', BMC Anesthesiology, 20(1), pp. 1–6. doi: 10.1186/s12871-020-01213-5.
3. Claassen, J. et al. (2004) 'Detection of electrographic seizures with continuous EEG monitoring in critically ill patients', Neurology, 62(10), pp. 1743–1748. doi: 10.1212/01.WNL.0000125184.88797.62.
4. DeLorenzo, R. J. et al. (1998) 'Persistent Nonconvulsive Status Epilepticus After the Control of Convulsive Status Epilepticus', Epilepsia, 39(8), pp. 833–840. doi: 10.1111/j.1528-1157.1998.tb01177.x.
5. Egawa, S. et al. (2020) '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', Neurocritical Care, 32(1), pp. 217–225. doi: 10.1007/s12028-019-00863-9.
6. Gavvala, J. et al. (2014) 'Continuous EEG monitoring: A survey of neurophysiologists and neurointensivists', Epilepsia, 55(11), pp. 1864–1871. doi: 10.1111/epi.12809.
7. Goenka, A., Boro, A. and Yozawitz, E. (2018) 'Comparative sensitivity of quantitative EEG (QEEG) spectrograms for detecting seizure subtypes', Seizure, 55, pp. 70–75. doi: 10.1016/j.seizure.2018.01.008.
8. Haider, H. A. et al. (2016) 'Sensitivity of quantitative EEG for seizure identification in the intensive care unit', Neurology, 87(9), pp. 935–944. doi: 10.1212/WNL.0000000000003034.
9. Herman, S. T. et al. (2015) 'Consensus statement on continuous EEG in critically Ill adults and children, part I: Indications', Journal of Clinical Neurophysiology, 32(2), pp. 87–95. doi: 10.1097/WNP.0000000000000166.
10. Herta, J. et al. (2017) 'Reduced electrode arrays for the automated detection of rhythmic and periodic patterns in the intensive care unit: Frequently tried, frequently failed?', Clinical Neurophysiology, 128(8), pp. 1524–1531. doi: 10.1016/j.clinph.2017.04.012.
11. Hilkman, D. M. W. et al. (2018) 'The Use of Continuous EEG Monitoring in Intensive Care Units in The Netherlands: A National Survey', Neurocritical Care, 29(2), pp. 195–202. doi: 10.1007/s12028-018-0525-9.

12. Koffman, L. et al. (2020) 'Continuous Electroencephalographic Monitoring in the Intensive Care Unit: A Cross-Sectional Study', Journal of Intensive Care Medicine, 35(11), pp. 1235–1240. doi: 10.1177/0885066619849889.
13. Kolls, B. J. et al. (2014) 'Integration of EEG Lead Placement Templates Into Traditional Technologist-Based Staffing Models Reduces Costs in Continuous Video-EEG Monitoring Service', Journal of Clinical Neurophysiology, 31(3), pp. 187–193. doi: 10.1097/WNP.0000000000000053.
14. Lybeck, A. et al. (2020) 'Bedside interpretation of simplified continuous EEG after cardiac arrest', Acta Anaesthesiologica Scandinavica, 64(1), pp. 85–92. doi: 10.1111/aas.13466.
15. Schultz, T. L. (2012) 'Technical tips: mri compatible eeg electrodes: Advantages, disadvantages, and financial feasibility in a clinical setting', Neurodiagnostic Journal, 52(1), pp. 69–81. doi: 10.1080/21646821.2012.11079844.
16. Sethi, N. K., Rapaport, B. S. and Solomon, G. E. (2014) 'An audit of continuous EEG monitoring in the neurological-neurosurgical intensive care unit', Journal of Clinical Neurophysiology, 31(5), pp. 416–417. doi: 10.1097/WNP.0000000000000072.
17. Swisher, C. B. et al. (2015) 'Baseline EEG pattern on continuous ICU EEG monitoring and incidence of seizures', Journal of Clinical Neurophysiology, 32(2), pp. 147–151. doi: 10.1097/WNP.0000000000000157.
18. Tu, B. et al. (2017) 'Diagnostic accuracy between readers for identifying electrographic seizures in critically ill adults', Epilepsia Open, 2(1), pp. 67–75. doi: 10.1002/epi4.12034.

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