Citation (APA)
Verboom, M., Drenthen, J., Louter, M., Straver, D. C. G., van der Jagt, M., van de Ruit, M., & van den Berg, R. (2026). Feasibility and agreement of a self-adhesive EEG electrode set versus conventional EEG in postanoxic coma. *Resuscitation*, *223*, Article 111086. https://doi.org/10.1016/j.resuscitation.2026.111086

RESUSCITATION 223 (2026) 111086

Available online at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Original paper

Feasibility and agreement of a self-adhesive EEG electrode set versus conventional EEG in postanoxic coma

Marit Verboom[a], *Judith Drenthen*[a], *Maartje Louter*[a], *Dirk C.G. Straver*[a], *Mathieu van der Jagt*[b], *Mark van de Ruit*[c], *Robert van den Berg*[a,*]

Abstract

Background: Electrode application for EEG prognostication in postanoxic coma patients is labor-intensive. We studied the usability of a self-adhesive forehead EEG electrode (Bittium BrainStatus™) and compared the accuracy of background classification with conventional EEG.

Methods: In 51 postanoxic coma patients, simultaneous monitoring using conventional EEG and a forehead electrode was performed. 5-min EEG fragments were classified according to the ACNS criteria by four experts, based on the conventional montage, the forehead electrode, and a montage based on the standard EEG recording but visualized as the forehead electrode.

Results: Forehead electrode recordings were of sufficient quality in 74.1% of fragments. Agreement was moderate for standard EEG versus the forehead electrode (κ: 0.56), and near perfect for conventional EEG versus conventional EEG visualized as the forehead electrode (κ: 0.85). Due to higher noise levels, detection rates of discontinuous and suppressed patterns were reduced.

Conclusion: EEG forehead electrode recordings were interpretable in a large proportion of cases. If signal quality is insufficient for assessment, additional standard EEG should be performed to allow definitive assessment.

Significance: The use of a self-adhesive forehead electrode set has the potential to substantially reduce EEG technician workload in the ICU and suggests considerable potential benefit as a screening-oriented EEG monitoring strategy in postanoxic coma.

Keywords: EEG electrodes, Postanoxic coma, Prognostication, Feasibility, Workload reduction

Introduction

Continuous electroencephalography (cEEG) monitoring is widely implemented as part of standard practice in post-resuscitation care in many intensive care units (ICU),[1,2] having proven its neuroprognostic value in patients with postanoxic coma.[3,4] In Europe, the annual incidence of out-of-hospital cardiac arrest (OHCA) is estimated at 67–170 per 100.000 inhabitants, whereas in-hospital cardiac arrest (IHCA) occurs in 1.6–2.4 per 1000 hospital admissions.[5] In the Netherlands, where cEEG is embedded in the national guideline 'Prognostication of postanoxic coma', approximately 4500 patients are admitted to the ICU due to a CA each year, and are likely monitored using cEEG.[6]

The application of EEG electrodes is time-consuming and requires well trained EEG technicians. Furthermore, EEG application is often restricted to daytime hours, and the need for technicians to be physically present during weekends is primarily driven by requests for cEEG monitoring in postanoxic coma patients. While this practical limitation does not necessarily hinder EEG monitoring in post-resuscitation care, it does concentrate much of the limited technician workforce on this single indication. Improving the efficiency of EEG monitoring at the ICU could enhance overall cost-effectiveness and increase the scalability of EEG for other clinical indications, like traumatic brain injury, where its use is currently limited.[7–9]

The application time for EEG in postanoxic coma patients can be reduced by using a limited number of EEG electrodes,[10–13] but a

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[*] Corresponding author at: Dr. Molewaterplein 40, 3015GD, Rotterdam, the Netherlands.
E-mail address: r.vandenberg@erasmusmc.nl (R. van den Berg).

https://doi.org/10.1016/j.resuscitation.2026.111086
Received 30 January 2026; Received in Revised form 6 March 2026; Accepted 23 March 2026

trained and experienced technician is required in most centers. In recent years, several systems have been specifically designed to simplify EEG application and reduce setup time. These systems include EEG caps with water- or dry electrodes. However, these alternatives are generally not suitable for prolonged monitoring in the ICU due to limitations in signal stability and durability, as well as patient discomfort. Consequently, other dedicated solutions for continuous EEG monitoring in the ICU have been proposed, but many have not yet been studied in a clinical setting or lack European CE approval.[14–16]

One solution developed for cEEG monitoring in critical care settings with medical CE approval is a self-adhesive forehead electrode set (Bittium BrainStatus™).[17–20] In three studies, performed at the centre where the electrode set was developed, the feasibility of its use in clinical settings (the emergency department, ICU and ambulance) was shown.[21–23] However, to our knowledge there are no published evaluations of the feasibility of this forehead electrode set for EEG background pattern classification for prognostic purposes at the ICU in postanoxic coma.

In this study, we evaluate the feasibility of a self-adhesive forehead electrode set with the intention to reduce cEEG monitoring workload at the ICU in patients with postanoxic coma using two complementary strategies: (1) we describe our experience with the forehead electrode set focusing on ease of use, signal quality, and other practical aspects and (2) we evaluate whether visual EEG background pattern assessment based on the forehead electrode set is comparable to that based on conventional EEG electrodes.

Methods

Patients

In our center, a tertiary care university hospital (Erasmus MC in Rotterdam, the Netherlands), all patients suffering from postanoxic coma are monitored as soon as possible after admission to the ICU using cEEG to guide neurological prognostication. Monitoring continues until at least 24 h after the return of circulation. From March-June 2024, and August-November 2024, we collected a convenience sample of patients if monitoring was initiated during office hours. In these patients, we performed cEEG monitoring using both the conventional EEG set-up as well as a self-adhesive forehead EEG electrode set. A clinical neurophysiologist assessed the EEG based on both the forehead electrode set as well as the conventional EEG set-up in real-time to gain experience with the new electrode set. As part of standard clinical practice, all patients were sedated and treated per Targeted Temperature Management (TTM) at 36 °C during the first 24 h of admission. The Erasmus MC Ethical Review Board approved the retrospective analysis of EEG data (MEC-2021-0145).

EEG monitoring protocol

As a first step, we attached the BrainStatus™ self-adhesive forehead EEG electrode set (further called the “forehead electrode set”) with electrodes Fp1, Fp2, F7, F8, Af7, Af8, Sp1, Sp2, T9, and T10 (Figs. 1A and 2A.1). The forehead electrode set was attached after

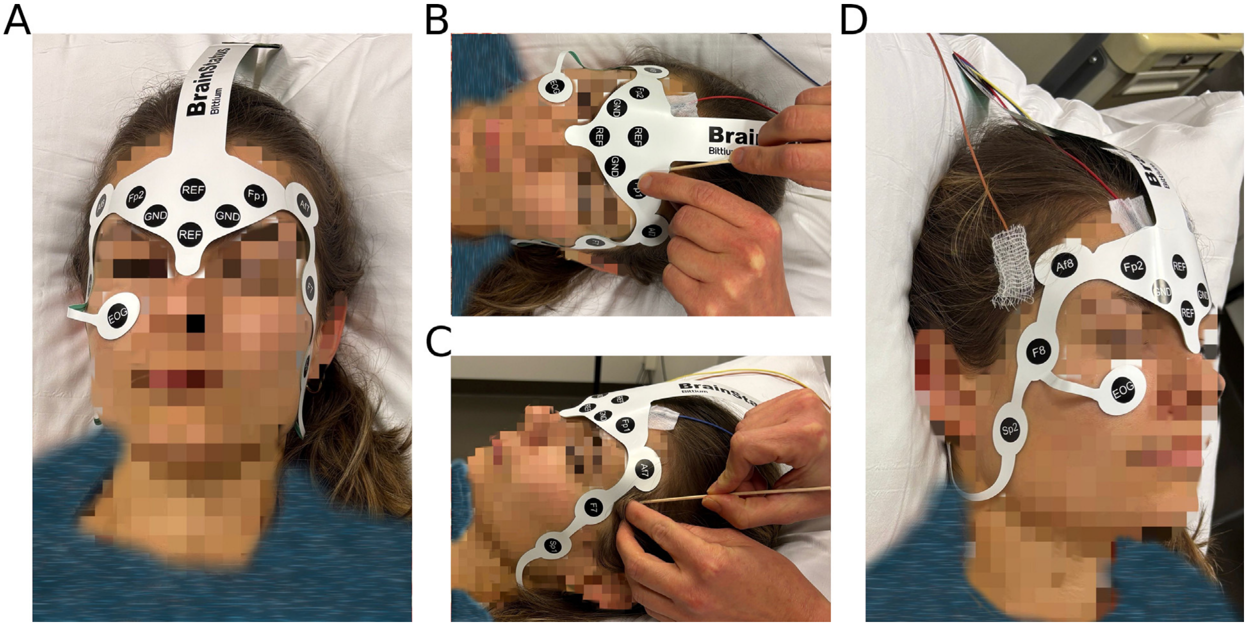


Fig. 1 – Setup of a forehead electrode set and conventional AgCl cup electrodes for simultaneous EEG recording.
Panel A: the forehead electrode set is attached to the skin after preparing with granular skin preparation gel (NuPrep) and cleaning with an antiseptic wipe. Panel B–C: the conventional EEG electrodes are placed according to the international 10–20 system. Panel B: Electrodes Fp1 and Fp2 are placed underneath the plastic connecting the electrodes of the forehead electrode set and therefore are slightly moved compared to the original location according to the 10–20 system. Panel C: the location of conventional EEG electrode F7 and F8 according to the 10–20 system are slightly more cranial and posterior on the scalp than F7 and F8 of the forehead electrode set. Panel D: the monitoring setup of the frontal electrodes after both the forehead electrode set and conventional EEG electrodes are attached.

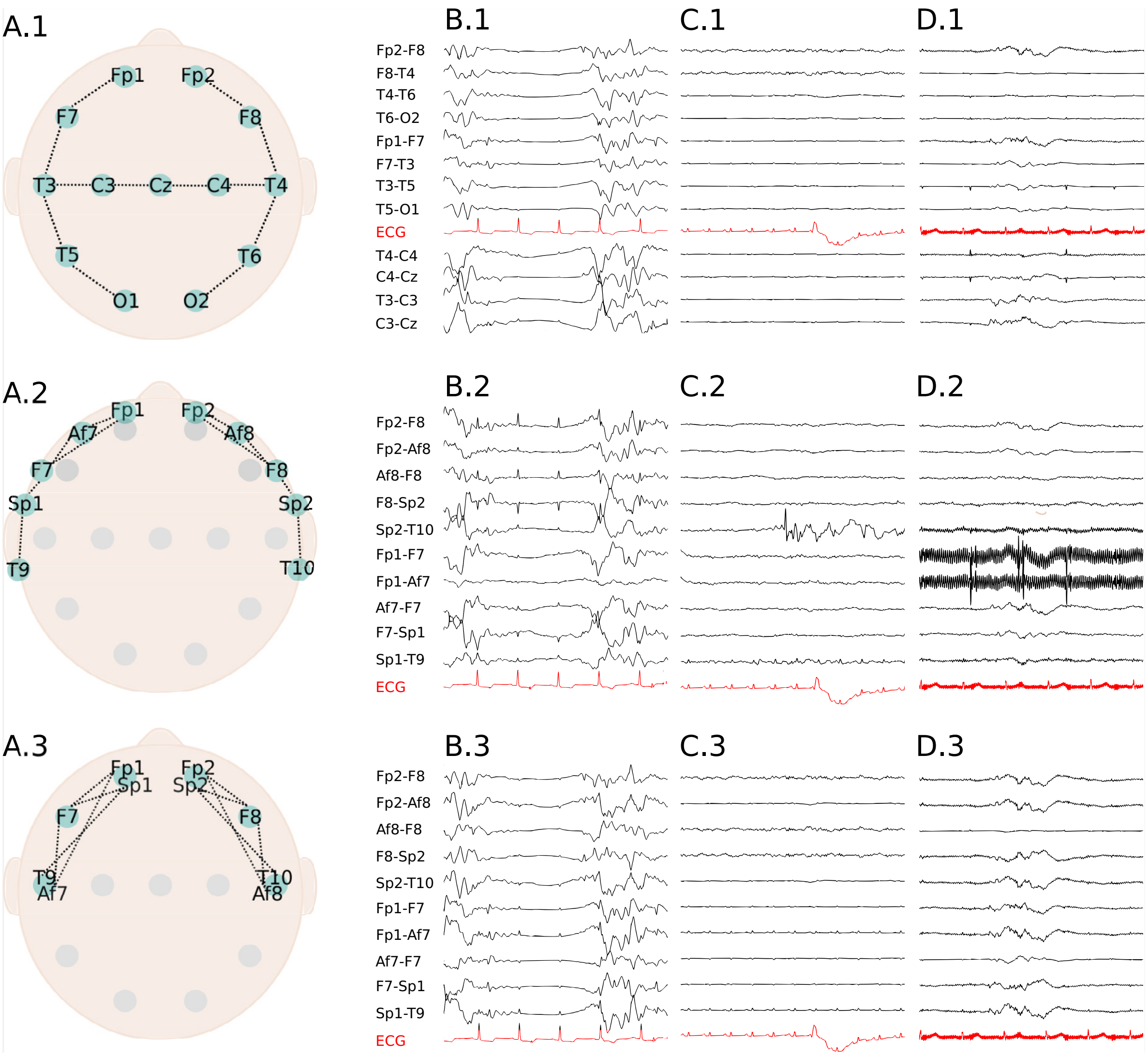


Fig. 2 – Different bipolar montages for visual assessment of EEG background patterns.
Panel A.1: Standard EEG. A bipolar montage based on 13 conventional EEG electrodes as part of standard monitoring protocol in postanoxic coma in our center. Panel A.2: Forehead EEG electrode set. A bipolar montage based on the BrainStatus™ forehead EEG electrode set. Panel A.3: Reduced EEG. A bipolar montage based on 6 conventional EEG electrodes, visualized as the montage of the forehead EEG electrode set. Standard electrode Fp1 was used for Fp1 and Sp1 (and Fp2 for Fp2 and Sp2), and standard T7 for T9 and Af7 (and T8 for T10 and Af8) of the forehead electrode set. In panel B–D, three different EEG fragments are visualized in the three different montages that were used for visual assessment of the EEG background pattern. EEG fragments are all shown at 70 µV. Panel B.1–B.3: The EEG fragment was classified as discontinuous in all three montages. The forehead EEG electrode set in B.2 shows larger ECG artefacts compared to the other montages. Panel C.1 and C.3 were classified as low voltage, while panel C.2 was classified as unable to classify due to artefacts. Panel D.1 and D.3 were classified as burst-suppression with non-identical bursts, and D.2 as unable to classify due to loose electrodes.

cleaning the skin using an antiseptic wipe and efforts were made to keep the impedance below 50 kΩ, as recommended by the user manual. Based on experience gained during the first evaluation period, we started cleaning the forehead using a granular skin preparation gel (NuPrep) followed by an antiseptic wipe during the second evaluation period to reduce electrode impedance further.

After applying the forehead electrode set, thirteen conventional AgCl cup electrodes were placed according to the international 10–20 system (Fp1, Fp2, F7, F8, T3, T4, T5, T6, O1, O2, C3, C4, Cz) as per local protocol. Efforts were made to maintain electrode impedance below 5kΩ. Electrode Fp1 and Fp2 were placed underneath the plastic connecting the electrodes of the forehead electrode set, without moving and/or detaching this system (Fig. 1B, C). Therefore, the exact locations of these two electrodes were slightly different from the 10–20 system (Figs. 1D and 2A.2–A.3).

cEEG monitoring with both electrode types was simultaneously performed using the OSG BrainRT system (Rumst, Belgium) with a sample frequency of 256 Hz and simultaneous video recording. The forehead electrode set was attached to the system via a shielded BrainStatus™ adapter cable. Data was recorded using Cz as a recording reference, a separate ground electrode, and an analog high-pass filter at 0.1 Hz. EEG recordings were initiated as soon as possible after admission to the ICU and continued for a minimum of 24 h after CA, or until the patient regained consciousness.

Practical considerations

During the first ten measurements, a researcher (MV) accompanied the EEG technician to the ICU to observe the usability of the self-adhesive forehead electrode set and to time the duration of the application of the standard EEG versus the forehead electrode set. During the second evaluation period, EEG technicians were instructed to report the occurrence of any abnormalities during electrode application and measurement setup to the research team. Furthermore, the reviewers of the EEG recordings (usually a clinical neurophysiologist and/or a neurologist in training) were asked to report their experience with the assessment of the EEG signals recorded using the forehead electrode set.

Visual assessment of EEG background pattern

In a retrospective analysis, four clinical neurophysiologists (JD, ML, DS, RvdB) independently classified the background pattern of all EEG fragments according to the American Clinical Neurophysiology Society (ACNS) Critical Care Criteria (version 2021)[24] into 9 categories (Table 1). During EEG recording, clinical neurophysiologists responsible for the clinical evaluation of the EEG were asked to annotate changing background patterns in the conventional EEG recordings. Using these annotations, we selected 5-min EEG fragments for assessment. If during continuous EEG monitoring of one patient more than one distinctive background pattern occurred, multiple EEG fragments of that patient were included for the retrospective analysis to increase the amount of- and the variation in the data. Visual assessment was performed based on three different montages (Fig. 2): (1) A bipolar montage based on the conventional EEG electrodes (further called “standard EEG”); (2) A bipolar montage based on the forehead BrainStatus™ electrode set, (“forehead electrode set”) and (3) a bipolar montage based on the conventional EEG electrodes, but limited to the frontal channels renamed to resemble the forehead electrode set (further called “reduced EEG”). Before visual analysis, the EEG fragments were bandpass filtered between 0.5 and 30 Hz (4th order infinite impulse response filter), and additionally, a 50 Hz notch-filter was applied to reduce line noise. Reviewers were able to change the scaling of the EEG fragments, but were unable to apply any additional filtering. Reviewers were blinded to the montage and without access to the initial annotations made during clinical evaluation to reduce bias. Additionally, EEG fragments were shown in random order and montage. If less than three out of four neurophysiologists agreed on the background pattern, EEG fragments were again classified during a consensus meeting with all reviewers.

Prognostication

The European Resuscitation Council Guidelines 2025 Post-Resuscitation Care recommend to perform EEG from day 1 after ROSC for prognostic purposes.[25] Accordingly, based on the background pattern classifications, we categorized the EEG fragments into prognostic categories as if the EEG fragments were recorded 24 h after cardiac arrest. In accordance with the ERC guideline, a suppressed background pattern with or without periodic discharges and burst-suppression patterns were labelled as indicators of a poor prognosis. All other patterns (continuous normal voltage, discontinuous, GPDs on a non-suppressed background) were assigned to the uncertain prognosis category. We evaluated whether fragments were assigned to a different prognostic category when using the forehead electrode set, compared with the standard EEG montage and/or the reduced EEG montage. At the time of recording, the standard EEG was used for prognostication.

Table 1 – Definitions of EEG background pattern categories used for visual classification of EEG fragments.

EEG background pattern	Definition
Continuous normal voltage	Continuous background pattern with amplitudes ≥20 µV for more than 90% of the EEG epoch
Low voltage	Background pattern with amplitudes 10–20 µV for more than 90% of the EEG epoch
Discontinuous	Cerebral activity during 50–90% of the EEG epoch, mixed with periods of suppression (≤10 µV)
Burst-suppression with non-identical bursts	A burst-suppression pattern with suppressions (≤10 µV) during ≥50% of the recording
Burst-suppression with identical bursts	A burst-suppression pattern in which all bursts demonstrate highly stereotyped morphology, with the first 500 ms of each burst appearing visually identical to the other bursts.
GPDs on a continuous background	Repetitive waveforms with a uniform morphology at nearly regular intervals, with each waveform lasting for ≤0.5 s or having ≤3 phases, with continuous background activity
GPDs on a suppressed background	Repetitive waveforms with a uniform morphology at nearly regular intervals, with each waveform lasting for ≤0.5 s or having ≤3 phases, with suppressed (<10 µV) background activity
Suppressed background	A suppressed background pattern during >99% of the entire EEG epoch
Unable to classify	Unable to classify due to artefacts (loose electrodes, movement, etc.) or because no consensus between raters could be reached.

Abbreviations: EEG = Electroencephalography. GPDs = Generalized Periodic Discharges.

Based on Critical Care Criteria of the American Clinical Neurophysiology Society (version 2021).[24]

Statistical analysis

To compare application time between the conventional EEG electrodes and the self-adhesive forehead electrode set, a paired *t*-test was used. Additionally, the McNemar test was used to assess differences in the proportion of EEG fragments deemed unclassifiable due to artefacts between the different montages. To compare EEG background pattern classification and prognostic categories across different electrode montages, we used different strategies. We computed the pairwise interrater agreement using Cohen's kappa score per montage (standard EEG, forehead electrode set, reduced EEG). Thereafter, we computed pairwise intermethod agreement between the different montages based on the consensus classifications of background patterns. Finally, we calculated the intermethod agreement after removal of EEG fragments that were unclassified due to artefacts.

Results

Practical evaluation

During the evaluation period, 51 patients were monitored using both standard EEG and the forehead electrode set. EEG technicians needed a brief training session (5–10 min), together with the basic application instructions provided on the package, to correctly position and attach the self-adhesive forehead electrode set according to the manufacturer's guidelines and initiate the recording. During the first 10 measurements, for which application time was recorded, the average time of application of the forehead electrode set was significantly shorter than that of standard EEG electrode application (5.1 versus 34.4 min (paired *t*-test, $p < 0.001$)) (Supplementary Materials A, Table S1). EEG technicians were generally positive about the user-friendliness of the forehead electrode set. However, several recurring points of feedback emerged.

First, the electrodes did not adhere properly when patients had facial hair (particularly affecting the Sp1 and Sp2 electrodes) or a low hairline (most electrodes were affected). Second, during the first few recordings, technicians had difficulty maintaining the electrode impedance low. Applying additional pressure and later additional skin preparation of the skin with granular gel helped address this. Third, an unexpected artefact at approximately 24 Hz was observed in some recordings of the forehead electrode set, which was less prominent in the standard EEG recording. This artefact was later traced back to the cooling mats that were used to regulate temperature during TTM. A final, less frequently encountered issue was that applying the forehead electrode set proved more challenging than the conventional electrodes in patients receiving mechanical ventilation in prone position. The forehead electrode set required lifting the patient's head during application, which often required the help of the ICU nurse or an additional EEG technician.

Visual classification of background pattern

Of the 51 patients monitored using both standard EEG and the forehead electrode set, 139 unique EEG fragments per montage (417 fragments in total) were included for visual analysis of background patterns. Examples of different fragments visualized in the three montages (standard EEG, forehead electrode set, reduced EEG) are shown in Fig. 2 and Supplementary Materials B. The average interrater agreement was substantial for the standard EEG montage (κ: 0.66, range 0.62–0.70), moderate for the forehead electrode set (κ: 0.58, range 0.51–0.73), and substantial for the reduced EEG montage (κ: 0.69, range 0.62–0.73). For 311 of 417 (74.6%) EEG fragments, $\geq$3 raters reached consensus based on the initial classification. For the remaining 106 fragments, consensus was reached during a meeting with all four reviewers. Three fragments were labelled as 'unable to classify', because consensus could not be reached. Further results are reported based on the consensus classification per EEG fragment.

For the 139 standard EEG and reduced EEG fragments of 51 patients, 13 EEG fragments (9.4%) from 7 (14.3%) and 8 (15.7%) unique patients, respectively, were unable to classify due to excessive artefacts. This was significantly higher for the forehead electrode set, with 36 fragments (25.9%) (standard EEG versus forehead electrode set: 13 vs. 36 fragments; $p < 0.001$, McNemar's test) from 20 unique patients (39.2%) (standard EEG versus forehead electrode set: 7 vs. 20 patients; $p < 0.001$, McNemar's test) deemed of insufficient quality to classify. Overall, the quality of the forehead electrode set was sufficient for background pattern classification after cardiac arrest in 103/139 (74.1%) of the EEG fragments. At least one EEG fragment of sufficient quality was available for 49 (96.1%) patients using standard EEG, 46 (90.2%) using the forehead electrode set, and 48 (94.1%) using the reduced EEG montage (overview of classifiable fragments per patient shown in Supplementary Fig. S1).

Comparison of EEG electrodes and montages

The intermethod agreement between standard EEG and the forehead electrode set was moderate (κ: 0.408), and that of standard EEG versus reduced EEG was substantial (κ: 0.788) (Table 2). After removal of all fragments that were labelled as 'unable to classify' in any of the montages, the intermethod agreement was still moderate for standard EEG versus the forehead electrode set (κ: 0.559), and near perfect for the standard EEG versus reduced EEG (κ: 0.850) (Table 2).

As shown in Fig. 3B, background pattern classification differed between standard EEG and the forehead electrode set. Recordings obtained with the forehead electrode set were more frequently classified as continuous normal voltage. EEG fragments were never classified as suppressed based on the forehead electrode set. Instead, fragments classified as such in the standard EEG montage were more frequently labeled as low voltage when using the forehead electrode set. Additionally, a shift from discontinuous to more continuous background patterns was observed between standard EEG and the forehead electrode set. Furthermore, burst-suppression patterns were often classified as 'unable to classify' based on the forehead electrode set. Similar patterns were observed when comparing the forehead electrode set with the reduced EEG montage (Fig. 3A). When comparing the classifications of the standard EEG with those of the reduced EEG, some shifts from continuous to discontinuous and vice-versa was observed (Fig. 3C). Almost all other background patterns were classified the same between the standard- and reduced EEG montages.

Prognostic categories

Fig. 4 and Table 2 show the agreement on prognostic categories after cardiac arrest of all EEG fragments based on the three different montages according to the ERC 2025 Post-Resuscitation Care guidelines.[25] Assuming that all fragments were recorded after 24 h from ROSC, differences in background pattern classification between the standard EEG and the forehead electrode set would have resulted in different prognostication in a subset of EEG

Table 2 – Background pattern classification and prognostic category agreement. Accuracy and agreements between the classification of EEG background pattern based on three different montages: standard EEG, a forehead EEG electrode set, and a reduced EEG montage visualized as the forehead EEG electrode set. Accuracy was calculated with the first montage described as the ground truth. Both accuracy and Cohen's kappa were calculated for all classified EEG fragments and for all fragments that were not labelled as unable to classify.

Comparison	Accuracy		Cohen's kappa	
	All fragments	Able to classify	All fragments	Able to classify
Background pattern classification				
Standard EEG vs. forehead electrode set	0.532	0.691	0.408	0.559
Standard EEG vs. reduced EEG	0.827	0.887	0.788	0.850
Reduced EEG vs. forehead electrode set	0.554	0.670	0.441	0.543
Prognostic category at 24 h after CA				
Standard EEG vs. forehead electrode set	0.647	0.856	0.297	0.439
Standard EEG vs. reduced EEG	0.892	0.959	0.779	0.878
Reduced EEG vs. forehead electrode set	0.691	0.856	0.383	0.439

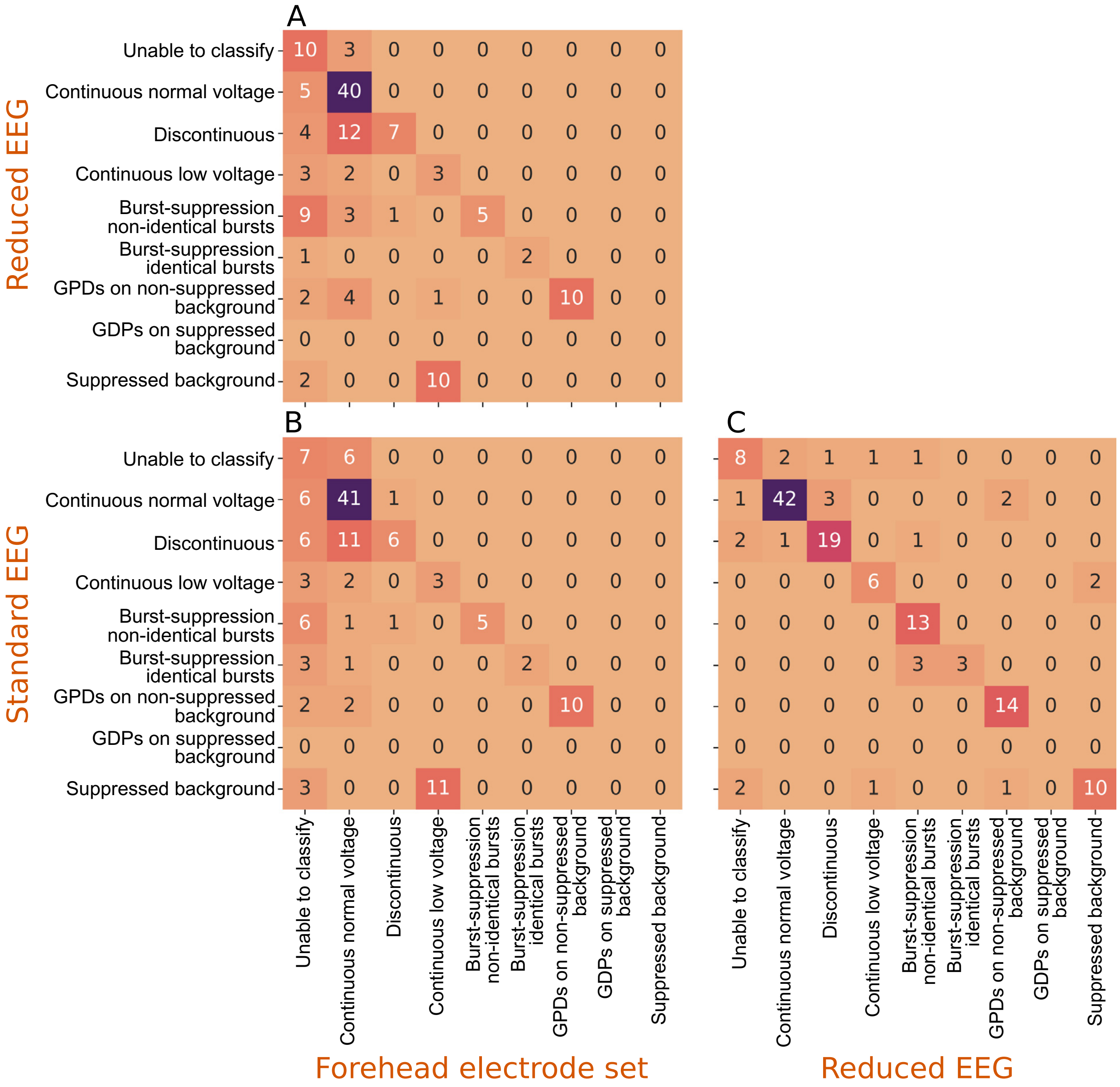
fragments (Fig. 4). Based on the forehead electrode set, no fragments would indicate a poor prognosis when this was not the case based on standard EEG (Fig. 4A). However, in 14 (10.1%) EEG fragments, an uncertain prognosis would have been assigned based on the forehead electrode set, whereas these would have been classified as indicating a poor prognosis based on the standard EEG. These fragments were either unable to be classified, or classified as a continuous normal voltage on the forehead electrode set, while these fragments were classified as burst-suppression or suppressed background on the standard EEG montage.

Discussion

In this study, we evaluated the feasibility of a self-adhesive forehead electrode set for cEEG monitoring in patients with postanoxic coma admitted to the ICU. To address this, we assessed both the practical usability of the forehead electrode set and its performance in EEG background pattern classification for prognostic purposes, comparing EEG results directly with those obtained with conventional EEG cup electrodes during simultaneous recordings. Overall, the forehead electrode set was well received by EEG technicians and was perceived to significantly reduce their workload. However, technical issues hamper its current use as a full replacement of conventional EEG electrodes for prognostic purposes in patients with postanoxic coma after cardiac arrest. Further research is necessary, based on this feasibility study, to address selection of patients where the forehead electrodes could reliably replace conventional EEG and in other settings to address external validity, before widespread implementation. Although there were more EEG fragments that could not be classified based on the forehead electrode set compared to standard EEG, the majority of recordings could be classified according to the ACNS criteria, and the agreement between the standard EEG and forehead electrode set was moderate. The observed differences in background pattern classification suggest differences in signal-to-noise ratio between the two systems. The higher apparent noise level in the forehead electrode set may hinder reliable assessment of EEG suppression, as the presence or absence of residual cerebral activity cannot be determined. Agreement was higher for standard versus reduced EEG than for standard EEG versus the forehead electrode set, suggesting that the observed differences between standard EEG and the forehead electrode set are more likely related to signal acquisition rather than to the reduced number of channels or the use of a frontal electrode montage. The agreement between standard EEG and the reduced EEG supports the feasibility of cEEG monitoring using a limited number of frontotemporal electrodes, as previously shown by 11). Although we did not formally test the effect of applying a reduced set of electrodes, but generated our reduced EEG montage by removing channels post-procedurally, this finding supports the use of a reduced set of standard EEG electrodes for monitoring after cardiac arrest. Few differences in classifications between standard EEG and reduced EEG were observed, mainly between continuous and discontinuous background patterns and between burst-suppression with identical- versus non-identical bursts.

Study strengths

A major strength of this study is the simultaneous acquisition of EEG recordings in the ICU with standard EEG electrodes according to the international 10–20 system and a forehead electrode set, allowing for direct comparison of the recordings. This allows for a comparison of background classification accuracy with reduced risk of bias, but also for comparison of the impact of artefacts on both recording systems. In addition, feasibility was evaluated from multiple perspectives by combining user feedback with a retrospective analysis of EEG background pattern classification. Importantly, the retrospective analysis was performed with reviewers blinded to the recording system by including an additional montage derived from a standard EEG that visually resembled the forehead electrode set. Using this method, we were able to separate the effects of different electrode types, number and position of electrodes, and quantify both interrater and intermethod variability. This approach enabled an objective assess-



A

Reduced EEG \ Forehead electrode set	Unable to classify	Continuous normal voltage	Discontinuous	Continuous low voltage	Burst-suppression non-identical bursts	Burst-suppression identical bursts	GPDs on non-suppressed background	GPDs on suppressed background	Suppressed background
Unable to classify	10	3	0	0	0	0	0	0	0
Continuous normal voltage	5	40	0	0	0	0	0	0	0
Discontinuous	4	12	7	0	0	0	0	0	0
Continuous low voltage	3	2	0	3	0	0	0	0	0
Burst-suppression non-identical bursts	9	3	1	0	5	0	0	0	0
Burst-suppression identical bursts	1	0	0	0	0	2	0	0	0
GPDs on non-suppressed background	2	4	0	1	0	0	10	0	0
GDPs on suppressed background	0	0	0	0	0	0	0	0	0
Suppressed background	2	0	0	10	0	0	0	0	0

B

Standard EEG \ Forehead electrode set	Unable to classify	Continuous normal voltage	Discontinuous	Continuous low voltage	Burst-suppression non-identical bursts	Burst-suppression identical bursts	GPDs on non-suppressed background	GPDs on suppressed background	Suppressed background
Unable to classify	7	6	0	0	0	0	0	0	0
Continuous normal voltage	6	41	1	0	0	0	0	0	0
Discontinuous	6	11	6	0	0	0	0	0	0
Continuous low voltage	3	2	0	3	0	0	0	0	0
Burst-suppression non-identical bursts	6	1	1	0	5	0	0	0	0
Burst-suppression identical bursts	3	1	0	0	0	2	0	0	0
GPDs on non-suppressed background	2	2	0	0	0	0	10	0	0
GDPs on suppressed background	0	0	0	0	0	0	0	0	0
Suppressed background	3	0	0	11	0	0	0	0	0

C

Standard EEG \ Reduced EEG	Unable to classify	Continuous normal voltage	Discontinuous	Continuous low voltage	Burst-suppression non-identical bursts	Burst-suppression identical bursts	GPDs on non-suppressed background	GPDs on suppressed background	Suppressed background
Unable to classify	8	2	1	1	1	0	0	0	0
Continuous normal voltage	1	42	3	0	0	0	2	0	0
Discontinuous	2	1	19	0	1	0	0	0	0
Continuous low voltage	0	0	0	6	0	0	0	0	2
Burst-suppression non-identical bursts	0	0	0	0	13	0	0	0	0
Burst-suppression identical bursts	0	0	0	0	3	3	0	0	0
GPDs on non-suppressed background	0	0	0	0	0	0	14	0	0
GDPs on suppressed background	0	0	0	0	0	0	0	0	0
Suppressed background	2	0	0	1	0	0	1	0	10

Fig. 3 – EEG background pattern classification agreement between three different montages.
Confusion matrices comparing EEG background pattern classifications across three montage configurations: standard EEG based on 12 bipolar channels, a self-adhesive forehead EEG electrode set with 10 bipolar channels, and a reduced EEG montage visualized as the forehead EEG electrode set montage. EEG background pattern classification was based on the Critical Care Criteria of the ACNS (2021 version).[24] Matrices illustrate the agreement in pattern assignment between montages across all fragments. Panel A: reduced EEG versus the forehead electrode set. Panel B: standard EEG versus the forehead electrode set. Panel C: standard EEG versus reduced EEG.

ment of whether signal quality obtained with the forehead electrode set is sufficient for cEEG monitoring in postanoxic coma patients admitted to the ICU.

Limitations and context specific considerations

Not all background patterns occurred with equal frequency. To address this and maximize the representation of each background pattern, we selected multiple EEG fragments per patient that corresponded to a change in background pattern. Despite this approach, GPDs on a suppressed background pattern did not occur in any EEG fragments, and the distribution of background patterns remained uneven. Most EEG fragments were continuous with normal amplitudes. Although this reflects clinical practice, this limits the interpretability of results for less common patterns.

For comparison of prognostic categories, classifications were based on the European guideline (version 2025).[25] However, the application of EEG-based prognostication may vary across countries and clinical settings, both within and outside Europe. Therefore, the present analysis primarily focuses on agreement at the level of individual background pattern categories based on the international ACNS criteria. Clinicians and researchers are encouraged to interpret these findings within the context of their local practice and guidelines.

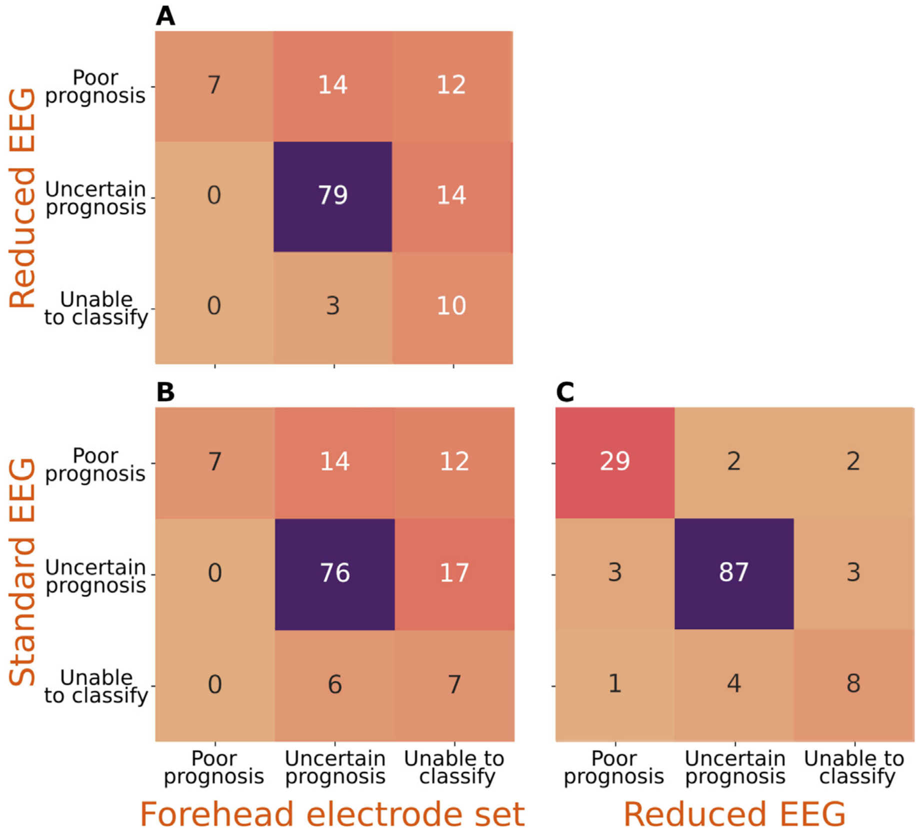


Fig. 4 – Agreement of classification per prognostic category between three different montages.
Confusion matrices comparing the prognostic association with EEG background pattern classifications based on standard EEG, a reduced EEG montage, and a forehead EEG electrode set. EEG background pattern classification was based on the Critical Care Criteria of the ACNS (2021 version).[24] Prognostic association with background patterns was based on the ERC Guidelines 2025 Post-Resuscitation Care, with the assumption that all EEG fragments were classified at 24 h after cardiac arrest A suppressed background (with or without periodic discharges) and burst-suppression patterns were considered as indicators of a poor prognosis. All other background patterns were labelled as an uncertain prognosis.

The interrater agreement among the four clinical neurophysiologists was lower than reported previously,[11] likely reflecting the selection of EEG fragments at moments of background pattern transition that are inherently more ambiguous than fragments during a stable period. Moreover, the classification options used in the retrospective analysis did not include the category 'nearly continuous', which is commonly used in clinical practice. As a result, some reviewers used 'continuous' while others selected 'discontinuous' for a similar pattern. Reviewers also indicated that longer EEG segments or concurrent video recordings would have aided in the interpretation of artefacts. Although available during real-time monitoring, these were not accessible during the retrospective analysis. The selection of fragments based on clinical annotations in the EEG, where the standard EEG montage is used for reviewing, could have introduced a bias towards this montage.

To ensure the availability of real-time video-EEG and integration within our local clinical workflow, the forehead electrode set was connected to the standard EEG system (OSG BrainRT, Rumst, Belgium) using an adapter cable specifically developed by the manufacturer for this purpose. Although the use of the forehead electrode set with a Bluetooth acquisition system is promoted, this configuration was not used in the present study. Therefore, it cannot be fully excluded that some of the observed noise in the recordings was related not only to the electrode set itself but also to the connecting cable.

Practical implications and recommendations

From a practical perspective, the forehead electrode set supports a shift toward point-of-care EEG monitoring in the ICU.[26,20] The ease of application suggests that, with adequate training in correct electrode placement, the system may be suitable for use by non-specialized professionals, such as ICU nurses, reducing the need for routine bedside involvement of EEG technicians. Combined with Bluetooth acquisition of the signals, this could allow reallocation of specialized EEG technicians to indications that require full-montage recordings, including epilepsy monitoring at the ICU. Such a workflow may also facilitate broader implementation of cEEG monitoring in settings with limited resources.[27,28]

The results of this study indicate that EEG background patterns can be assessed in approximately 75% of patients monitored using the forehead electrode set. Agreement with classifications based on standard EEG was moderate, with background patterns assessed using the forehead electrode set showing a more favorable pattern than those of the standard EEG. In particular, low-voltage patterns identified using the forehead electrode set were most often classified as isoelectric on standard EEG. Therefore, in recordings showing too many artefacts or a low-voltage pattern on the forehead electrode set, which together account for approximately one third of all recordings in this study, we would recommend acquisition of a standard EEG to enable reliable prognostic assessment. In the remaining cases, screening with the reduced electrode set appears sufficient, although clinicians should remain aware that classification based on the reduced set may occasionally appear more favorable.

Assuming that all EEG fragments were obtained ≥24 h after cardiac arrest, no cases were observed in which a pattern with uncertain prognostic significance on standard EEG was classified as indicative of a poor prognosis based on the forehead electrode set. While this finding is clinically reassuring, the risk of incorrectly assigning a poor neurological prognosis cannot be fully excluded and remains an important consideration, given the serious consequences such as premature withdrawal of life-sustaining therapies.

Conversely, recent evidence suggests that EEG contributes to clinical decision-making in only a small subset of post-cardiac arrest patients.[29] In the present study, a shift from a poor prognostic classification based on standard EEG to an uncertain prognostic classification based on the forehead electrode set was observed in 26 EEG fragments. However, 12 of these fragments were not classifiable due to artefacts or uncertainty on the forehead electrode set montage. In routine clinical practice, such uncertainty would likely lead to additional standard EEG recording, allowing for definitive prognostic assessment. The potential reduction in prognostic certainty should therefore be weighed against the substantial time savings and reduced workload for EEG technicians associated with the forehead electrode set, rather than interpreted as missed identification of poor prognostic patterns.

As use of this system may influence clinical decision making and ICU resource utilization, cost-effectiveness is best evaluated in a pragmatic implementation study that captures both workflow efficiency and clinical impact, as recently performed for standard cEEG monitoring after cardiac arrest.[30] Such a study should include healthcare staff time, including EEG technicians, neurologists, and ICU nurses, as well as the need for additional standard EEG recordings, frequency of poor prognostic classifications, and ICU costs related to prolonged treatment in cases of prognostic uncertainty. In addition to cost-effectiveness, the environmental sustainability of the forehead electrode set should be considered, as the set comes with single-use materials and plastic packaging.

Conclusion

This study demonstrates that a forehead EEG electrode set (Bittium BrainStatus™) is usable for cEEG monitoring in patients with postanoxic coma in the ICU. In the majority of recordings, signal quality and background pattern classification were sufficient. Importantly, use of the forehead electrode set would not have led to incorrect assignment of a poor neurological prognosis, while cases of diagnostic uncertainty would in clinical practice prompt acquisition of a standard EEG for definitive assessment. The substantial reduction in technician workload and the potential for point-of-care EEG support its role as a complementary, screening-oriented, monitoring strategy at the ICU. Future studies should focus on pragmatic implementation and cost-effectiveness to define the optimal role of the system within post-resuscitation care.

Declaration of generative AI in the manuscript preparation process

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to obtain critical feedback on structure and clarity and to support the formulation of text in a way that maximizes readability for a broad readership. After using this tool, the authors reviewed, revised, and edited all generated content as necessary. The authors take full responsibility for the content of the final manuscript.

Credits and permission

The individual depicted in Fig. 1 of this manuscript has provided consent for the use of this image in the present publication. The individual visible in this figure is an author of this manuscript (MV) and confirms that the image may be published without restriction.

CRediT authorship contribution statement

Marit Verboom: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Judith Drenthen:** Writing – review & editing, Data curation. **Maartje Louter:** Writing – review & editing, Data curation. **Dirk C.G. Straver:** Writing – review & editing, Data curation. **Mathieu van der Jagt:** Writing – review & editing, Conceptualization. **Mark van de Ruit:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Robert van den Berg:** Writing – review & editing, Supervision, Methodology, Data curation, Conceptualization.

Funding

This work was financially supported by an internal grant of the Erasmus MC (Koers23) aimed at improving the efficiency of care and reducing the workload of healthcare workers. The funding source was not involved in study conceptualization and design, data acquisition, analysis and interpretation of the data and/or the writing of the manuscript.

Declaration of competing interest

The authors declare that they have no conflict of interest related to this research. No financial or personal relationships that could influence the research outcomes have been identified by the authors.

Acknowledgements

The authors would like to thank Geert Geleijnse, Marc Geerts, Karla Biesheuvel, all technicians of the department of Clinical Neurophysiology of the Erasmus MC, the ICU nurses specialized in neurological patients, and all MSc Technical Medicine students for their valuable advice, critical insights, dedicated efforts, and above all, the enjoyable collaboration.

Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.resuscitation.2026.111086.

Author details

[a]Department of Neurology, Erasmus MC, Rotterdam, the Netherlands [b]Department of Intensive Care Adults, Erasmus MC, Rotterdam, the Netherlands [c]Department of Biomechanical Engineering, Delft University of Technology, the Netherlands

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GLOSSARY

ACNS: American Clinical Neurophysiology Society
EEG: electroencephalography