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ORIGINAL WORK

Evaluating the Impact of Point-of-Care Electroencephalography on Length of Stay in the Intensive Care Unit: Subanalysis of the SAFER-EEG Trial

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Abstract

Background: Electroencephalography (EEG) is needed to diagnose nonconvulsive seizures. Prolonged nonconvulsive seizures are associated with neuronal injuries and deleterious clinical outcomes. However, it is uncertain whether the rapid identification of these seizures using point-of-care EEG (POC-EEG) can have a positive impact on clinical outcomes.

Methods: In a retrospective subanalysis of the recently completed multicenter Seizure Assessment and Forecasting with Efficient Rapid-EEG (SAFER-EEG) trial, we compared intensive care unit (ICU) length of stay (LOS), unfavorable functional outcome (modified Rankin Scale score ≥ 4), and time to EEG between adult patients receiving a US Food and Drug Administration–cleared POC-EEG (Ceribell, Inc.) and those receiving conventional EEG (conv-EEG). Patient records from January 2018 to June 2022 at three different academic centers were reviewed, focusing on EEG timing and clinical outcomes. Propensity score matching was applied using key clinical covariates to control for confounders. Medians and interquartile ranges (IQRs) were calculated for descriptive statistics. Nonparametric tests (Mann–Whitney U-test) were used for the continuous variables, and the χ^2 test was used for the proportions.

Results: A total of 283 ICU patients (62 conv-EEG, 221 POC-EEG) were included. The two populations were matched using demographic and clinical characteristics. We found that the ICU LOS was significantly shorter in the POC-EEG cohort compared to the conv-EEG cohort (3.9 [IQR 1.9–8.8] vs. 8.0 [IQR 3.0–16.0] days, $p = 0.003$). Moreover, modified Rankin Scale functional outcomes were also different between the two EEG cohorts ($p = 0.047$).

Conclusions: This study reveals a significant association between early POC-EEG detection of nonconvulsive seizures and decreased ICU LOS. The POC-EEG differed from conv-EEG, demonstrating better functional outcomes compared with the latter in a matched analysis. These findings corroborate previous research advocating the benefit of early diagnosis of nonconvulsive seizure. The causal relationship between the type of EEG and metrics of interest, such as ICU LOS and functional/clinical outcomes, needs to be confirmed in future prospective randomized studies.

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Introduction

A significant number of patients with acute brain injury (ABI) in in-patient clinical settings have nonconvulsive seizures [1–5]. There is substantial evidence from both human and animal studies that nonconvulsive seizures are associated with deleterious effects on neurons and have a negative impact on clinical outcomes [5–15].

Electroencephalography (EEG) is the gold standard tool for detecting nonconvulsive seizures, and timely institution of EEG within 1 h of suspicion of nonconvulsive seizures has been recommended in current guidelines [16–21]. Conventional continuous EEG monitoring can be resource intensive and requires technical and clinical expertise for implementation in academic and community centers [22–25]. This makes continuous access to EEG challenging in not only community hospitals but also large tertiary care hospitals. Further, even in institutions where there is continuous access to EEG, timely acquisition and interpretation can still be daunting after-hours. A recent study estimated that at least one seizure is missed in 17% of high-risk patients [26] while awaiting EEG acquisition. Variability in the timing of EEG reporting can impact treatment and, hence, optimal control of seizures. The timeliness of therapeutics in seizure management has been associated with the refractoriness of seizures and long-term morbidity and mortality [9, 27–29]. It is known that refractory and super-refractory status epilepticus have been associated with increased hospital length of stay (LOS) and higher morbidity and mortality [30].

Mortality is a primary clinical outcome, and the intensive care unit (ICU) LOS potentially reflects the severity of a patient's clinical condition and portends a substantial resource burden for the health care systems, patients, and their families [31, 32]. Longer ICU LOS has been associated with worse mortality burden, an increased rate of in-hospital complications, and elevated morbidity [33–35]. The primary goal of intensive care is to enable early diagnostic and therapeutic strategies and reduce the LOS in the ICU.

Point-of-care EEG (POC-EEG) is a recent addition to our clinical diagnostic arsenal that impacts the timeliness of EEG acquisition as well as clinical decision-making at the bedside [36–39]. Further, there is evidence in community hospitals that POC-EEG leads to an increase in EEG coverage in ICUs and emergency departments, with a faster time to its acquisition [40, 41].

The primary objective was to assess the effect of POC-EEG on patient outcomes, whereas the secondary aim was to investigate potential factors causing variations among the groups. We hypothesize that POC-EEG enables rapid rule-out of seizures and guides timely therapeutics for patients with concern for seizures. Hence, it may shorten their LOS in the ICU.

Methods

This study is a subanalysis of data collected in the Seizure Assessment and Forecasting with Efficient Rapid-EEG (SAFER-EEG) trial, which was a retrospective comparative effectiveness study recently conducted at four institutions: Massachusetts General Hospital (MGH), University of New Mexico (UNM), University of Wisconsin–Madison, and Yale University (YAL). For this retrospective observational study, electronic patient records were reviewed and screened for eligibility. Using consecutive sampling from studies performed from January 1, 2018, to June 30, 2022, adult patients were enrolled into two primary cohorts: those who had received POC-EEG and those who had received conventional EEG (conv-EEG). In both cohorts, patients were included if they were at least 18 years old; if they received EEG during their hospitalization, including in the emergency department for at least 1 h (POC-EEG) or 4 h (conv-EEG); and if their EEG was deemed as readable. The recording time of 1 h for POC-EEG was chosen based on the proposed minimum recording duration to estimate the 72-h seizure risk using the 2HELPS2B algorithm [42, 43], whereas the 4-h cutoff was selected as part of the end points of the original SAFER-EEG trial to investigate the noninferiority of the seizure risk assessments done with POC-EEG to those done with conv-EEG. The POC-EEG cohort included EEG performed with Ceribell EEG (Sunnyvale, CA), a reduced-montage rapid EEG that can be placed by any health care provider without any specialized EEG training [44]. This cohort included either patients with POC-EEG only or POC-EEG followed by conv-EEG, in which the patients were monitored first with POC-EEG followed by conv-EEG. Three of the sites, YAL, UNM, and MGH, use POC-EEG and conv-EEG as part of their standard of care per institutional protocols guiding indication for POC-EEG. The institutional protocol at UNM indicates POC-EEG as a primary EEG modality in the emergency department and is available and used round the clock for seizure rule-out in other
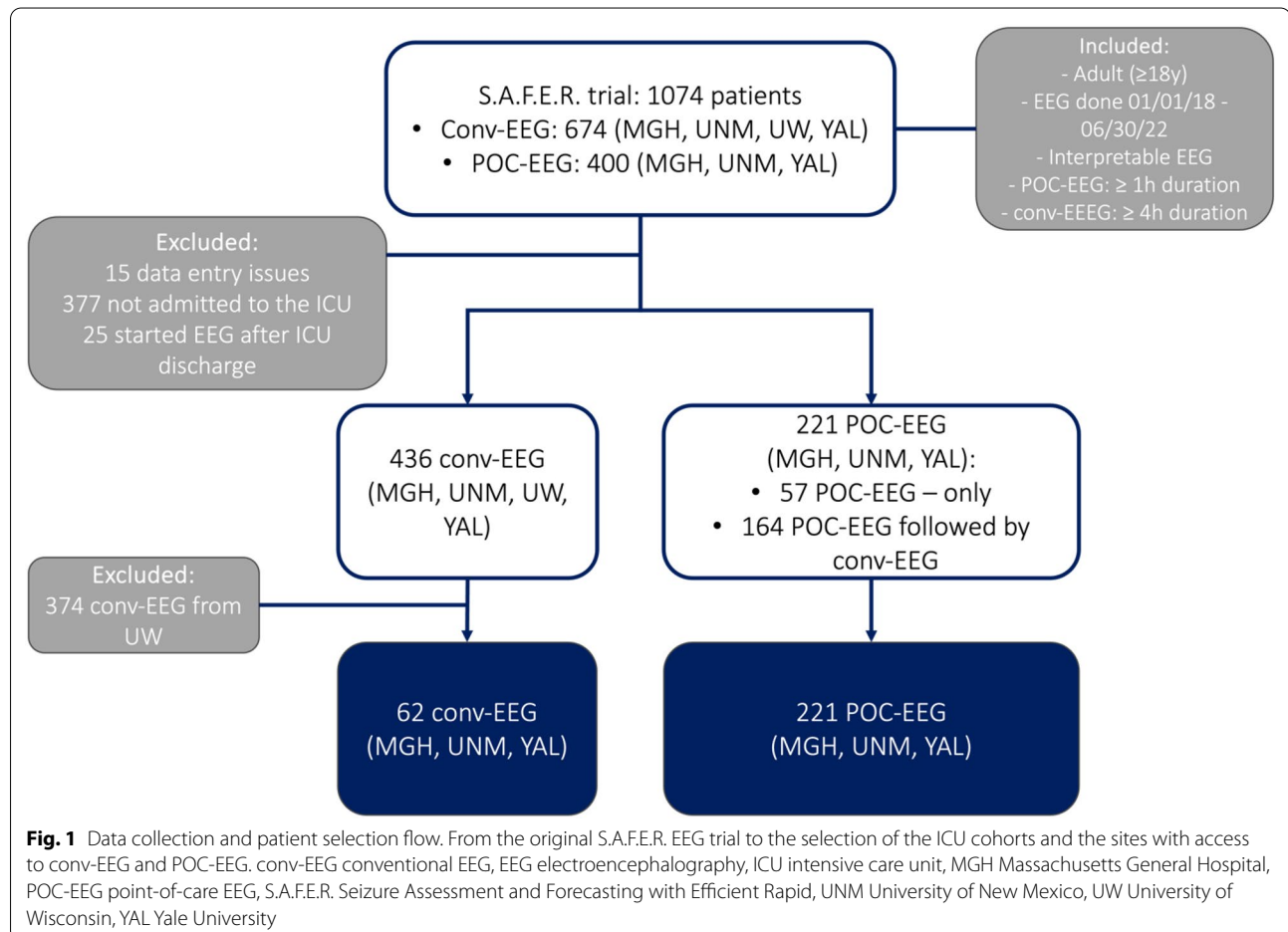
parts of the hospital in acute in-patient setting as a standard of care per clinician discretion. The participating sites YAL and MGH used POC-EEG similarly in their emergency departments and mostly on weekends and after 5 p.m. through 8 a.m. on weekdays. However, POC-EEG could be ordered at any time if there were resource limitations as determined by the clinical team and/or EEG team during business hours. We, therefore, focused our analysis on the other three sites only. At the time of this study, POC-EEG had not been integrated into the clinical workflow at the University of Wisconsin–Madison.

The research team at individual study sites reviewed electronic records and charts to capture patients' demographics, admission scores and diagnosis, and ICU admission and discharge, along with other clinical variables; abnormal EEG findings were rereviewed. The EEG findings were categorized using standard nomenclature [45], and selected patterns that have been associated with increased risk of in-hospital seizures were extracted along with relevant seizure information [42].These EEG patterns consisted of lateralized periodic discharges, lateralized rhythmic delta activity, generalized periodic discharges, brief potentially ictal rhythmic discharges, and bilateral independent periodic discharges. The key information that was derived related to seizures consisted of seizure start and stop times, number of seizures, and seizure classification. All data were entered into a secure central database that was used for further analysis. For this analysis, we selected the subset of patients who were admitted to the ICU at some point during their hospital stay, regardless of initial admission service, and for whom the EEG was started during or before their ICU stay. We excluded records with missing ICU admission or discharge dates and those for which data entry errors could not be amended with the research team. Figure 1 shows the SAFER-EEG study criteria, and the inclusion/exclusion criteria followed for this analysis.

Clinical Outcomes

We measured the ICU LOS from the electronic records documenting the dates of admission to and discharge from the ICU. To assess functional outcomes, we used the modified Rankin Scale (mRS) score at discharge. Patients with an mRS score ≥ 4 at discharge, including

Fig. 1 Data collection and patient selection flow. From the original S.A.F.E.R. EEG trial to the selection of the ICU cohorts and the sites with access to conv-EEG and POC-EEG. conv-EEG conventional EEG, EEG electroencephalography, ICU intensive care unit, MGH Massachusetts General Hospital, POC-EEG point-of-care EEG, S.A.F.E.R. Seizure Assessment and Forecasting with Efficient Rapid, UNM University of New Mexico, UW University of Wisconsin, YAL Yale University

death, were considered to have unfavorable outcomes. We also estimated the time from general admission to the start of the EEG.

Addressing Confounding Factors

We mitigated some of the key confounding factors that could impact the findings of our study. Firstly, given the triage nature of POC-EEG and its increased use in the emergency department [40, 41], shorter ICU LOS could be due to the type of patients who had received POC-EEG (i.e., early-triage patients for POC-EEG vs. long-stay patients for conv-EEG). To address this, we analyzed clinical outcomes in the subset of patients for whom EEG was started within 24 h of general hospital admission. Secondly, shorter ICU LOS might occur if the patients in one cohort were sicker and died earlier, effectively reducing their overall stay. To account for this, the next subanalysis was on the survivor groups, defined as study participants who were discharged from the hospital to home or a long-term care facility. To account for the impact of primary etiology, particularly those differences between the EEG cohorts, we split the cohorts into three primary diagnosis groups: (1) ABI due to structural etiology, which included vascular and hemorrhagic (traumatic and nontraumatic) insults; (2) non-ABI of structural etiology and nonstructural ABI, which included cerebral mass, cyst, encephalitis, encephalopathies, post cardiac arrest, seizure, and Status Epilepticus (SE); and (3) chronic brain injury and other, which included nonprimary central nervous system pathology. Finally, given the complexities in the care and outcomes of patients post cardiac arrest [46, 47] and the small number of patients available to categorize them separately, we performed an additional subanalysis removing these patients from both EEG cohorts.

Cohort Matching using Clinical Covariates

To control for the absence of prospective randomization, we used the clinical variables to find a 1:1 match, without replacement, between the conv-EEG and the POC-EEG cohorts. The clinical covariates used for matching were age ≥ 65 years, mRS score at the start of the EEG, Glasgow Coma Scale (GCS) score at the start of the EEG, suspected clinical seizure on admission, number of diagnoses on admission, and hemorrhagic (traumatic and nontraumatic) or other vascular diagnosis on admission. We used the Match-It package on R-Studio [48] to process the data and run the propensity score matching algorithm to identify matches between our cohorts. The resulting matching was deemed acceptable if the absolute standardized difference in means for all clinical variables between the EEG groups was ≤ 0.1.

Statistical Analysis

We report medians and interquartile ranges (IQRs) as descriptive statistics, and we used nonparametric tests (Mann–Whitney U-test) for the continuous variables and the χ^2 test for the proportions to determine statistical differences across our different populations and subgroups. To assess the effect on functional outcomes, we used a multivariate logistic regression model to estimate associations of unfavorable outcomes to EEG type. An α of 5% was used to determine significance; for the multivariate model and subanalyses, the reported p values are uncorrected.

Results

A total of 283 patients admitted to the ICU were included in the analysis (Fig. 1): 62 in the conv-EEG cohort and 221 in the POC-EEG cohort. Table 1 summarizes the demographics and admission scores between the two EEG cohorts.

Comparison of Clinical Characteristics and Outcomes between the Unmatched Cohorts

Table 1 shows that the two unmatched cohorts were similar in age, sex, presence of coma measured through GCS scores, mRS scores on admission, and mortality. However, the unmatched POC-EEG cohort had a higher median number of admission diagnoses (conv-EEG 1 vs. POC-EEG 2, $p < 0.001$) and a lower proportion of primary diagnosis of ABI of structural etiology (conv-EEG 36% vs. POC-EEG 22%, $p = 0.033$). The proportion of patients who started their EEG during weekends or outside regular working hours (8 a.m. to 5 p.m.) was significantly higher for the POC-EEG cohort (conv-EEG 31% vs. POC-EEG 66%, $p < 0.001$).

We found that patients who had EEG monitoring started with POC-EEG had, as a group, significantly shorter ICU LOS than those in the conv-EEG cohort. The median ICU LOS in the unmatched POC-EEG group was 4.5 (IQR 2.2–11.3) days, in contrast to 8.0 (IQR 3.0–16.1) days in the conv-EEG cohort (Table 2). In all the subpopulation analyses, we observed the same trend of shorter median ICU LOS for the POC-EEG cohort, although some of these differences did not reach statistical significance (Supplementary Table 1).

Further, when categorizing the cohorts by their EEG findings into patients with seizure or epileptiform patterns and those without any of these findings, we measured a similar trend of lower ICU LOS for the POC-EEG cohort (Supplementary Table 2). In this table, we demonstrate two subpopulations: the first with positive seizure or epileptiform activity, measured in days, and the second with negative seizure and epileptiform activity days.

Table 1 Demographics and population summaries in conv-EEG and POC-EEG cohorts

	conv-EEG	POC-EEG (unmatched)	*p*- value (unmatched)	Matched POC-EEG casespa-tients	*p*-value (matched)
Number of casespatients	62	221		62	
Age, averageg. (SDs.d.), years	60.6 (17.3)	61.5 (17.2)	0.765	62.9 (15.6)	0.304
Sex (% femaleF)	41.4	53.7	0.643	46.7	0.718
Avgerage. mRS on admission (SDs.d.)	1.3 (1.7)	1.5 (1.7)	0.181	1.4 (1.7)	0.616
Averagevg. GCS on admission (SDs.d.)	9.4 (4.6)	8.8 (4.6)	0.702	9.5 (4.7)	0.957
Median number of admission diagnosis (IQR)	1 (1–2)	2 (1–2)	< 0.001	1 (1–2)	0.484
In-hospital mortality (%)	37%	30%	0.311	31%	0.448
Diagnosis groups					
ABI structuralstruct. (%) (ischemic stroke, non-traumatic hemorrhagic, and TBI), *n* (%)	22 (36%)	49 (22%)	0.033*	13 (21%)	0.073
Non-ABI structuralstruct. and& other ABI (%) (cerebral mass, cyst, encephalitis, encephalopathies, post -cardiac arrest, seizure, and SE), *n* (%)	28 (45%)	120 (54%)	0.203	31 (50%)	0.590
Post -cardiac arrest	7 (11%)	22 (10%)	0.759	7 (11%)	1
Seizure or SE	8 (13%)	42 (19%)	0.505	13 (21%)	0.231
Others	13 (21%)	56 (25%)	0.4787	11 (18%)	0.649
Other (%) (cChronic functional [(e.g.,. migraines]), movement disorders, psychiatric diseases, and non-nervous system), *n* (%)	12 (19%)	52 (24%)	0.4821	18 (29%)	0.208

Demographic comparisons are shown before and after matching was performed using clinical covariates that might impact length of stayLOS

ABI acute brain injury, *conv-EEG*, conventional EEG, *EEG* electroencephalography, *GCS* Glasgow Coma Scale, *IQR* interquartile range, *mRS* modified Rankin Scale, *POC-EEG* point-of-care EEG, *SE* xxx, *TBI* traumatic brain injury, *ABI* acute brain injury, *mRS* modified Rankin Scale, *GCS* Glasgow Coma Scale

* Xxx

Table 2 Summary ICU LOS findings in conv-EEG and POC-EEG cohorts

Cohorts	conv-EEG	POC-EEG	*p* value
Full cohort			0.0111*
Number of patients	62	221	
Median ICU LOS (IQR), days	8.0 (3.0–16.0)	4.5 (2.2–11.3)	
Average (SD) days	12.7 (13.4)	9.0 (10.9)	
Matched cohorts			
Full cohort			0.003**
Number of patients	62	62	
Median ICU LOS (IQR), days	8.0 (3.0–16.0)	3.9 (1.9–8.8)	
Subpopulation: excluding post cardiac arrest			0.015*
Number of patients	48	48	
Median ICU LOS (IQR), days	8.2 (3.0–15.7)	3.9 (1.9–9.1)	
Subpopulation: 24-hour cutoff door-to-EEG time			0.0195*
Number of patients	28	28	
Median ICU LOS (IQR), days	6.3 (2.9–12.3)	3.0 (1.9–4.6)	
Subpopulation: survivors			0.026*
Number of patients	34	34	
Median ICU LOS (IQR), days	7.8 (2.7–15.3)	3.7 (1.9–7.7)	

Median ICU length of stay days reported with 25th and 75th percentiles, and the number of subjects for each cohort. The *p*P- value was from the Mann–-Whitney *U*-test for difference in medians. Matching was done using clinical covariates that might impact LOS. For the sub-analyses, matching was done in the cohorts of patients who received EEG within 24 h of admission ("24-h cut-off door-to-EEG time"), and in patients who did not expiredie ("survivors")

conv-EEG conventional EEG, *EEG* electroencephalography, *ICU* intensive care unit, *IQR* interquartile range, *LOS* length of stay, *POC-EEG* point-of-care EEG, *POC-EEG* point-of-care EEG, *sub-pop* sub-population

* *p*-value ≤ 0.05, **p*-value ≤ 0.01

In the positive seizure or epileptiform activity group, the patients in the POC-EEG group had a median ICU LOS of 4.8 days, whereas the patients in the conv-EEG group had a median ICU LOS of 13.2 days, with a total of 23 patients ($p = 0.03$), suggesting a statistically significant difference between the conv-EEG and POC-EEG group regarding ICU LOS for this subpopulation. Next, in the subpopulation with negative seizure and epileptiform activity (measured in days), the conv-EEG group had a median ICU LOS of 6.7 days, whereas the POC-EEG group had a median ICU LOS of 4 days ($p = 0.089$), which suggests that the difference in the ICU LOS between the conv-EEG and POC-EEG groups for this subpopulation is not statistically significant. Thus, we can infer that for the subpopulation with positive seizure or epileptiform activity days, the use of POC-EEG is associated with a significantly shorter ICU stay compared to conv-EEG. However, for the subpopulation with negative seizures and epileptiform activity days, although the ICU stay is shorter for the POC-EEG group, this difference is not statistically significant.

There are two possible explanations for this finding related to seizures and epileptiform patterns. First, early detection and hence medical decision-making could lead to less seizure and epileptiform burden. Additionally, there are differing practice patterns or heuristics that influence how long a patient remains on EEG independent of specific EEG patterns, which could introduce bias related to individual physicians or institutional protocols.

While assessing functional outcomes between the two cohorts (Table 3), we found that the conv-EEG cohort had a trend of a slightly larger proportion of patients with an mRS score of 4 or higher (unfavorable outcome). However, the difference was not statistically significant (67% in POC-EEG group vs. 76% in conv-EEG group, $\chi^2 = 1.94$, $p = 0.164$).

Finally, Table 4 shows a summary of epochs related to time to EEG acquisition across both cohorts. In the unmatched groups, the POC-EEG cohort had a significantly faster door-to-EEG time than the conv-EEG cohort (POC-EEG 6.1 [IQR 1.9–24.2] hours vs. conv-EEG 25.3 [IQR 13.4–96.0] hours, $p < 0.0001$), and this significantly lower time to EEG for the POC-EEG cohort was found across the other subpopulations analyzed (Supplementary Table 3).

Comparison of Clinical Characteristics and Outcomes between the Matched Cohorts

After controlling for clinical confounds, we found that the POC-EEG and conv-EEG cohorts were similar across all the covariates, with equivalent age, sex, and admission scores (GCS and mRS scores) and similar median number of diagnoses and distribution of admission diagnosis groups (see Table 1). Assessing the ICU LOS in the matched cohorts, we again observed significantly different ICU LOS between the two cohorts (POC-EEG$_{matched}$ 3.9 [IQR 1.9–8.8] days vs. conv-EEG 8.0 [IQR 3.0–16.1] days). The median ICU LOS for the POC-EEG cohort was still significantly shorter than the ICU LOS for the conv-EEG group ($p = 0.003$). We performed separate matching in the 24-h door-to-EEG and survivors subpopulations, which yielded equivalent demographics between the EEG cohorts. In these subanalyses, the median ICU LOS was significantly shorter for the matched POC-EEG cohort compared with the conv-EEG (Table 1). Moreover, in the matched populations, we found that the proportion of patients with unfavorable outcomes was significantly lower for the POC-EEG cohort (58%; $\chi^2 = 3.95$, $p = 0.047$) (Table 3). Similarly, when using a multivariate model in the unmatched population to control for clinical covariates, we found a strong trend that POC-EEG was associated with lower odds of unfavorable outcomes (mRS score ≥ 4). However, this trend did not reach significance (adjusted odds ratio 0.52 [95% confidence interval 0.25–1.01], $p = 0.061$) (Table 3). Lastly, we found shorter door-to-EEG time across the matched POC-EEG cohorts (POC-EEG$_{matched}$ 5.9 [IQR 1.5–17.1] hours vs. conv-EEG 25.3 [IQR 13.4–96.0] hours, $p < 0.0001$). This trend was present in the subset of patients who received EEG

Table 3 Functional outcomes at discharge conv-EEG and POC-EEG

Cohorts	conv-EEG	POC-EEG	*p*- value (unmatched)	POC-EEG (matched)	*p*-value (matched)
Full cohort: % poor outcome (number of casespatients)	76% (47)	67% (147)	0.164	56% (36)	0.047*
Odds ratio ([95% C.I.)]	Reference	0.52 ([0.25–1.0])	0.061	N/A	N/A

Poor outcomes were determined as a modified Rankin ScalemRS score $\geq$ 4 at discharge. For the Oodds rRatio analysis, a multivariate logistic regression model was used, with the same clinical covariates used for propensity -score matching. *p*- values for the comparison of proportions are from the χ^2Chi-square test, and for the coefficient of the logistic model in the Oodds Rratio estimation

CI confidence interval, *conv-EEG* conventional EEG, *EEG* electroencephalography, *N/A* not applicable, *POC-EEG* point-of-care EEG

* Xxx

Table 4 Summary of times to EEG in conv-EEG and POC-EEG cohorts

Cohorts	conv-EEG	POC-EEG	*p* value
Full cohort			< 0.0001**
Number of patients	62	221	
Median time to EEG (IQR), hours	25.3 (13.4–96.0)	6.1 (1.9–24.2)	
Matched cohorts			
Full cohort			< 0.0001**
Number of patients	62	62	
Median time to EEG (IQR), hours	25.3 (13.4–96.0)	5.9 (1.5–17.1)	
Subpopulation: 24-hour cutoff door-to-EEG time			< 0.0001**
Number of patients	28	28	
Median time to EEG (IQR), hours	13.5 (7.1–18.4)	2.9 (0.6–7.3)	
Subpopulation: survivors			< 0.0001**
Number of patients	34	34	
Median time to EEG (IQR), hours	25.3 (12.1–98.3)	2.9 (1.6–12.5)	

Median time to EEG in hours, reported with 25th and 75th percentiles, and the number of subjects for each cohort. Matching was done using clinical covariates that might impact LOS. Similar to the ICU LOS sub-analyses, matching was done in the full cohort and in the subpopulation of patients who received EEG within 24 h of admission ("24-h cut-off door-to-EEG time"), and in patients who did not expiredie ("survivors"). *p-value $\leq$ 0.5; **p-value $\leq$ 0.01

conv-EEG conventional EEG, *EEG* electroencephalography, *ICU* intensive care unit, *IQR* interquartile range, *LOS* length of stay, *POC-EEG* point-of-care EEG, *sub-pop* subpopulation

* $p \leq 0.5$, ** $p \leq 0.01$

within 24 h of admission and those who survived their hospital stay (Table 4).

Discussion

To the best of our knowledge, this is the first study assessing the impact of the type of EEG tool on ICU LOS of adult patients admitted to the hospital. In this study, we demonstrated shorter ICU LOS for patients in whom POC-EEG was chosen as an initial EEG modality compared to conv-EEG. These results were consistent in both unmatched and matched cohorts (matching for population and controlling for clinical variables). This suggests that the results are not an artifact of differences in patient demographics, disease etiologic states, or clinical factors, such as disease severity. The diagnosis group of ABI was significantly different between POC-EEG and conv-EEG cohorts; however, once the populations were matched based on disease etiologic states, ICU LOS remained lower for the POC-EEG cohort. It is important to note that all three academic centers (MGH, YAL, and UNM) have close to 24/7 conv-EEG coverage and technicians and staff, in addition to POC-EEG availability. Nevertheless, we observed a consistent difference in the ICU LOS between the two different EEG cohorts in the patients across these centers and a significant difference in favorable functional outcomes (mRS score < 4) between cohorts. Also, in the matched populations in Table 3, we found that the proportion of patients with unfavorable

outcomes was significantly lower for the POC-EEG cohort (58%; $\chi^2 = 3.95$, $p = 0.047$).

The differences we found in ICU LOS and functional outcomes in the POC-EEG group compared with the conv-EEG group may be partly explained by the findings summarized in Table 4. The door-to-EEG acquisition time was significantly lower in the POC-EEG group compared with the conv-EEG group, even in these institutions with nearly 24/7 conv-EEG coverage. This could imply that patients possibly had sooner diagnostic information and therapeutics instituted in the POC-EEG group. We note in Supplementary Table 2 that in the subpopulation with positive seizure or epileptiform activity, the use of POC-EEG was associated with a significantly shorter ICU LOS compared to the use conv-EEG. This could suggest that we detect seizures and epileptiform abnormalities faster in the POC-EEG group, leading to a reduction in refractoriness because time to diagnosis is directly related to refractoriness of seizures [27]. Furthermore, because we observed that the trend held in patients without seizure or epileptiform activity, rule-outs may also contribute to the overall reduction in ICU LOS for the POC-EEG cohort. This could be due to patients receiving less empirical treatment and experiencing fewer unnecessary interventions, such as medications, intubation, and mechanical ventilation, among many others.

We did not find any difference regarding mortality between the two EEG cohorts, POC-EEG and conv-EEG. The SAFER-EEG trial included patients who

survived the hospital course beyond the first 24 h. As seen over the last decade in various studies surrounding neuromonitoring and advanced monitoring, mortality is a challenging outcome to study because it can be impacted by various clinician-driven and patient-driven factors, including prognostication of outcomes and secondary complications in the hospital, among many others [49]. Further, it is the clinical decision-making based on the type of monitoring tools and the timeliness of it that impacts patient outcomes [50–52]. It has been demonstrated in the prospective observational study, Does Use of Rapid Response EEG Impact Clinical Decision Making? "DECIDE" trial, that POC-EEG can assist with bedside decision-making for clinicians [40]. Our results demonstrate a difference in functional outcomes (mRS score < 4: favorable outcomes) between the conv-EEG and POC-EEG cohorts that was statistically significant in the matched cohort (Table 3). These findings can be explained by the optimal timing and accessibility of the data, which can drive clinical decision-making (quicker in the case of POC-EEG application and usage). The biological plausibility could be related to the early institution of therapeutics and preventing refractory states in seizure management. We were not able to elucidate details of the intensity of therapeutics because this part of the clinical data was not available as a part of the SAFER-EEG trial.

This study is hypothesis generating, and the retrospective nature of the study is rate limiting. Heterogeneity is also a commonplace among different health care centers and providers that can drive decision-making for the type of EEG as a first choice. Most of the patients in this study received a higher number of POC-EEG during after-hours (after 5 p.m.) and on weekends, which are usually time areas with clinical challenges and resource limitations surrounding obtaining conv-EEG. Further, prospective studies probing this hypothesis could yield a better understanding and exploration of the type of EEG and timeliness of treatment and the rate of interventions that patients receive and could provide further validation of the study findings.

This is a retrospective multicenter study, and there could be inherent bias in patient groups that is not accounted for in the current analysis. The large academic centers participating in the study may also receive patient transfers, generating a pool of patients who may have a higher clinical acuity and have more complex medical conditions and comorbidities than in other smaller/community hospitals. Because of the study's retrospective nature, there are additional limitations surrounding data/information about EEG order and read times, antiseizure medication dosage and administration times, intubation, and other factors that might affect LOS, complicating more in-depth analysis to explain the difference in ICU LOS. It

is possible that patients receiving POC-EEG versus conv-EEG first had differences in therapeutic intensity, quality, and consistency of interventions based on EEG data. These factors can influence clinical outcomes. Additionally, selection bias for the type of EEG by the provider and variability among different institutions could impact this analysis. Such granular data that can provide insights into these possibilities were not collected in the SAFER-EEG trial. The study collected information on time of admission, etiology of admission, time to EEG order, and time to acquisition from admission, among others. However, time of onset of symptoms to EEG acquisition and granular EEG data from symptom onset to resolution would be difficult to obtain with accuracy in a retrospective study and were not collected. We have highlighted the necessity for future prospective studies to fill this gap in the literature and to provide a more definitive understanding of the correlation between clinical manifestation onset and EEG acquisition timing as well as the impact on clinical decision-making and clinical outcomes. Lastly, we used matching in this study to control for known confounders by pairing study participants with similar characteristics in both the POC-EEG and conv-EEG groups. However, it only accounts for the confounders that we selected for the matching process. Unmatched confounders can still influence the outcome, potentially leading to biased results. This method might also inadvertently highlight the confounding effect of unselected variables, such as specific causes within a broader category.

Conclusions

In this study, we found significant differences in the ICU LOS and functional outcomes between the POC-EEG cohort and the conv-EEG cohort when adjusting for population differences and accounting for the clinical factors. The study once again demonstrated a significant delay in time to conv-EEG, which could be one of the factors driving this association. Future prospective studies or randomized trials may assist in validating this study's findings and understanding the rationale supporting it.

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Conflicts of interest
The authors declare no conflicts of interest.

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This study was approved by the local institutional review boards, and the requirement for informed consent was waived.

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