Neurocrit Care
https://doi.org/10.1007/s12028-020-00939-x

NEUROCRITICAL CARE SOCIETY

ORIGINAL WORK

Validation of the 2HELPS2B Seizure Risk Score in Acute Brain Injury Patients

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Abstract

Background and Objective: Seizures are common after traumatic brain injury (TBI), aneurysmal subarachnoid hemorrhage (aSAH), subdural hematoma (SDH), and non-traumatic intraparenchymal hemorrhage (IPH)—collectively defined herein as acute brain injury (ABI). Most seizures in ABI are subclinical, meaning that they are only detectable with EEG. A method is required to identify patients at greatest risk of seizures and thereby in need of prolonged continuous EEG monitoring. 2HELPS2B is a simple point system developed to address this need. 2HELPS2B estimates seizure risk for hospitalized patients using five EEG findings and one clinical finding (pre-EEG seizure). The initial 2HELPS2B study did not specifically assess the ABI subpopulation. In this study, we aim to validate the 2HELPS2B score in ABI and determine its relative predictive accuracy compared to a broader set of clinical and electrographic factors.

Methods: We queried the Critical Care EEG Monitoring Research Consortium database for ABI patients age ≥ 18 with > 6 h of continuous EEG monitoring; data were collected between February 2013 and November 2018. The primary outcome was electrographic seizure. Clinical factors considered were age, coma, encephalopathy, ABI subtype, and acute suspected or confirmed pre-EEG clinical seizure. Electrographic factors included 18 EEG findings. Predictive accuracy was assessed using a machine-learning paradigm with area under the receiver operator characteristic (ROC) curve as the primary outcome metric. Three models (clinical factors alone, EEG factors alone, EEG and clinical factors combined) were generated using elastic-net logistic regression. Models were compared to each other and to the 2HELPS2B model. All models were evaluated by calculating the area under the curve (AUC) of a ROC analysis and then compared using permutation testing of AUC with bootstrapping to generate confidence intervals.

Results: A total of 1528 ABI patients were included. Total seizure incidence was 13.9%. Seizure incidence among ABI subtype varied: IPH 17.2%, SDH 19.1%, aSAH 7.6%, TBI 9.2%. Age ≥ 65 ($p = 0.015$) and pre-cEEG acute clinical seizure ($p < 0.001$) positively affected seizure incidence. Clinical factors AUC = 0.65 [95% CI 0.60–0.71], EEG factors AUC = 0.82 [95% CI 0.77–0.87], and EEG and clinical factors combined AUC = 0.84 [95% CI 0.80–0.88]. 2HELPS2B AUC = 0.81 [95% CI 0.76–0.85]. The 2HELPS2B AUC did not differ from EEG factors ($p = 0.51$), or EEG and clinical factors combined ($p = 0.23$), but was superior to clinical factors alone ($p < 0.001$).

Conclusions: Accurate seizure risk forecasting in ABI requires the assessment of EEG markers of pathologic electrocerebral activity (e.g., sporadic epileptiform discharges and lateralized periodic discharges). The 2HELPS2B score is a reliable and simple method to quantify these EEG findings and their associated risk of seizure.

Keywords: Critical care EEG, Continuous EEG, 2HELPS2B, Seizure, Acute brain injury

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Introduction

Acute symptomatic seizures occur as a consequence of multiple brain injury subtypes [1–6]. In this study, we investigated traumatic brain injury (TBI), aneurysmal subarachnoid hemorrhage (aSAH), subdural hematoma (SDH), and non-traumatic intraparenchymal hemorrhage (IPH)—collectively defined herein as "acute brain injury" (ABI). The majority of seizures in ABI patients are electrographic only and require continuous electroencephalogram (cEEG) monitoring for detection [7]. cEEG remains a limited resource in most settings, creating a need for tools to stratify seizure risk. ABI subtype and severity variably affect seizure incidence [7–11]. Clinical factors such as age, coma, and recent or remote seizure history also affect seizure risk [9–14]. Previous critical care EEG studies suggest that epileptiform activity, such as electrographic findings on the so-called ictal–interictal continuum, may be indicative of pathological electro-cerebral activity and thus represent an important predictor for electrographic seizures [11–17]. Many clinical and EEG factors contribute to seizure risk in hospitalized patients, yet the relative importance of these factors remains an area of investigation.

We previously developed the 2HELPS2B algorithm as a tool to generally assess seizure risk in hospitalized patients undergoing cEEG [12]. The goal was to use the fewest number of factors while maintaining a high level of accuracy [12, 18, 19]. 2HELPS2B uses five electrographic factors and one clinical factor (acute or remote prior seizure) to quantitate near-term seizure risk (Fig. 1). The initial 2HELPS2B study included all non-elective hospitalized cEEG patients, but did not specifically analyze seizure risk in ABI patients. The Critical Care EEG Monitoring Research Consortium (CCERMC), from which the 2HELPS2B score was derived, has continued to expand (current $N = 8743$)—facilitating the study of seizure risk in this subpopulation.

In the current study, we examined seizure risk after ABI with three objectives. First, we compared a set of 18 electrographic factors against clinical factors for seizure prediction. Clinical factors assessed were age, coma, ABI type, presence of encephalopathy, and suspected or confirmed acute pre-cEEG seizure. Next, we assessed for added value in using clinical and electrographic factors combined. Finally, we compared 2HELPS2B to these clinical and electrographic predictors; here, we aimed to determine how a larger set of clinical and electrographic factors would fare against the reduced set of six factors found in 2HELPS2B. Of note, we excluded patients with a remote seizure history, distinguishing scoring herein from 2HELPS2B proper; results are generalizable to non-epileptic ABI patients only. We hypothesized that EEG risk factors would be superior to our limited set of clinical factors for ABI seizure prediction and that 2HELPS2B would capture most of the predictive power of the combined EEG/clinical factors while maximizing simplicity.

Risk Factor						Points
Frequency > **2Hz** [a]						1
Sporadic **E**pileptiform Discharges						1
LPD/BIPD/LRDA						1
Plus Features [b]						1
Prior **S**eizure						1
Brief Ictal Rhythmic Discharge						2
						Total Score
Total Score:	0	1	2	3	4	5	>6
Seizure Risk:	<5%	12%	27%	50%	73%	88%	>95%

Fig. 1 Illustration of factors used to calculate the 2HELPS2B score. The total score represents the sum of points, which is associated with a particular seizure risk. *BIPD* brief independent periodic discharge, *cEEG* continuous EEG, *GPD* generalized periodic discharge, *LPD* lateralized periodic discharge, *LRDA* lateralized rhythmic delta activity. [a]Frequency > 2 Hz applies to GRDA, LRDA, BIPDs, LPDs, or GPDs. [b]Plus features are defined as superimposed rhythmic, fast, or sharp activity for GRDA, LRDA, BIPDs, LPDs, or GPDs

Methods

The CCERMC database was queried for patients with an admitting diagnosis of acute TBI, aSAH, SDH, or IPH. CCERMC data were collected between February 2013 and November 2018. The database contained clinical and EEG data from 8743 consecutive patients that underwent non-elective cEEG at Yale University/Yale New Haven Hospital, Brigham and Women's Hospital, or Emory University Hospital. Study exclusion criteria were defined as having an admitting diagnosis other than ABI, age < 18, cEEG monitoring for < 6 h, and history of epilepsy or remote seizure. 2HELPS2B does not distinguish between acute versus remote seizure history; however, we elected to exclude patients with an underlying predisposition for seizures. As such, only patients with an acute clinical seizure prior to EEG monitoring, in the setting of ABI, were scored accordingly under 2HELPS2B. In sum, we included only non-epileptic ABI patients ≥18 years old who underwent > 6 h of EEG monitoring. The primary outcome was the presence or absence of electrographic seizures at any point during cEEG monitoring. The American Clinical Neurophysiology Society terminology does not define seizure, yet as in the original 2HELPS2B study [12], we utilized the Young et al. [20] criteria to define seizures. The total length of EEG monitoring was tracked, in days, for each patient and is reported by

median, total range, and interquartile range. Electrographic features were logged, and 2HELPS2B scoring completed, retrospectively using the entire monitoring period. However, we did not track when EEG monitoring began in relation to the ABI event, and we did not log the sequence of electrographic features observed during the EEG monitoring period. The institutional review board (IRB) at each institution approved the study. A waiver for informed consent was granted by each institution's IRB.

Clinical factors assessed were age, coma (Glasgow Coma Score [GCS] < 8), ABI type, presence of encephalopathy (defined as any alteration of consciousness, but not coma; i.e., GCS 8-14), and pre-cEEG acute clinical seizure. A GCS of 15 ("alert") was tracked, but was not utilized as a component in the clinical factors group. Each patient was anticipated to have one reported GCS category; patients with missing or multiple selections in this category were counted as missing data. cEEG factors included 18 electrographic findings: lateralized periodic discharge (LPD), sporadic epileptiform discharge (SED), lateralized rhythmic delta activity (LRDA), generalized periodic discharge (GPD), generalized rhythmic delta activity (GRDA), bilateral independent periodic discharge (BIPD), frequency > 2 Hz (for LRDA, BIPDs, LPDs, or GPDs); plus features (defined as superimposed rhythmic, fast, or sharp activity of LRDA, BIPDs, LPDs); brief ictal rhythmic discharge (BIRD), posterior dominant rhythm (PDR), variability, burst suppression, any discontinuity of the background, asymmetry of the background/focal slowing, and an alpha, theta, beta, or delta background.

2HELPS2B uses six factors (Fig. 1): one clinical factor and five electrographic factors. The only clinical factor used is known or suspected clinical seizure prior to EEG monitoring, including acute or remote seizures and history of epilepsy (1 point); as mentioned above, patients with epilepsy or a remote seizure history were excluded from the study. Therefore, a point was only awarded for ABI patients that experienced a confirmed or suspected acute clinical seizure prior to EEG monitoring. The five electrographic findings include: BIRD (2 points); LPDs, LRDA or BIPD (1 point); SEDs (1 point); frequency > 2 Hz for LRDA, BIPDs, LPDs, or GPDs (1 point); and plus features (superimposed rhythmic, fast, or sharp activity) found on LRDA, BIPDs, LPDs (1 point). A 5% seizure risk is associated with a 0 score; 1 amounts to a 12% risk and 2 to a 27% risk. At 3 there is a 50% risk of seizure, 73% at a score of 4, and 88% at 5; 6 or 7 confers a > 95% seizure risk (Fig. 1). Previously defined cut points for 2HELPS2B have been developed for low-, medium-, and high-risk patients [18]. These subgroups represent risk categories that may require differing durations of EEG monitoring. A 2HELPS2B score of 0 indicates low risk of seizure; 1 represents a moderate risk, and 2 or higher portends a high seizure risk [18, 19].

For univariate analyses, contingency tables were made. Odds ratios were calculated using logistic regression; *p* values were calculated using the Fisher exact test. We randomly divided the patient population into 50% training dataset and 50% test dataset. The training dataset was used to fit elastic-net logistic regression with internal tenfold cross-validation to minimize mean-square error for lambda in order to generate three models—clinical factors alone, EEG factors alone, and EEG and clinical factors in combination. A grid search with 0.1 intervals was used to determine L1/L2 mixing parameters, again looking for the lowest mean-square error in the training cohort. Lastly, these models were compared to each other and to the 2HELPS2B model via the test dataset using the receiver operator characteristic (ROC) analysis. Area under the curve (AUC) was calculated for each model using pROC package in R. Bootstrapping was utilized to generate confidence intervals. AUC comparison was performed using permutation testing (coin package). All statistical analysis was performed in R [21].

Results

A total of 1528 ABI patients were included after applying exclusion criteria (Fig. 2). The time range of EEG monitoring for all ABI patients was one to 21 days. The total median monitoring duration and interquartile range of monitoring duration were 2 days. ABI patient analysis is summarized in Table 1. IPH and aSAH each represented an approximate third of the ABI dataset; the final third comprised TBI and SDH patients. Total seizure incidence was 13.9%. IPH and SDH had seizure incidences of 17.2% and 19.1%, respectively. The seizure incidences for TBI and aSAH were 9.2% and 7.6%.

Univariate analyses for clinical factors are given in Table 1. Sex and the presence of encephalopathy or coma were found to represent an insignificant risk of seizure;

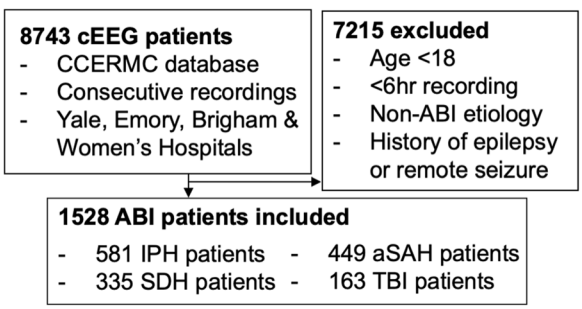

Fig. 2 Flowchart of methods. CCERMC database recordings represent the cohort from the original 2HELPS2B study. Exclusion criteria are illustrated, as is the final subtype makeup of ABI patients. *ABI* acute brain injury, *aSAH* aneurysmal subarachnoid hemorrhage, *CCERMC* Critical Care EEG Research Consortium, *cEEG* continuous EEG, *IPH* non-traumatic intraparenchymal hemorrhage, *SDH* subdural hemorrhage, *TBI* traumatic brain injury

Table 1 Univariate seizure risk factors for ABI patients on cEEG

Variable	Number (%) of patients with finding	Proportion with seizure (%)	OR	95% CI	*p* value
ABI patients	1528 (100)	213 (13.9)	–	–	–
aSAH	449 (29.4)	34 (7.6)	0.41	0.28–0.60	< 0.001
IPH	581 (38.0)	100 (17.2)	1.53	1.15–2.05	0.004
SDH	335 (21.9)	64 (19.1)	1.65	1.20–2.30	0.002
TBI	163 (10.7)	15 (9.2)	0.60	0.33–1.01	0.067
Alert[a]	233 (15.2)	23 (9.9)	0.58	0.36–0.88	0.010
Encephalopathy[a]	600 (39.3)	83 (13.8)	0.97	0.73–1.30	0.850
Coma[a]	304 (19.9)	51 (16.8)	1.34	0.96–1.84	0.078
Sex (male)	743 (48.6)	105 (14.1)	0.97	0.77–1.02	0.600
Age (> 65 years)	560 (36.6)	94 (16.8)	1.44	1.07–1.93	0.015
Pre-cEEG seizure[d]	142 (9.3)	33 (23.2)	2.03	1.32–3.06	< 0.001
GPD	222 (14.5)	32 (14.4)	1.05	0.69–1.55	0.830
LPD[d]	298 (19.5)	133 (44.6)	11.60	8.42–16.00	< 0.001
SED[d]	391 (25.6)	110 (28.1)	3.93	2.91–5.30	< 0.001
LRDA[d]	92 (6.0)	39 (42.4)	2.71	1.96–3.72	< 0.001
BIPD[d]	37 (2.4)	9 (24.3)	2.35	1.07–4.78	0.023
GRDA	345 (22.6)	37 (10.7)	0.69	0.47–1.00	0.050
Frequency > 2 Hz[b,d]	22 (1.4)	6 (27.3)	2.35	0.84–5.80	0.077
Plus features[c,d]	161 (10.5)	58 (36.0)	4.40	3.05–6.31	< 0.001
BIRD[d]	139 (9.1)	50 (36.0)	4.23	2.87–6.20	< 0.001
PDR	319 (20.9)	28 (8.8)	0.53	0.34–0.80	0.003
Variability	1360 (89.0)	192 (14.1)	1.15	0.73–1.91	0.568
Burst suppression	85 (5.6)	19 (22.4)	1.85	1.06–3.10	0.020
Any discontinuity of the background	491 (32.1)	83 (16.9)	1.42	1.05–1.91	0.020
Background asymmetry/focal slowing	686 (44.9)	149 (21.7)	3.73	2.48–4.64	< 0.001
Alpha background	178 (11.6)	13 (7.3)	0.45	0.24–0.78	0.008
Theta background	435 (28.5)	39 (9.0)	0.52	0.36–0.74	< 0.001
Beta background	21 (1.4)	1 (4.8)	0.31	0.02–1.48	0.250
Delta background	218 (14.3)	21 (9.6)	0.62	0.38–0.98	0.050

ABI acute brain injury, *aSAH* aneurysmal subarachnoid hemorrhage, *ASD* anti-seizure drugs, *BIPD* bilateral independent periodic discharge, *BIRD* brief ictal rhythmic discharge, *cEEG* continuous electroencephalogram, *GPD* generalized periodic discharge, *GRDA* generalized rhythmic delta activity, *IPH* non-traumatic intraparenchymal hemorrhage, *IQR* interquartile range, *LPD* lateralized period discharge, *LRDA* lateralized rhythmic delta activity, *OR* odds ratio, *PDR* posterior dominant rhythm, *SDH* subdural hemorrhage, *SED* sporadic epileptic discharge, *TBI* traumatic brain injury

[a] 25.6% of ABI patient had missing data for the alert, encephalopathy, or coma variables

[b] Frequency > 2 Hz applies to LRDA, BIPDs, LPDs, or GPDs

[c] Plus features are defined as superimposed rhythmic, fast, or sharp activity for LRDA, BIPDs, LPDs

[d] 2HELPS2B scoring criteria

coma trended toward significance. ABI patients older than 65 years had a higher likelihood of seizure. Seizures were less likely for patients that were alert. An acute suspected or confirmed clinical seizure prior to cEEG monitoring denoted the highest clinical risk factor for seizure. aSAH and TBI had a lower risk of seizure during EEG monitoring, whereas IPH and SDH had a higher risk. An approximate one-quarter of patients had missing data for coma, encephalopathy, or alert variables. Univariate analyses for electrographic factors can be found in Table 1. LPDs had the highest risk of seizures. SEDs, BIPD, BIRD, LRDA, focal slowing, and plus features (superimposed rhythmic, fast, or sharp activity for LRDA, BIPDs, LPDs) were indicative of a higher seizure risk. Burst suppression and discontinuity of the background showed the modest increased risk of seizures. ABI patients with GRDA, PDR, and an alpha or theta background had a decreased risk of seizures. Four of the electrographic factors had a statistically nonsignificant OR for seizures: GPD, frequency > 2 Hz (for LRDA, BIPDs, LPDs, or GPDs), variability, and a beta background.

2HELPS2B results are summarized in Tables 1 and 2. All but one of the six factors (Table 1) that contribute to 2HELPS2B were found to have a statistically significant positive risk association for seizure in ABI; this single nonsignificant variable, frequency > 2 Hz for GRDA, LRDA, BIPDs, LPDs, or GPDs, trended toward significance. The lone clinical factor utilized from the algorithm, pre-cEEG acute clinical seizure (Table 1), had the highest OR for seizure during EEG monitoring among all clinical factors considered. Table 2 displays 2HELPS2B risk categorization for the total cohort and each ABI subtype. Of note, low- and medium-risk scores were particularly well represented in the dataset. A score of 0 displayed an approximate 3% seizure risk, whereas increasing scores displayed increasing seizure risk as well as variability between ABI groups. Please refer the supplementary materials document for complete score breakdown (Supplementary Table 1) and risk calibration plot (Supplementary Figure 1).

Multivariate analyses are displayed within the ROC graph in Fig. 3. The clinical factors we examined displayed a modest AUC for seizure prediction. Clinical factors had a lower AUC for predicting seizures after ABI as compared to electrographic factors. Clinical factors in combination with electrographic factors did not exhibit a significant difference in AUC as compared to the 18 electrographic factors alone. The AUC of 2HELPS2B did not significantly differ from that of electrographic factors ($p = 0.51$), or electrographic plus clinical factors ($p = 0.23$). 2HELPS2B showed a significantly higher AUC as compared to clinical factors alone ($p < 0.001$).

Discussion

Our findings confirmed that seizure rates vary among ABI subtypes. Electrographic signs of pathological electro-cerebral activity (LPDs, LRDA, BIPD, SEDs, and BIRD) were a greater risk factor for seizures in ABI patients without a history of epilepsy when compared to injury subtype or the other clinical risk factors we examined. Clinical factors had a lower predictive power than electrographic factors. Clinical factors added minimal predictive value to cEEG. The major limitation of this conclusion is that a relatively narrow set of clinical factors were analyzed in this study. Potentially, a more comprehensive clinical/radiographic feature set would perform better. 2HELPS2B reduces electrographic factors to the most powerful predictors of seizures and incorporates the single most powerful clinical predictor: acute suspected or confirmed pre-EEG clinical seizure. 2HELPS2B seizure risk categorization was especially consistent for low-risk ABI patients. The AUC of 2HELPS2B did not differ statistically from the larger set

Table 2 2HELPS2B risk score categorization for all patients and per ABI subtype

Seizure risk (2HELPS2B score)	ABI patients		aSAH		IPH		SDH		TBI	
	No. (%) of patients with finding	Proportion (%) with seizure	No. (%) of patients with finding	Proportion (%) with seizure	No. (%) of patients with finding	Proportion (%) with seizure	No. (%) of patients with finding	Proportion (%) with seizure	No. (%) of patients with finding	Proportion (%) with seizure
Low (0)	685 (44.9)	19 (2.8)	204 (45.4)	5 (2.5)	243 (41.8)	8 (3.3)	149 (44.5)	3 (2.0)	89 (54.6)	3 (3.4)
Medium (1)	445 (29.1)	58 (13.0)	126 (28.1)	8 (6.3)	182 (31.3)	32 (17.6)	89 (26.5)	14 (15.7)	48 (29.4)	4 (8.3)
High (≥ 2)	398 (26.0)	136 (34.2)	119 (26.5)	21 (17.6)	156 (26.9)	60 (38.5)	97 (29.0)	47 (48.5)	26 (16.0)	8 (30.8)
Total	1528 (100)	213 (13.9)	449 (29.4)	34 (7.6)	581 (38.0)	100 (17.2)	335 (21.9)	64 (19.1)	163 (10.7)	15 (9.2)

ABI acute brain injury, *aSAH* aneurysmal subarachnoid hemorrhage, *IPH* non-traumatic intraparenchymal hemorrhage, *TBI* traumatic brain injury

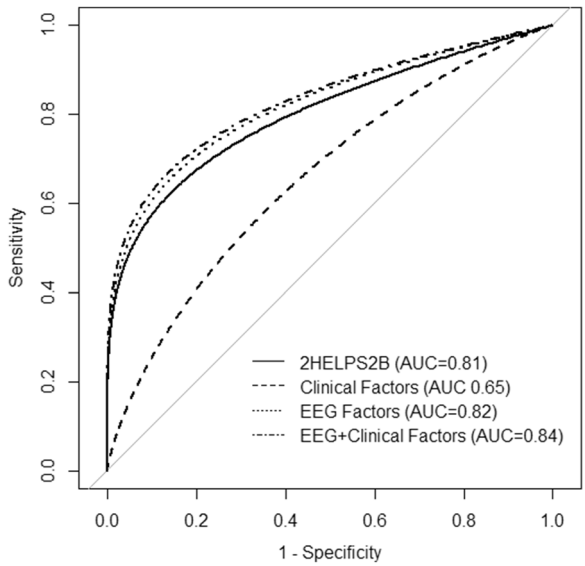

Fig. 3 Receiver operator curve for seizure risk factor groups. Receiver operating characteristics and confidence intervals for each risk group were created via bootstrapping. The solid gray line represents the null classifier. AUC for clinical factors alone was 0.65 [95% CI 0.60–0.71]. AUC for electrographic factors was 0.82 [95% CI 0.77–0.87], and for electrographic factors and clinical factors in tandem 0.84 [95% CI 0.80–0.88]. 2HELPS2B had an AUC of 0.81 [95% CI 0.76–0.85]. The 2HELPS2B AUC did not differ from electrographic factors ($p = 0.51$), or electrographic factors plus clinical factors ($p = 0.23$). 2HELPS2B had a significantly higher AUC as compared to clinical factors alone ($p < 0.001$). *AUC* area under the curve

of electrographic factors, or clinical and electrographic factors combined, but 2HELPS2B did have a statistically superior AUC when compared to clinical factors alone. An additional major drawback of these findings is that we used the entire EEG monitoring period, without concern for timing or sequence of events, for electrographic risk factor observation.

The current study highlights that cEEG-detected pathological electro-cerebral activity, as quantified by the 2HELPS2B score, is a potentially useful predictor of seizures in non-epileptic ABI patients. While the clinical factors in this study were limited, these factors alone do not offer robust seizure prediction value. Even when used to supplement EEG, clinical factors provide insignificant benefit to EEG alone. Additionally, 2HELPS2B risk categorization is effective in identifying ABI patients with low seizure risk. Therefore, EEG screening should be considered when stratifying seizure risk in ABI patients. 2HELPS2B represents a viable method toward this end.

Previous studies correspond with our results. We reaffirm that EEG is essential for seizure risk stratification in critically ill patients [11, 13, 18, 22]. Results also align with the original and follow-up 2HELPS2B studies [12, 18, 19]. Variance in seizure incidence among ABI subtypes correlates with previous reports [7, 18, 20, 23]. This suggests that the cohort found herein broadly represents patient populations across tertiary care centers. Odds ratios for clinical factors displayed mixed results and are thus comparable to previous studies [11–14]. Clinical factors do tend to exhibit wide predictive variance throughout the literature, further emphasizing the need for reliable risk stratification methods such as 2HELPS2B.

This study has limitations. We excluded patients with epilepsy or a remote seizure history; thus, our results may underestimate seizure risk in epileptic ABI patients. Selection bias may affect our results, as not all ABI patients receive cEEG > 6 h. The database did not provide information regarding when EEG monitoring began after ABI. Additionally, notation of electrographic features and 2HELPS2B scoring was completed over the entire monitoring period, and exact timing and sequence of these events were not recorded. Subsequent 2HELPS2B validation studies address such concerns [18, 19]. More detailed clinical information for patients was not evaluated either, e.g., radiologic imaging, injury severity, and comorbidities. Future studies should address these issues. Combination of diverse clinical pathologies into a single group, ABI, may limit findings because risk factors vary between ABI subtypes. However, this combination of pathologies was intentional. Our primary aim was to assess electrographic signs of pathological electro-cerebral activity as a surrogate for overall seizure risk, that is, despite variable risks across ABI types. Lastly, the effect of sedative and anti-seizure drugs was not evaluated, as the CCERMC database does not include detailed information in regard to their use. These drugs may influence the incidence of seizures and other electrographic factors, such as LPDs. Prospective studies specifically aimed to address this matter are planned.

Conclusions

Electrographic markers of pathological electro-cerebral activity are important predictors of acute symptomatic seizure risk in ABI patients. EEG risk stratification may prove to be a useful tool for seizure forecasting in the neurocritical care setting, though further study is needed. Screening ABI patients with EEG and calculating risk with 2HELPS2B may be a useful clinical strategy to improve seizure detection rates while minimizing excessive cEEG use [18, 19].

Electronic supplementary material

The online version of this article (https://doi.org/10.1007/s12028-020-00939-x) contains supplementary material, which is available to authorized users.

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Acknowledgements
Critical Care EEG Monitoring Research Consortium provided research infrastructure to complete this study.

Author Contributions
EM analyzed the data, drafted the manuscript for intellectual content, and formatted and edited the manuscript for submission. AS was responsible for design and conceptualization of the study and data analysis in addition to revision of the manuscript for intellectual content. The remainder of the authors contributed to data collection, study conception, and critical review of the manuscript.

Source of support
This study was supported by a Research Infrastructure Award from the American Epilepsy Society and the Epilepsy Foundation.

Conflict of interest
Dr. Hirsch, over the last 12 months, received research support to Yale University for investigator-initiated studies from Monteris, Upsher-Smith, and The Daniel Raymond Wong Neurology Research Fund at Yale. Consultation fees were collected for advising Adamas, Aquestive, Ceribell, Eisai, Medtronic and UCB. Royalties were received for authorship from UpToDate-Neurology, and from Wiley for book co-authorship: "Atlas of EEG in Critical Care", by Hirsch and Brenner. Also received honoraria for speaking from Neuropace. All additional authors report that they have no conflicts of interest.

Ethical Approval/Informed Consent
This research study adhered to ethical standards. The IRB at each institution approved of the study. Given the de-identified and retrospective nature of the research, a waiver for informed consent was granted by each institution's IRB.

Publisher's Note

Published online: 27 February 2020

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