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Clinical paper

Evoked potentials improve multimodal prognostication after cardiac arrest

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Abstract

Aim: Predicting recovery in comatose post-cardiac arrest patients requires multiple modalities of prognostic assessment. In isolation, absent N20 cortical responses in somatosensory evoked potentials (SSEPs) are a specific predictor of poor outcome. It is unknown whether SSEP results, when assessed in the context of prior knowledge (demographic and clinical information), change the pretest predicted probability of recovery.

Methods: In a single center retrospective study, a cohort of 323 patients admitted to post-cardiac arrest service at a tertiary care center were classified into a group based on SSEP testing. We built adjusted logistic regression models including clinical examination findings on the day SSEPs were recorded to generate a pre-test outcome probability for awakening, withdrawal of life-sustaining therapy (WLST) and survival to discharge. We then added the upper extremity N20 cortical response results to the model to obtain updated outcome probabilities. ROC curve was used to determine the additive effect of using SSEPs to the model. Survival to discharge, awakening, and WLST due to neurological reasons were designated as primary, secondary and tertiary outcomes, respectively.

Results: Analyses showed that evoked potentials are ordered in sicker patients. Adding SSEP to the model increased the proportion of patients with less than 1% and 5% chance of survival, as well as the proportion of patients with over 95% chance of WLST. AUC for survival increased from 0.85 to 0.93 when SSEP was included ($p = 0.006$).

Conclusion: Adding the N20 SSEP response results to prior knowledge changed the predicted probability of WLST and survival to discharge in comatose post-arrest patients.

Keywords: Somatosensory evoked potential, Cardiac arrest, Prognostication, Withdrawal of life support, Awakening, Survival

Abbreviations: BAEP, brainstem auditory evoked potential; EEG, electroencephalography; EP, evoked potential; FOUR, full outline of unresponsiveness; LOS, length of stay; MRI, magnetic resonance imaging; PCAC, Pittsburgh cardiac arrest catetogry; PCAS, post-cardiac arrest service; ROSC, return of spontaneous circulate; TH, therapeutic hypothermia; SSEP, somatosensory evoked potential; WLST, withdrawal of life-sustaining therapies; WLST-N, withdrawal of life-sustaining therapies due to perceived poor neurological prognosis.

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Introduction

More than 550,000 cardiac arrests occur in the United States annually, and most patients that achieve return of spontaneous circulation (ROSC) and survive to hospital admission are initially comatose.[1] In this cohort of comatose survivors of cardiac arrest, withdrawal of life-sustaining therapies (WLST) for perceived poor neurologic prognosis is the most common proximate cause of death.[2] Unfortunately, accurately discriminating between patients with recoverable and irrecoverable injury is challenging particularly shortly after the injury. After anoxic brain injury, thalamocortical connectivity can be disrupted, and structural damage to these white matter tracts measured with magnetic resonance imaging (MRI) is strongly predictive of poor prognosis.[3] The functional correlate of this structural injury is loss of thalamocortical connectivity which is reflected eletrophysiologially as a loss of N20 cortical responses. Individual outcome predictors, such as clinical exam, electroencephalography (EEG), somatosensory evoked potentials (SSEPs) and neuroimaging are not sufficient to preclude recovery when considered in isolation.[4] We have previously demonstrated that a multimodal evaluation including computed tomography of the brain, clinical examination and EEG improves diagnostic accuracy in this population.[5]

Absent SSEP N20 cortical responses obtained at least 3 days after ROSC are highly associated with poor outcome after cardiac arrest.[6,7] We reviewed data from our facility to determine if recording SSEPs in conjunction with prior prognostic assessment incorporating baseline demographic data and neurological assessments altered the pretest probability of awakening from coma (primary outcome), WLST due to perceived poor neurological prognosis (WLST-N; secondary outcome) and survival to discharge (tertiary outcome) in post-cardiac arrest patients undergoing therapeutic hypothermia.

Methods

Study design and clinical setting

Study was approved by the University of Pittsburgh Institutional Review Board (IRB) and was granted a waiver of consent. We performed a retrospective cohort study including consecutive comatose patients cared for at a single tertiary care center after in- or out-of-hospital cardiac arrest between February 2009 and December 2014, to ensure a homogeneous clinical and electrophysiological assessment by the same group of clinicians and electrophysiologists. We considered patients to be comatose if they did not follow verbal commands. It was our standard of care during this time to induce therapeutic hypothermia (TH) to 33 °C for 24 h in these patients.[8–10] We sedated patients with propofol, fentanyl, or midazolam infusions to suppress shivering and maintain ventilator synchrony and comfort.

Demographic variables and clinical exam

We abstracted demographic variables including age, gender, primary rhythm of arrest, location of arrest, Pittsburgh Cardiac Arrest Category (PCAC), hospital length of stay, survival to discharge and cause of death from the chart. PCAC is a validated illness severity score that is measured within the first 6 h of hospital arrival and defined as follows: I- Awake and following commands, II- Coma with intact brainstem responses with mild cardiopulmonary dysfunction, III- Coma with intact brainstem responses and moderate to severe cardiopulmonary dysfunction, IV- Coma with at least one absent brainstem reflex.[11,12]. At day 3 after ROSC, one of the post-cardiac arrest service (PCAS) attending physicians assessed neurological function using full outline of unresponsiveness (FOUR) exam. FOUR score has 4 different components: motor response or FOUR-Motor, eye response or FOUR-Eye, brain stem response or FOUR-Brainstem and respiration or FOUR-Respiration. Each component of FOUR score has a range of 0–4 that positively correlates with degree of neurological recovery.[11]

Evoked potential testing

All patients in group 3 underwent somatosensory evoked potentials (SSEP) recording on day 3 in response to independent, bilateral ulnar or median nerve and tibial or peroneal nerve stimulation. Additionally, brainstem auditory evoked potentials (BAEPs) in response to independent bilateral auditory stimulation were recorded.

Upper and lower extremity SSEPs

All peripheral stimulating electrodes and recording electrodes were placed with the patient supine. Needle electrodes were utilized in all cases unless contraindicated. Patients were all intubated and sedated. When possible, short acting paralytic was administered just prior to the commencement of recording to improve signal quality by reducing EMG interference thereby increasing the signal to noise ratio.[13] Specifically, we considered the signal to be present if amplitude of at least 0.1 μV could be recorded. Small amplitude but reliable responses either bilaterally or unilaterally were considered "present". Further, the presence of cortical responses, as opposed to far-field subcortical responses, was made based on a greater than 4 ms latency diffencene between the coritical and subcortical recordings.

Ulnar or median nerve stimulation was performed independently at the wrist and peroneal or tibial nerve stimulation was performed independently at the head of the fibula or medial malleolus of the ankle respectively using sub-dermal bipolar needle electrode pairs.

Recording electrode placement for upper extremity SSEP cortical responses was P4-Fz and P3-Fz with scalp electrodes placed per the international 10–20 system. A non-cephalic cervical electrode was localized at the C2 spinous process or mastoid (M) and referened to Fz, and additional electrodes were placed at the erbs point bilaterally (EPs and EPd). The subcortical recording allowed for differentiation of thalamo-cortical (N20-P30) potentials from brainstem (P14-N18) potentials. Lower extremity SSEP cortical recording electrodes were placed at Pz-Fz and P3-P4 and non-cephalic recordings were made from C2 or mastoid referenced to Fz. Peripheral responses were recorded at the popliteal fossa. Lower extremity SSEPs were evaluated for the presence of an P35-N45 complex. Constant current stimulation frequency was set to 3.43 Hz with 0.2−0.3 milliseconds pulse duration. Band pass filters were set at 10–300 Hz for the cortical channel, 30–1000 Hz for the cervical channel, and 100Hz- 1 kHz for the erbs point channel.

The analysis time was 100 ms. Depending on the signal quality, the averages were computed for either 128 or 256 trials. Stimulation

intensity was set at a supermaximal threshold and increased until the cortical amplitude no longer increased with increasing intensity. Presence of the N20 waveform was verified based on a latency that was at least > 4 ms later than the predominant negativity measured from the cervical/brainstem channel.

Brainstem auditory evoked potentials

For BAEPs mono-aural stimulations were delivered through an ear insert at 95 dB-HL intensity and 17.6 Hz frequency, of 50 ms duration clicks with alternating polarity (rarefaction/condensation) to reduce the electrical stimulus artifact and to cancel cochlear microphonics at the ipsilateral side. At the same time, the contralateral ear was stimulated at 65 dB-HL with white noise for masking purposes. The recording was performed through standard subdermal, scalp needle electrodes located at both ear lobes or in front of the tragus on each side referenced to the vertex (A1/Cz and A2/Cz) sites from the modified 10–20 International system. Bandpass filtering used was 100 to 1000 Hz with a gain of 100 K for all of the channels. For interpretation of results 1024 trials were averaged per epoch. While the BAEP was not a focus of this study, it was rare that the BAEP was absent and if wave V was absent, it was assumed that the patient had peripheral hearing loss based on the presence or absence of wave I.

All evoked potential data was interpreted by an MD and/or PhD neurophysiologist board certified in clinical neurophysiology. Data was scrutinized for the presence or absence of cortical, subcortical (brainstem) and peripheral responses in every patient and an interpretation was made within 24 h of the study being performed.

Outcome measures

Survival to hospital discharge was recorded as the primary outcome. PCAS attending physicians recorded awakening (defined as the ability to follow verbal commands) as the secondary outcome in the studied patients. We also recorded WLST-N as the tertiary outcome. WLST ensued a discussion between PCAS team, critical care team and the decision maker, after taking into consideration different aspects of patient history (age and pre-existing morbidities), clinical trajectory (clinical exam) and assistive modalities (imaging and electrophysiology studies).

Neuro-prognostication

For the purposes of this study, a single study author (PM) performed a structured chart review to classify all included patients into one of 4 groups with respect to ascertainment of SSEPs as one element of a multimodality prognostic assessment (Fig. 1): Group 1: Too sick for EP (those patients with unstable cardiovascular status or prior intent to WLST; evoked potentials for those patients would not have changed their prognosis); Group 2: Intermediate – Without EP (patient not categorized in groups 1 or 4 who did not have their evoked potentials recorded); Group 3: Intermediate– With EP (patient not categorized in groups 1 or 4 who had their evoked potentials recorded) and Group 4: Too well for EP (patients with good exam and trajectory, i.e., spontaneous movements, for whom evoked potentials would not change their good prognosis).

Statistical analysis

We summarized baseline clinical characteristics and outcomes using descriptive statistics, and used chi2, *t*-test and Wilcoxon Rank Sum test to compare these data elements between groups of patients. We built adjusted logistic regression models including baseline patient characteristics and FOUR score subscales on the day SSEPs were performed to generate a pre-test outcome probability for awakening, WLST-N and survival to discharge. We then added N20 cortical response results to the model to obtain updated outcome probabilities. We compared the pre- and post-test predicted outcomes overall, and specifically compared the proportion of patients with extreme outcome estimates less than 1% or 5% probability of awakening or survival, and number of patients with more than 95% or 99% probability of WLST-N. ROC analysis was

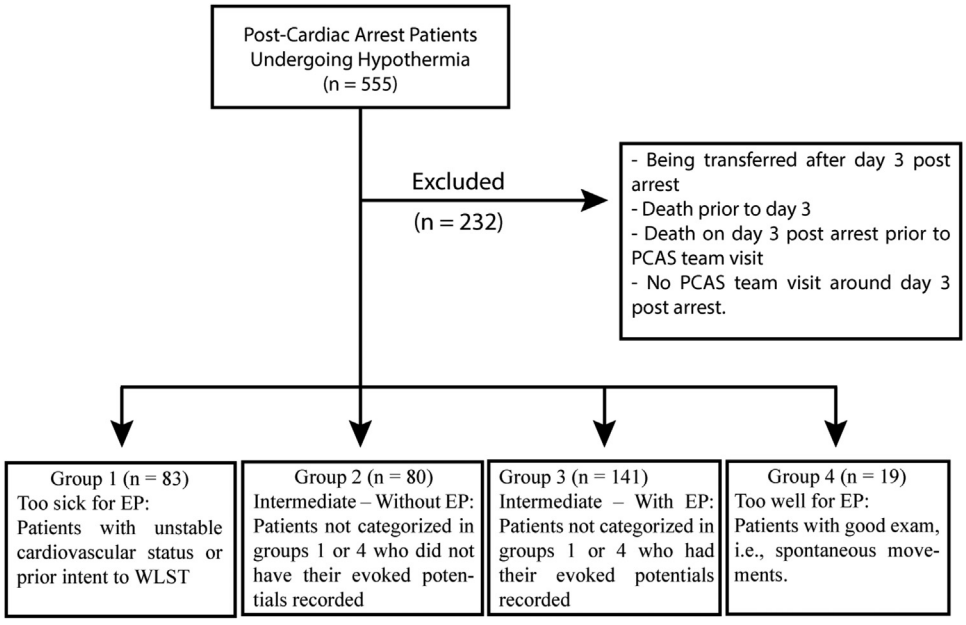

Fig. 1 – Consort diagram of post-cardiac arrest patients undergoing therapeutic hypothermia.

used to compare the prediction model for survival with and without SSEPs. We used Stata Version 14.1 (StataCorp, College Station, TX) for all analyses.

Results

Demographics and post-arrest data

We included 555 patients admitted to our facility between 2009 and 2014. Among this cohort, 232 subjects were excluded due to reasons including: being transferred after day 3 post arrest, death prior to day 3, death on day 3 prior to PCAS team visit or no PCAS team visit on day 3 (Fig. 1). The remaining 323 patients were classified as follows: Group 1: Too sick for EP (n = 83); Group 2: Intermediate– Without EP (n = 80); Group 3: Intermediate– With EP (n = 141); and Group 4: Too well for EP (n = 19). Table 1 illustrates demographic characteristics of each group of patients. Survival rate for Group 1 was very low (2%) in contrast to Group 4 (90%). In Groups 2 and 3, those who received SSEP testing had a significantly lower survival rate compared to those patients who did not receive SSEP (Group 3: 23% vs Group 2: 53%; $p < 0.001$). Hospital stay was shorter for patients who underwent SSEP compared with those who did not get SSEP (Group 3: 7 days vs. Group 3: 15 days; $p < 0.001$).

Presence or absence of upper extremity somatosensory evoked potentials (N20)

Among 141 patients who had SSEP testing performed at day 3 post arrest, 39% had an intact N20 response on SSEP (Supplemental Table). In patients with present SSEP N20 responses, a higher percentage of patients had cardiac arrest in hospital (29% vs. 12%; $p < 0.01$). PCAC IV illness severity was more prevalent in patients without intact N20 responses (78% vs. 42%; $p < 0.001$). The presence of N20 responses was associated with recovery and a higher rate of following commands (33% vs. 1%; $p < 0.001$) and survival (53% vs. 5%; $p < 0.001$). A higher rate of tibial nerve evoked potentials (60% vs. 3%; $p < 0.001$) and BAEPs (90% vs. 76%; $p = 0.04$) was observed in patients with intact N20 responses.

Multivariate logistic regression and survival to discharge

Fig. 2 represents the individual probabilities of outcome including or excluding upper extremity SSEP. Including SSEP recording in the model shifts the predicted probability of awakening (Fig. 2A,B) and

Table 1 – Demographic and clinical characteristics of 4 groups of patients, including too sick for EP (Group 1), intermediate– without EP (Group 2), intermediate– with EP (Group 3), and too well for EP (Group 4).

	Too sick	Intermediate– No Evoked Potential	Intermediate– Evoked Potential	Too well
Total patients	83	80	141	19
Age, in years (IQR)	55 (43–65)	59.5 (49.75–67)	56 (48-66)	63 (50.5–72.5)
Gender				
Male, n (%)	46 (55%)	48 (60%)	84 (60%)	9 (47%)
Female, n (%)	37 (45%)	32 (40%)	57 (40%)	10 (53%)
Presenting rhythm, *n (%)*				
VT or VF	23 (28%)	34 (43%)	39 (28%)	8 (42%)
PEA	25 (30%)	21 (26%)	50 (35%)	3 (16%)
Asystole	29 (35%)	14 (17%)	40 (28%)	2 (11%)
Missing	6 (7%)	11 (14%)	12 (9%)	6 (32%)
Location of CPR, *n (%)*				
OHCA	70 (84%)	58 (72%)	115 (82%)	14 (74%)
IHCA	13 (16%)	22 (28%)	26 (18%)	5 (26%)
Pittsburgh Cardiac Arrest Category, n (%)				
I	0 (0%)	0 (0%)	1 (1%)	0 (0%)
II	19 (23%)	31 (39%)	24 (17%)	10 (53%)
III	8 (10%)	16 (20%)	9 (6%)	4 (21%)
IV	50 (60%)	20 (25%)	90 (64%)	3 (16%)
Missing	6 (7%)	13 (16%)	17 (12%)	2 (10%)
Survived, n (%)	2 (2%)	42 (53%)	33 (23%)	17 (90%)
Length of stay, in days (IQR)	5 (4–5)	15 (8–23.5)	7 (5–13)	15 (12–24)
Cause of Death, n (%)				
Re-arrest	8 (10%)	6 (16%)	6 (5%)	1 (50%)
Brain death	9 (11%)	0 (0%)	5 (5%)	0 (0)
Withdrawal– Non neurologic	1 (1%)	3 (8%)	13 (12%)	0 (0)
Withdrawal– Neurologic	63 (78%)	29 (76%)	85 (78%)	1 (50%)
Length of stay– Survived (IQR)	13 (4–22)	20 (17–30)	26 (18.5–33.5)	17 (13–24)
Length of stay– Died (IQR)	5 (4–5)	8 (6–12)	6 (4–8)	9 (7–10)

CPR = cardiopulmonary resuscitation; EP = evoked potential; IHCA = inside hospital cardiac arrest; IQR = interquartile range; OHCA = outside hospital cardiac arrest; PEA = pulseless electrical activity; VF = Ventricular fibrillation; VT = ventricular tachycardia.

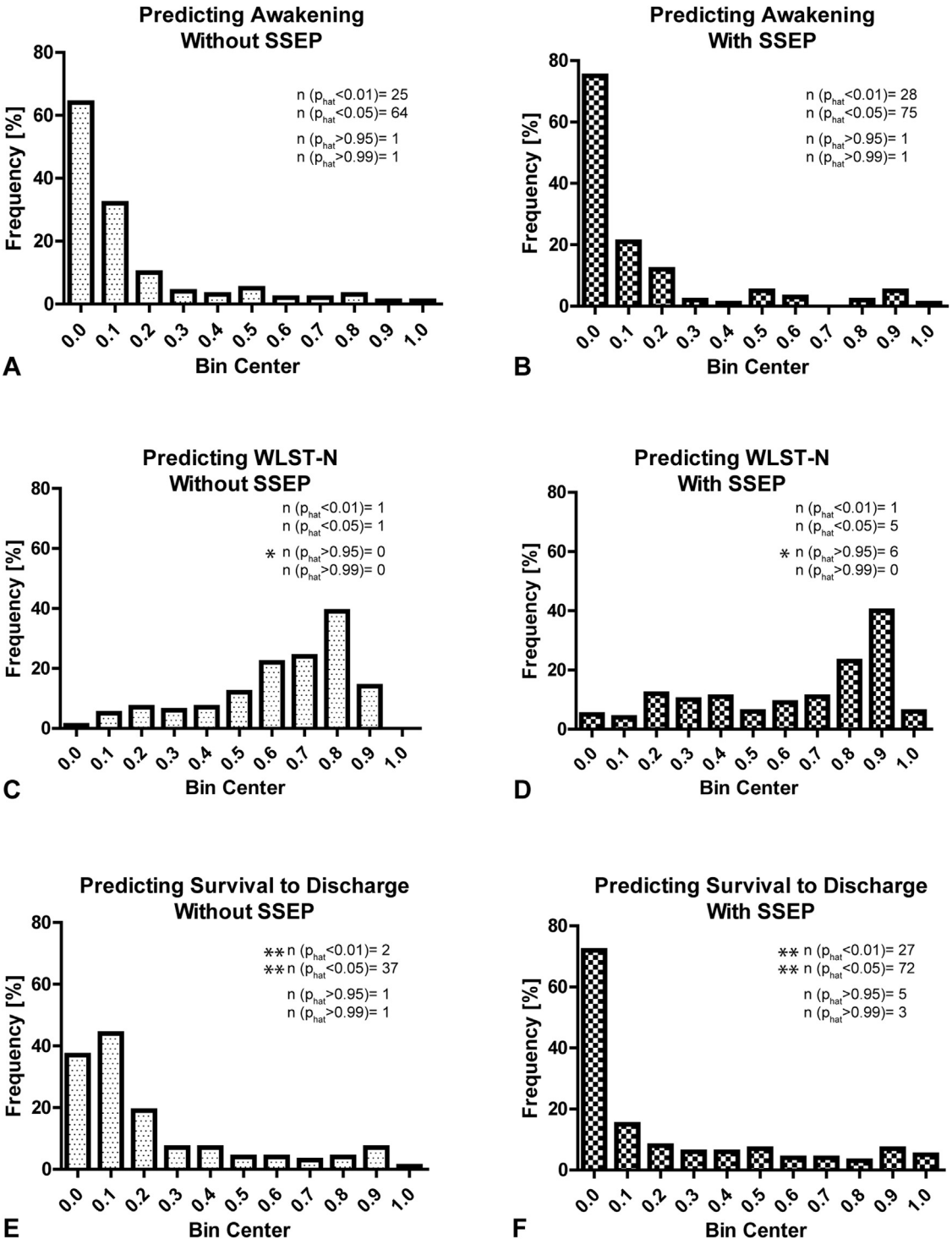

Fig. 2 – Histogram of predicted probability of outcomes in models that exclude Median-SSEP (A, C, E) or include Median-SSEP (B, D, F). Outcomes include awakening and following commands (A, B), WLST due to neurological outcome (C, D) and survival to discharge (E, F). A shift in bin center toward either 0.0 or 1.0 is seen when SSEP testing affects the prediction model. Insets demonstrate number of patients with predicted probabilities less than 1% and 5%, or more than 95% and 99%. Test of proportions revealed that including Median-SSEP significantly increases number of patients with more than 95% probability of WLST due to perceive poor neurological outcome (C, D; *$p < 0.05$). Including Median-SSEP also significantly increases the number of patients with less than 1% or 5% probability of survival to discharge (E, F; **$p < 0.01$).

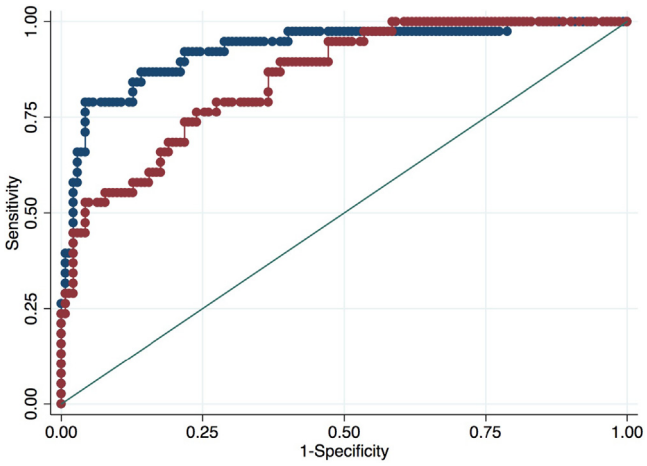

Fig. 3 – ROC curve for the survival model with (blue circles) and without (red circles) use of SSEP. AUC improved from 0.85 to 0.93 with inclusion of SSEP (p = 0.006) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

survival to discharge (Fig. 2E,F) towards 0, demonstrating an association of SSEP with awakening and survival. Adding SSEP did not increase the proportion of patients with less than 1% and 5% of awakening (Insets in Fig. 2A,B). However, the addition of SSEP increased the proportion of patients with less than 1% and 5% chance of survival (Insets in Fig. 2E,F). Including SSEP increased the proportion of patients with over 95% chance of WLST-N (Insets in Fig. 2C,D). Including SSEP in the model to predict survival increased the AUC from 0.85 to 0.93 (p = 0.006; Fig. 3).

Discussion

In our cohort, SSEP test results predicted awakening, survival and WLST-N. Incorporating the presence of N20 cortical responses into prior knowledge improves prediction of survival and WLST but not awakening. This study uniquely demonstrates that even after consideration of early post-arrest illness severity, clinical and demographic factors, and neurological examination, knowledge of SSEP results changes the post-test probability of favorable outcomes, particularly in the subset of patients with extremely low predicted survival to hospital discharge. This is especially significant in light of the patient population tested in this observational study: those patients already considered to be at the margins of predicted outcome (e.g. too sick or too well for outcome to be deemed uncertain by expert clinicians) were not included in our analysis. As noted in Fig. 1, roughly 1/3 of patients have high diagnostic certainty at day 3 when SSEP testing may be completed in our facility. Of those with diagnostic uncertainty, the majority receive SSEP testing. Absence of SSEP N20 in those patients (61%; 86 from 141 patients) was associated with rare patient awakening (1%). Thus, in practice it appears in our cohort that SSEP testing may have been used as a final confirmatory test of poor predicted prognosis before WLST in most patients.

The intermediate group without SSEP testing (Group 2) demonstrated higher survival and a longer length of stay (LOS) than in the intermediate group with SSEP testing (Group 3). Group 2 had more shockable rhythms and a lower illness severity on hospital arrival, suggesting a more viable cohort that clinicians were willing to give additional time for recovery. The rate of WLST-N was comparable between Groups 2 and 3, while the length of stay in non-survivors was shorter in patients with SSEP. There was a good overlap between clinical exam findings and electrophysiological responses, however, in one patient with good motor and verbal exam no N20 response was recorded. Presence of N20 despite absence of brainstem reflexes was more prevalent and observed in 8 patients, which may be described by anatomic separation of medial lemnisci and cranial nerves pathways.

As with all retrospective studies, we are limited by not all patients having SSEP testing. Similar to the TTM study group, not all patients require this modality.[14] However, these data demonstrate how a clinical group has tailored testing to a cohort with high likelihood of the test changing care. When considering neurologic prognosis, the possibility of a self-fulfilling prophecy always remains. Comatose patients included in this study comprised a wide spectrum of clinical exam reactivity, and although categorizing patients and limiting analysis to group 3 aims to provide a more homogenous group for analysis, heterogeneity still remains and must be taken into consideration before any generalization. The median LOS for those receiving SSEP testing was 7 (IQR 5, 13) days suggesting against rapid WLST-N commonly found in this population.[2] We note that our local practice is to pursue multiple testing modalities including serial examinations, CT imaging of the brain, EEG as well as SSEP and BAEP testing. Interpretations of the current results should be made within the constraints of a single-center retrospective study. Future studies should consider SSEP testing in cohorts of indeterminate prognosis (Groups 2 and 3) to determine if further refinement of prognosis is achieved in a larger cohort.

Conclusions

When incorporated to a multimodal prognostic model, bedside SSEP testing is associated with changes in the probability of survival and WLST-N, but not awakening.

Conflicts of interest

PM: None. JE: Reports grants from NINDS, during the conduct of the study. MH: None. PDT: None. DJC: None. CWC: None. JRB: None. JCR: Reports grants from Mallinkrodt, LLC, grants from BrainCools, LLC, outside the submitted work.

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Appendix A. Supplementary data

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REFERENCES

1. Benjamin EJ, Blaha MJ, Chiuve SE, et al. Heart Disease and Stroke Statistics-2017 Update: A Report From the American Heart Association. Circulation 2017;135:e146–603.
2. Elmer J, Torres C, Aufderheide TP, et al. Association of early withdrawal of life-sustaining therapy for perceived neurological prognosis with mortality after cardiac arrest. Resuscitation 2016;102:127–35.
3. Luyt CE, Galanaud D, Perlbarg V, et al. Diffusion tensor imaging to predict long-term outcome after cardiac arrest: a bicentric pilot study. Anesthesiology. 2012;117:1311–21.
4. Sandroni C, Cariou A, Cavallaro F, et al. Prognostication in comatose survivors of cardiac arrest: an advisory statement from the European Resuscitation Council and the European Society of Intensive Care Medicine. Resuscitation 2014;85:1779–89.
5. Youn CS, Callaway CW, Rittenberger JC. Post Cardiac Arrest S. Combination of initial neurologic examination, quantitative brain imaging and electroencephalography to predict outcome after cardiac arrest. Resuscitation 2017;110:120–5.
6. Zandbergen EG, Hijdra A, Koelman JH, et al. Prediction of poor outcome within the first 3 days of postanoxic coma. Neurology 2006;66:62–8.
7. Wijdicks EF, Hijdra A, Young GB, Bassetti CL, Wiebe S. Quality Standards Subcommittee of the American Academy of N. Practice parameter: prediction of outcome in comatose survivors after cardiopulmonary resuscitation (an evidence-based review): report of the Quality Standards Subcommittee of the American Academy of Neurology. Neurology 2006;67:203–10.
8. Calderon LM, Guyette FX, Doshi AA, Callaway CW, Rittenberger JC. Post Cardiac Arrest S. Combining NSE and S100B with clinical examination findings to predict survival after resuscitation from cardiac arrest. Resuscitation 2014;85:1025–9.
9. Rittenberger JC, Guyette FX, Tisherman SA, DeVita MA, Alvarez RJ, Callaway CW. Outcomes of a hospital-wide plan to improve care of comatose survivors of cardiac arrest. Resuscitation 2008;79:198–204.
10. Rittenberger JC, Popescu A, Brenner RP, Guyette FX, Callaway CW. Frequency and timing of nonconvulsive status epilepticus in comatose post-cardiac arrest subjects treated with hypothermia. Neurocrit Care 2012;16:114–22.
11. Coppler PJ, Elmer J, Calderon L, et al. Validation of the Pittsburgh Cardiac Arrest Category illness severity score. Resuscitation 2015;89:86–92.
12. Rittenberger JC, Raina K, Holm MB, Kim YJ, Callaway CW. Association between Cerebral Performance Category, Modified Rankin Scale, and discharge disposition after cardiac arrest. Resuscitation 2011;82:1036–40.
13. Endisch C, Storm C, Ploner CJ, Leithner C. Amplitudes of SSEP and outcome in cardiac arrest survivors: A prospective cohort study. Neurology 2015;85:1752–60.
14. Dragancea I, Horn J, Kuiper M, et al. Neurological prognostication after cardiac arrest and targeted temperature management 33 degrees C versus 36 degrees C: Results from a randomised controlled clinical trial. Resuscitation 2015;93:164–70.