Background Frequency Patterns in Standard Electroencephalography During Targeted Temperature Management as an Early Prognostic Tool in Out-of-Hospital Cardiac Arrest Survivors: a retrospective cohort study

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Abstract

Background

Electroencephalography is a widely used tool for detecting epileptiform and assessing neurological outcomes after cardiac arrest. We investigated the prognostic value of standard electroencephalography during early post-cardiac arrest period and evaluated the performance of electroencephalography findings combined with other clinical features for predicting good outcome.

Methods

This observational registry-based study was conducted at tertiary care hospital in Korea. Data of all consecutive adult comatose out-of-hospital cardiac arrest survivors who underwent electroencephalography during targeted temperature management between 2010 and 2018 were extracted. Electroencephalography findings, classified according to the American Clinical Neurophysiological Society critical care electroencephalography terminology, and good neurologic outcome-related clinical features were identified via multivariable logistic analysis.

Results

Good outcomes were observed in 36.5% of 170 patients. Median electroencephalography time was 22.0 hours. Electroencephalography background, voltage and other findings (burst suppression, reactivity to pain stimuli) significantly differed between good and poor outcome groups. Electroencephalography background with dominant alpha and theta waves had the highest odds ratio of 9.8 (95% confidence interval 3.9-24.9) in multivariable logistic analysis. Electroencephalography background frequency enabled identification of a good neurologic outcome (sensitivity, 83.87%; specificity, 75.93%). Combination of other clinical features (age<65 years, initial shockable rhythm, resuscitation duration<20 min) with electroencephalography findings increased predictive
performance for good neurologic outcomes (sensitivity, 95.2%; specificity, 100%).

Conclusions
Background frequency patterns of standard electroencephalography during targeted
temperature management may play a role as an early prognostic tool in out-of-hospital
cardiac arrest patients.

INTRODUCTION
Hypoxic-ischaemic brain injury is common after resuscitation from cardiac arrest (CA).
Most out-of-hospital cardiac arrest (OHCA) survivors are initially unconscious at hospital
admission [1, 2], and they undergo intensive post-resuscitation care including targeted
temperature management (TTM) [3]. Despite substantial allocations of medical resources,
the overall outcomes of OHCA remain dismal, with only 8.3% survivors with a good
neurological outcome and eligible for discharge [4]; furthermore, withdrawal of life-
sustaining therapy (WSLT) owing to perceived poor neurological prognosis is a leading
cause of death [5–7]. Multimodal approach and delayed timing (after > 72 h) of
prognostication has been recommended to minimise the possibility of inaccurate WSLT for
patients who demonstrate a change in neurological recovery [3]. However, one of the most
pressing issues for relatives and healthcare workers is to rapidly obtain reliable
information regarding the probability of achieving favourable neurological outcomes.
Although numerous studies have focused on discovering factors for poor neurologic
outcome, it is essential to develop strategies for predicting good neurologic outcomes
among OHCA survivors in order to appropriately tailor medical therapies for each patient.
Electroencephalography (EEG) in post-CA patients has been used for dual purposes:
detection of seizure activity in the early stage of TTM and prognostication of neurological
outcomes. The current guideline describes the prognostic role of standard EEG at ≥ 72
hours after CA [3]. However, recent studies have reported the feasibility of using EEG as
an early prognostic tool for OHCA survivors [5, 8, 9]. Continuous EEG monitoring provides more real-time information than standard intermittent EEG; however, its requirement for an extensive amount of medical resources and timely unavailability are major limitations in clinical practice [9, 10]. Moreover, its prognostication value has not yet reached a consensus because the reliability of EEG has been limited by varying classification systems and inter-rater variability. Thus, American Clinical Neurophysiology Society (ACNS) recently proposed a standardised EEG terminology that can be suitably used for critically ill patients after CA [11].

Here, the objective was to investigate the prognostic value of standard intermittent EEG during early post-CA period based on the standardised ACNS terminology [11] and evaluate the performance of EEG findings combined with other clinical features for predicting good outcome.

METHODS

Study design and patients

This retrospective, observational, registry-based cohort study was conducted at the emergency intensive care unit (ICU) of a tertiary care university-affiliated teaching hospital in Korea. Data were extracted from OHCA registry containing prospectively collected data of consecutive adult patients (≥ 18 years) with OHCA since January 2010 [12]. The Institutional Review Board of the University of Ulsan College of Medicine reviewed and approved the study protocol (No. 2019 – 1883), and informed consent was waived because of the retrospective nature of the study.

We included comatose patients with successfully resuscitated non-traumatic OHCA who were subjected to TTM between January 2010 and December 2018 and underwent routine EEG during TTM period [within 72 h after return of spontaneous circulation (ROSC)]. We
excluded patients who could not undergo EEG assessment within 72 h after ROSC or who showed poor-quality EEG data. All patients were followed up for 1 month after experiencing CA and were also subjected to neurologic assessment according to Cerebral Performance Category (CPC) score.

Management and data collection

All patients were treated according to the then-current advanced cardiac life support guidelines.[3, 13] TTM was performed for all unconscious patients using Arctic Sun Energy Transfer Pad (Medivance Corp., Louisville, CO, USA), and the target temperature (33°C or 36°C) was maintained for 24 h. After 24 h, patients were rewarmed at a rate of 0.25°C/h following the maintenance of normothermia for 72 h after ROSC. The temperature was monitored using an oesophageal temperature probe. A combination of midazolam, propofol and remifentanil was used for sedation and analgesia. If necessary, a neuromuscular blocking agent was administered to control shivering. Patients with seizure activity observed on electroencephalograms were treated with valproate or levetiracetam. Standard EEG examination was performed as soon as possible after ICU admission, but it was delayed whenever the patient was admitted to ICU on weekends or after daytime between 8 AM and 6 PM on weekdays owing to practical issues. A 30-min scalp EEG was performed by the Stellate EEG system in which 21 electrodes placed according to the international 10–20 electrode system (Fp1-2, F7-8, T7-8, P7-8, F3-4, C3-4, P3-4, O1-2, Fz, Cz, Pz), with a sampling rate of 200 Hz and a 0.1-Hz high-pass filter. All patients received standard intensive care according to institutional protocol. WSLT was legally prohibited in South Korea during the study period.

Demographic and clinical data, including age, sex, previous medical history, resuscitation profiles such as the presence of a witness during collapse, initially documented rhythm, resuscitation duration and interventions performed in Emergency Department, were
obtained. Two board-certified epileptologists (M.K., Y.S.K) reviewed and interpreted EEG recordings, blinded to the outcome. Background EEG were categorised according to the predominant frequency (alpha, theta, delta waves; Fig. 1), voltage (attenuation or suppressed, < 10 uV; low voltage, 10–20 uV; normal; >20 uV), others (reactivity, stage II sleep transients, burst suppression or burst attenuation) and superimposed findings such as sporadic epileptiform were also assessed according to ACNS guidelines [11]. Discontinuous background (10–49% periods of suppression/attenuation or 50–99% periods of suppression or attenuation with burst suppression/attenuation) with attenuated/suppressed voltage or burst suppression/attenuation categorized to undetermined frequency. All discordant EEG findings were discussed until a consensus was reached. The primary endpoint was a good neurological outcome at 1 month defined as a Cerebral Performance Category score of 1 (no significant impairment) or 2 (moderate impairment but able to complete activities of daily living).

Statistical analysis

Because of a non-normal distribution, continuous variables are presented as median values with interquartile ranges (IQRs) using Kolmogorov-Smirnov test. Categorical variables are expressed as an absolute number and percentage. The patients were categorised into two groups based on their CPC scores at 1 month: a good neurologic outcome group (CPC 1 and 2) and a poor neurologic outcome group (CPC 3–5). Comparisons of demographic and clinical characteristics between the good and poor neurologic outcome groups were performed using Mann-Whitney U-test for continuous variables and Chi-square test for categorical variables. Clinical features and EEG findings of potential prognostic value were first examined at baseline using univariate logistic analysis, with a cut-off p value of < 0.05. We selected significant variables on the basis of clinical judgment. Age of < 65 years, resuscitation duration of < 20 min, initial shockable
rhythm, predominant background EEG frequency (alpha and theta waves vs. delta and undetermined waves), suppressed voltage (all activity, < 10 μV), burst suppression or burst attenuation and reactivity to pain stimuli were candidates for the multivariable model, and these variables were assessed using multiple logistic regression analysis.[11, 14] The results of the multivariate logistic regression analyses were summarised by estimating the odds ratios (ORs) and 95% confidence intervals (CI). The Hosmer-Lemeshow test for logistic regression model was performed. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for good neurological outcome at 1 month were calculated. Two-tailed p values of < 0.05 were considered to be statistically significant. All statistical analyses were performed using IBM SPSS for Windows, version 21.0 (IBM Corp., Armonk, NY, USA).

RESULTS

A total of 172 non-traumatic comatose OHCA survivors who underwent standard intermittent EEG during TTM were admitted during the study period; of them, 2 were excluded because of poor-quality ECG data (Fig. 2). Thus, 170 patients were ultimately included in the study. Patients were categorised into the good (n = 62, 36.5%) and poor (n = 108, 63.5%) neurological outcome groups, respectively.

The demographic and clinical characteristics of the patients are summarised in Table 1. The median patient age was 60.0 years, and two-thirds of them were males (66.5%). Median EEG time after ROSC was 22.0 [12.8–40.3] h. The patients in the good neurologic outcome group were younger (median, 54.5 vs. 62.0 years; p = 0.002) and had a higher rate of initial shockable rhythm (69.4% vs. 21.3%; p < 0.001) as well as a higher likelihood of having a witnessed CA (85.5% vs. 68.5%; p = 0.014). Flow time did not differ statistically between the two groups (median, 0.0 vs. 0.0 min, p = 0.617), but resuscitation duration was shorter in the good neurologic outcome group (median, 12.0 vs. 27.0 min, p
Among continuous or nearly continuous background pattern (54.7%), alpha and theta waves were more prevalent in the good neurologic outcome group in contrast to the delta wave. Undetermined background activity was predominant in the poor neurologic outcome group (Table 2; p < 0.001). Majority of patients in the good neurologic outcome group had normal voltage (83.9%). Burst suppression/burst attenuation and reactivity to pain stimuli were detected in < 20% of the total study patients (12.9% and 16.5%, respectively), but there were significant differences between the good and poor neurologic groups (4.8% vs. 17.6%; p = 0.017 for burst suppression/burst attenuation; 27.4% vs. 10.2%; p = 0.004 for reactivity to pain stimuli).

### Table 1

Demographic and clinical characteristics of out-of-hospital cardiac arrest patients subjected to targeted temperature management according to neurologic outcome at 1 month.

| Characteristics                  | Total (n = 170) | Good neurologic outcome (n = 62) | Poor neurologic outcome (n = 108) | p value |
|----------------------------------|----------------|---------------------------------|----------------------------------|---------|
| Age, years                       | 60.0 (45.8–71.0) | 54.5 (39.0–64.3)               | 62.0 (49.0–73.0)               | 0.002   |
| Age < 65 years                   | 107 (62.9%)     | 47 (75.8%)                      | 60 (55.6%)                      | 0.008   |
| Male                             | 113 (66.5%)     | 44 (71.0%)                      | 69 (63.9%)                      | 0.347   |
| Previous medical history         |                |                                 |                                 |         |
| Hypertension                     | 58 (34.1%)      | 15 (24.2%)                      | 43 (39.8%)                      | 0.039   |
| Diabetes mellitus                | 43 (25.3%)      | 9 (14.5%)                       | 34 (31.5%)                      | 0.014   |
| Acute myocardial infarction      | 8 (4.7%)        | 2 (3.2%)                        | 6 (5.6%)                        | 0.712   |
| Congestive heart failure         | 12 (7.1%)       | 7 (11.3%)                       | 5 (4.6%)                        | 0.125   |
| Chronic kidney disease           | 20 (11.8%)      | 4 (6.5%)                        | 16 (14.8%)                      | 0.103   |
| Malignancy                       | 13 (7.6%)       | 3 (4.8%)                        | 10 (9.3%)                       | 0.379   |
| Arrest characteristics           |                |                                 |                                 |         |
| Presence of a witness            | 127 (74.7%)     | 53 (85.5%)                      | 74 (68.5%)                      | 0.014   |
| Bystander CPR                    | 120 (70.6%)     | 44 (71.0%)                      | 76 (70.4%)                      | 0.934   |
| Initial shockable rhythm         | 66 (38.8%)      | 43 (69.4%)                      | 23 (21.3%)                      | < 0.001 |
| No flow time, min                | 0.0 (0.0–3.0)   | 0.0 (0.0–3.0)                   | 0.0 (0.0–3.8)                   | 0.617   |
| Resuscitation duration, min      | 22.0 (10.0–35.3) | 12.0 (6.8–23.0)              | 27.0 (16.0–40.0)              | < 0.001 |
| Time from ROSC to target temperature, hours | 5.4 (3.9–7.4) | 5.8 (4.8–7.3) | 5.1 (3.8–7.5) | 0.134 |
| Time from ROSC to EEG, hours     | 22.0 (12.8–40.3) | 20.0 (10.8–34.5)            | 23.0 (14.3–49.3)               | 0.145   |

Values are expressed as median (interquartile ranges) or n (%) as appropriate.

CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; EEG, electroencephalography.
| EEG findings                        | Total (n = 170) | Good neurologic outcome (n = 62) | Poor neurologic outcome (n = 108) | p value |
|------------------------------------|-----------------|----------------------------------|-----------------------------------|---------|
| **Background frequency**           |                 |                                  |                                   | < 0.001|
| Dominant alpha waves               | 61 (35.9%)      | 37 (59.7%)                       | 24 (22.2%)                        |         |
| Dominant theta waves               | 17 (10.0%)      | 15 (24.2%)                       | 2 (1.9%)                          |         |
| Dominant delta waves               | 15 (8.8%)       | 2 (3.2%)                         | 13 (12.0%)                        |         |
| Undetermined                       | 77 (45.3%)      | 8 (12.9%)                        | 69 (63.9%)                        |         |
| **Background voltage**             |                 |                                  |                                   | < 0.001|
| Attenuation or suppressed (< 10 uV)| 64 (37.6%)      | 5 (8.1%)                         | 59 (54.6%)                        |         |
| Low voltage (10–20 uV)             | 13 (7.6%)       | 5 (8.1%)                         | 8 (7.4%)                          |         |
| Normal (> 20 uV)                   | 93 (54.7%)      | 52 (83.9%)                       | 41 (38.0%)                        |         |
| **Other background findings**      |                 |                                  |                                   |         |
| Burst suppression/burst attenuation| 22 (12.9%)      | 3 (4.8%)                         | 19 (17.6%)                        | 0.017   |
| Reactivity to pain stimuli         | 28 (16.5%)      | 17 (27.4%)                       | 11 (10.2%)                        | 0.004   |
| Stage II Sleep transients          | 9 (5.3%)        | 6 (9.7%)                         | 3 (2.8%)                          | 0.075   |
| Sporadic epileptiform discharge    | 14 (8.2%)       | 4 (6.5%)                         | 10 (9.3%)                         | 0.522   |

Values are expressed as n (%).

In univariate analysis, age, initial shockable CA rhythm, presence of a witness during CA, resuscitation duration and EEG findings, such as predominant background EEG frequency and voltage, burst suppression or burst attenuation and reactivity to pain stimulus, were associated with good neurologic outcome. After multivariate logistic regression analysis, age of < 65 years (adjusted OR, 2.930; 95% CI, 1.131–7590; p = 0.027), initial shockable CA rhythm (adjusted OR, 9.698; 95% CI, 3.683–25.537; p < 0.001), < 20-min resuscitation duration (adjusted OR, 4.087; 95% CI, 1.528–10.931; p = 0.005) and EEG background with dominant alpha and theta waves (adjusted OR, 9.800; 95% CI, 3.851–24.941; p < 0.001) were associated with good neurologic outcome at 1 month (Table 3).
The presence of EEG background with dominant alpha and theta waves predicted good neurologic outcomes with a sensitivity of 83.87%, a specificity of 75.93%, a positive predictive value of 66.67% and a negative predictive value of 89.13% (Table 4). The performance of EEG findings in combination with other clinical features for the prediction of good outcomes was summarised in Table 4. The dominant presence of alpha and theta waves observed on EEG within 72 h of ROSC or OHCA along with an initial shockable CA rhythm predicted good neurologic outcomes with a sensitivity of 95.16% and a specificity of 62.04%. The presence of all the four criteria predicted good neurologic outcomes with a specificity of 100.0% and a positive predictive value of 100.0%.
Table 4
Predictive value of clinical and electroencephalography findings for good neurologic outcome.

| EEG pattern and clinical features | Good neurologic outcome (n = 62) | Poor neurologic outcome (n = 108) | Sensitivity | Specificity | PPV | NPV | Accuracy |
|-----------------------------------|----------------------------------|-----------------------------------|-------------|-------------|-----|-----|----------|
| EEG pattern                       | 52                               | 26                                | 83.87%      | 75.93%      | 66.67% | 89.13% | 78.82%   |
| EEG pattern or initial rhythm     | 59                               | 41                                | 95.16%      | 62.04%      | 59.00% | 95.71% | 74.12%   |
| EEG pattern and initial rhythm    | 36                               | 8                                 | 58.06%      | 92.59%      | 81.82% | 79.37% | 80.00%   |
| EEG pattern and initial rhythm and age | 27                             | 4                                 | 43.55%      | 96.30%      | 87.10% | 74.82% | 77.06%   |
| EEG pattern and initial rhythm and resuscitation duration | 21                             | 4                                 | 33.87%      | 96.30%      | 84.00% | 71.72% | 73.53%   |
| EEG pattern and initial rhythm and age and resuscitation duration | 17                             | 0                                 | 27.42%      | 100.00%     | 100.00% | 70.59% | 73.53%   |

EEG pattern: background frequency with dominant alpha and theta waves; initial rhythm: initial shockable rhythm; age: age of < 65 years; resuscitation duration: resuscitation duration of < 20 min.

DISCUSSION

The present study adds to the current understanding regarding the use of EEG as an early prognostic tool after OHCA. Standard EEG examination revealed that 45.9% (78/170) of the non-traumatic OHCA survivors had dominant alpha and theta waves, and the presence of these EEG findings indicated a good neurologic outcome with a sensitivity of 83.87% and a negative predictive value of 89.13% during the early period. Furthermore, EEG findings combined with other clinical features, including age, shockable rhythm and resuscitation duration, led to an increase in predictive performance for good neurologic outcomes, with a sensitivity of 95.2% and a specificity of 100%.

EEG is very sensitive for detecting hypoxic and ischemic brain injury, widely available, non-invasive and has a robust body of evidence supporting its utility for prognostic purposes [14, 15]. EEG findings in post-CA patients, such as burst suppression, low
voltage (< 20 µV), lack of reactivity and sporadic epileptiform features, have been suggested to be prognostic tools [16–21]. Recently, literatures have suggested that in certain carefully selected patient subsets, aggressive invasive management may improve outcomes. Thus, it is essential to develop a technique for identifying patients who may have a chance of neurological recovery after experiencing OHCA. However, previous observational studies have focused on the identification of EEG findings, such as myoclonic jerks and burst suppression, for poor neurologic outcome with a low false positive rate and have given rise to concerns of confirmation bias, also known as self-fulfilling prophecy [3]. This is particularly important since WLS is a leading cause of death in post-CA patients. In this registry-based study, we included all consecutive comatose OHCA survivors who underwent EEG during TTM from areas where WSLT was legally prohibited.

We determined that EEG findings of predominant alpha and theta waves, absence of a low voltage, non-existence of burst suppression and reactivity to pain stimulus showed a significant association with good neurologic outcome in univariable logistic regression analysis [19]. However, after adjusting for other clinical prognostic features including age, initial CA rhythm and resuscitation duration, only the detection of dominant alpha and theta waves on a standard electroencephalogram was a significant prognostic finding for good neurologic outcome (adjusted OR, 9.800; 95% CI, 3.851–24.941; p < 0.001).

Although EEG is a commonly used ancillary test for neurological prognosis after CA, the use of different classification systems and inter-rater variability, including reproducibility and reliability, serve as limitations [22]. Thus, the standardised classification of EEG findings as either highly malignant, malignant or benign patterns based on the ACNS terminology appears to improve EEG prognostic accuracy [19]. However, published data focusing on the background EEG frequency of early standard EEG in an era of early TTM is
The background of EEG is suppressed at a cerebral blood flow rate of < 10 mL/100 g of brain tissue/min [23]. The ongoing brain oscillatory activities occurring during the resting state represent dynamic changes in the brain, while the integrity of corticothalamic circuits reflects the degree of brain damage [23]. Here, our strategy for evaluating the predominant background EEG frequency, categorised into generalised delta activity of 1–3 cycles per second (Hz), theta activity of 4–7 Hz and alpha activity of 8–12 Hz, was simple and relatively objective. The dominant alpha and theta waves showed a good neurologic outcome with a sensitivity of 83.87% and a negative predictive value of 89.13% in the early period. It has been proposed that a single theta (5–7 Hz) wave is produced when a low level of afferent input to neocortical neurons gives rise to spontaneous oscillations of Layer V pyramidal cells at this frequency, thereby indicating an initial stage of improvement in corticothalamic integrity [24, 25]. Alpha (8–12 Hz) is linked to normal, tonic firing mode of the thalamus, which represents normal integrity of the corticothalamic circuit. Our results are consistent with the reports of previous EEG spectral analysis-based studies on CA survivors, which revealed that the patients who showed the presence of alpha and theta frequency bands while undergoing continuous EEG monitoring after CA had favourable outcome as opposed to the patients with a lower frequency band [26, 27]. In line with these studies, we identified three clinical factors, namely age of < 65 years (adjusted OR, 2.930; 95% CI, 1.131–7590), initial shockable rhythm (adjusted OR, 9.698; 95% CI, 3.683–25.537) and resuscitation duration of < 20 min (adjusted OR, 4.087; 95% CI, 1.528–10.931), that were associated with good neurologic outcomes at 1 month. Patients with EEG findings or shockable initial rhythm are predicted to have a good neurologic outcome with a sensitivity of 95.2%, whereas those with EEG findings as well as the three above-mentioned clinical factors are predicted to have a good neurologic outcome with a specificity of 100%. Our findings suggested that a
combination of findings of early standard EEG during TTM and the three clinical features could have practical implications in the identification of comatose OHCA survivors with good neurologic outcomes.

LIMITATIONS
The results of our study should be interpreted in the context of the following limitations. First, the timing of standard EEG examination could affect the outcome. Although at our centre, standard EEG is usually performed as soon as possible after ICU admission, the median EEG examination period was 22 h because of its unavailability on a 24/7 basis. Nevertheless, our heterogeneous EEG timing during TTM reflected the real-world situation and can be generalizable to other settings. Second, although sedation policies and treating physicians remained unchanged, the likelihood of clinically important EEG findings and transitions or different effects of drugs, including sedative agents and antiepileptic drugs, should be considered. Third, the long study period between 2010 and 2018 accompanied by changes in treatment guidelines might affect the outcome of OHCA survivors. Fourth, this study was based on data from a single institution and had an observational study design, which limited generalisation and gave rise to an unmeasurable confounding bias. Finally, despite our sample size being relative larger than that of previous studies, there was an inevitably high potential of random effect generation resulting from a small sample.

CONCLUSION
This study demonstrated that standard intermittent EEG findings of predominant background frequency during the early post-CA period could be an early prognostic tool to identify patients with good neurologic outcomes. Furthermore, a combination of EEG findings and three other clinical features (age < 65 years, initial shockable rhythm and
resuscitation duration of < 20 min) has practical implications for early prognostication of good neurologic outcome. Further prospective multi-centre studies are warranted to validate the predictive value of early standard intermittent EEG findings proposed in this study.

Abbreviations

ACNS
American Clinical Neurophysiology Society
CA
cardiac arrest
CI
confidence interval
CPC
Cerebral Performance Category
EEG
electroencephalography
ICU
intensive care unit
IQR
interquartile ranges
NPV
negative predictive value
OHCA
out-of-hospital cardiac arrest
OR
odds ratio
PPV
positive predictive value
TTM
targeted temperature management
WSLT
withdrawal of life-sustaining therapy
Declarations

**Ethics approval and consent to participate**

The Institutional Review Board of the University of Ulsan College of Medicine reviewed and approved the study protocol (No. 2019-1883), and informed consent was waived because of the retrospective nature of the study.

**Consent for publication**

Not applicable.

**Availability of data and materials**

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Competing interests**

None of the authors have potential conflicts of interest to be disclosed.

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**Authors' contributions**

YJK, and WYK designed the study; YJK, MK, YSK and WYK collected the data; YJK, MK and WYK analyzed the data; YJK, MK, YSK and WYK interpreted the data; YJK, MK and WYK wrote the paper; and all authors reviewed and approved the final manuscript.

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Figures
Figure 1

Example of predominant background electroencephalography frequency in out-of-hospital cardiac arrest survivors subjected to targeted temperature management.

(A) predominant alpha waves, (B) predominant theta waves, (C) predominant delta waves, (D) undetermined background electroencephalography.
Adult non-traumatic Out-Of-Hospital Cardiac Arrest patients treated with TTM who underwent EEG within 72 hours after ROSC (N=172)

→ Poor EEG quality (N=2)

Study Patients (N=170)

Good neurologic outcome (N=62, 36.5%)

Poor neurologic outcome (N=108, 63.5%)

Figure 2

Patient flow diagram. Abbreviations: TTM, targeted temperature management; EEG, electroencephalography; ROSC, return of spontaneous circulation.