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Halaman judul
Halaman judul mencakup: a) judul manuskrip yang dibuat sesingkat mungkin, spesifik informatif dan ringkasan judul tidak lebih dari 40 karakter (hitung huruf dan spasi) yang dicantumkan dibawah judul, b) nama penulis disusun berurutan dengan nama mahasiswa sebagai pengarang pertama, diikuti oleh Pembimbing sebagai pengarang kedua. Nama penulis ditulis lengkap tanpa gelar dan dicantumkan seperti aslinya, tidak dibalik seperti pada daftar pustaka dan sitasi, c) alamat setiap penulis, nama departemen dan lembaga afiliasi penulis, d) nama dan alamat penulis untuk korespondensi serta nomor telepon, nomor faksimili, alamat email. Judul penelitian dibuat jelas, singkat, spesifik, informatif, dan sesuai dengan topik manuskrip. Jumlah kata tidak lebih dari 12 kata agar mudah dan cepat dipahami pembaca.

Abstrak dan kata kunci
Abstrak berjumlah 200-250 kata ditulis dalam bahasa Indonesia dan Inggris. Abstrak berisikan latar belakang termasuk tujuan penelitian, metode, hasil, dan kesimpulan. Kata kunci dicantumkan di bawah abstrak pada halaman yang sama sebanyak 4-6 kata. Bagian abstrak merupakan ringkasan dari isi makalah yang dibuat secara singkat, informatif, dengan menekankan pada aspek baru dan penting dari penelitian.

Teks
Teks makalah manuskrip dibagi dalam beberapa bagian dengan judul sebagai berikut: ***Pendahuluan, Metode, Hasil, Pembahasan, Kesimpulan dan saran.***

Pendahuluan
a. Latar belakang merupakan bagian yang menjelaskan alasan mengapa masalah ini penting untuk diteliti. Bagian ini memuat penjelasan mengapa masalah itu dipandang menarik, penting, dan perlu diteliti untuk mencari pemecahannya. Penjelasan dapat diperoleh dari penelusuran pustaka yang berkaitan erat dengan masalah yang diteliti.
b. Keaslian penelitian dikemukakan dengan menunjukkan bahwa masalah yang dihadapi belum pernah dipecahkan oleh peneliti terdahulu atau dinyatakan dengan tegas perbedaan penelitian ini dengan penelitian terdahulu.
c. Tujuan penelitian yang menjelaskan hasil yang akan dicapai.

Metode
Metode penelitian berisi uraian terpadu dan sistematis mengenai bagaimana penelitian akan dilaksanakan. Metode terdiri dari :
a. Desain
b. Populasi / sampel (subjek) penelitian
Diuraikan kriteria inklusi dan eksklusi subjek penelitian, cara pemilihan sampel (subjek penelitian) secara random atau non-random, serta besar sampel yang akan di pilih. Teknik pemilihan sampel harus dijelaskan secara rinci. Bila perlu dibuat alur pemilihan sampel.
c. Bahan dan alat serta pengukuran
Bahan dan alat yang harus disajikan pada laporan terbatas pada bahan (materi) dan alat utama yang diperlukan untuk penelitian dan harus disebutkan spesifikasinya. Prosedur pengukuran perlu dijelaskan sesuai dengan tahapan yang dilakukan.
d. Alur kerja penelitian
Jalannya penelitian perlu dijelaskan mengenai jenis pendekatan yang dipakai untuk
mendapatkan data, melalui pendekatan laboratorium, klinik, komunitas, observasi, dll.
e. Analisis data
Perlu dijelaskan jenis teknik statistik yang digunakan untuk menjawab masalah dan mencapat tujuan penelitian. Data yang diperoleh dapat dianalisis menggunakan teknik statistik secara parametrik dan non-parametrik.

Hasil
Suatu hasil penelitian hendaknya disajikan dengan jelas, logis, runut, sehingga mudah untuk dimengerti. Hasil penelitian sebaiknya ditampilkan selain dalam bentuk narasi dapat pula berupa gambar, tabel, foto, dan grafik sehingga memudahkan untuk dipahami. Hasil dan interpretasi analisis statistik dituliskan secara jelas dalam uraian hasil penelitian.
Pada tahap awal disajikan distribusi karakteristik subjek penelitian, yang biasanya dibuat pada sebuah tabel. Kemudian disajikan temuan penting yang diperoleh, kalau cukup banyak sebaiknya pada sebuah tabel. Bila terbatas misalkan hanya satu atau dua temuan cukup dalam bentuk narasi/teks.
Tabel, bagan/gambar, grafik dibuat dengan jelas, diberi nomor urut serta keterangan yang jelas. Keterangan

tabel diletakan di atas tabel dan keterangan gambar diletakkan di bawah gambar. Maksimal tabel dan gambar 5. Semua tabel, grafik dan gambar diberi nomor dan keterangan yang jelas. Setiap tabel dianalisis dan diinterpretasi secara sistematik, dan hasilnya ditulis di bawah tabel tersebut. Perhitungan statistik detail tidak perlu ditulis dalam bagian hasil ini. Bila perhitungan statistik dianggap perlu ditulis, maka sebaiknya diletakkan dalam lampiran saja.

Pembahasan
Langkah awal harus diuraikan temuan penting yang diperoleh dari penelitian sesuai dengan tujuan penelitian. Kemudian bandingkan hasil penelitian yang diperoleh dengan hasil-hasil penelitian sebelumnya. Perlu dijelaskan kesesuaian dan ketidaksesuaian hasil penelitian yang didapat terhadap kerangka teori atau hasil penelitian lain yang telah dilakukan sebelumnya. Selanjutnya menggunakan teori-teori yang ada uraikan mekanisme terjadinya hasil penelitian tersebut. Bagian pembahasan juga menjelaskan mengenai kelemahan dan kelebihan penelitian yang telah dilakukan. Uraikan implikasi dari hasil penelitian yang diperoleh.

Kesimpulan
Kesimpulan hendaknya dibuat dalam bentuk narasi dan menguraikan secara singkat, jelas, padat menurut urutan yang sistematis. Bagian ini memuat tentang hasil penelitian yang telah diperoleh untuk menjawab tujuan penelitian. Saran menguraikan perlunya dilakukan penelitian lebih lanjut untuk memperbaiki kelemahan/ keterbatasan dari penelitian yang telah dilakukan.

Ucapan terima kasih
Ditujukan kepada pihak-pihak yang memberikan bantuan dana dan dukungan antara lain dukungan dari bagian dan lembaga, para professional yang memberikan kontribusi dalam penyusunan makalah, dan untuk penguji I maupun penguji II. Pembimbing tidak perlu dicantumkan pada Ucapan Terima Kasih karena sudah dicantumkan sebagai penulis.

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Daftar referensi/rujukan hanya mencatumkan rujukan yang telah digunakan dan ditulis menurut sistem Vancouver.

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3. Setelah terdaftar silakan unggah naskah manuskrip dan isi form yang terdapat di dalam website, dan ikuti langkah selanjutnya.

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□ File manuskrip harus berformat OpenOffice, Ms. Word atau RTF dokumen, *font* 12, *Times New Roman, double spacing.*
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□ Pelaporan data manuskrip dari penelitian yang melibatkan manusia dan hewan memerlukan persetujuan formal (kaji etik) oleh dewan peninjau atau komisi etik institusi yang bersangkutan.
□ Daftar rujukan memuat semua rujukan yang terdapat di dalam manuskrip dan ditulis sesuai urutan pengutipannya menggunakan sistem Vancouver.

Daftar Isi

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CASE REPORT

Case Series: EEG Patterns and Neurological Outcomes Following Return of Spontaneous Circulation (ROSC)

Serial Kasus: Pola EEG dan Hubungannya dengan Luaran Pasien Pasca-Kembalinya Sirkulasi Spontan (ROSC)

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ABSTRACT

Return of spontaneous circulation after cardiopulmonary resuscitation is often followed by hypoxic-ischemic brain injury, which may affect neurological recovery. Electroencephalography (EEG) is commonly used to evaluate brain function and prognosis in these patients. EEG patterns can be classified into benign, malignant, and highly malignant categories, which reflect the severity of brain injury. Objective of this study was to evaluate the relationship between EEG patterns and clinical outcomes in patients after return of spontaneous circulation. This case series included six patients who underwent EEG examination more than 24 hours after cardiac arrest. EEG findings were classified according to the Westhall classification and compared with clinical outcomes using the Cerebral Performance Category (CPC) scaler The Results were Four patients showed highly malignant EEG patterns, including electrocerebral inactivity or continuous suppression, and all had poor outcomes (CPC 4–5). Two patients with benign EEG patterns had relatively better outcomes (CPC 3–4). No patient achieved good neurological recovery (CPC 1–2). Low EEG reactivity was observed in all cases, and amplitudes below 10 μV were mostly found in patients with CPC 5. Highly malignant EEG patterns were strongly associated with poor neurological outcomes after return of spontaneous circulation. EEG may be useful as part of a multimodal approach for prognostic evaluation in post-cardiac arrest patients.

Keywords: CPC; EEG; Encephalopathy; ROSC.

ABSTRAK

LKembalinya sirkulasi spontan setelah resusitasi jantung paru sering diikuti oleh cedera otak hipoksik-iskemik yang dapat memengaruhi pemulihan neurologis. Elektroensefalografi (EEG) sering digunakan untuk menilai fungsi otak dan prognosis pada pasien-pasien ini. Pola EEG dapat diklasifikasikan menjadi kategori jinak, ganas, dan sangat ganas yang mencerminkan derajat cedera otak. Tujuan artikel ini adalah Mengevaluasi hubungan antara pola EEG dan luaran klinis pada pasien pasca-kembalinya sirkulasi spontan. Serial kasus ini mencakup enam pasien yang menjalani pemeriksaan EEG lebih dari 24 jam setelah henti jantung. Temuan EEG diklasifikasikan berdasarkan klasifikasi Westhall dan dibandingkan dengan luaran klinis menggunakan skala Cerebral Performance Category (CPC). Hasilnya adalah empat pasien menunjukkan pola EEG sangat ganas (*electrocerebral inactivity* atau supresi kontinu) dan seluruhnya memiliki luaran buruk (CPC 4–5). Dua pasien dengan pola EEG jinak menunjukkan luaran yang relatif lebih baik (CPC 3–4). Tidak ada pasien dengan CPC 1 atau 2. Reaktivitas EEG rendah ditemukan pada seluruh kasus, dan amplitudo di bawah 10 μV terutama ditemukan pada pasien dengan CPC Pola EEG sangat ganas berhubungan kuat dengan luaran neurologis buruk setelah kembalinya sirkulasi spontan. EEG dapat bermanfaat sebagai bagian dari pendekatan multimodal dalam evaluasi prognosis pasien pasca-henti jantung.

Kata Kunci: CPC; EEG; Encephalopati ROSC.

INTRODUCTION

Return of spontaneous circulation (ROSC) after cardiopulmonary resuscitation (CPR) marks the beginning of a complex recovery process in cardiac arrest patients and is frequently followed by hypoxic-ischemic encephalopathy (HIE), a major cause of poor neurological outcomes. To assess neurological prognosis in comatose patients after ROSC, the American Heart Association (AHA) recommends electroencephalography (EEG) as one of the prognostic tools. EEG allows direct evaluation of brain activity and may help predict neurological recovery, with its prognostic value considered optimal around 24 hours after cardiac arrest, while serial monitoring may provide additional information.[1-7]

The use of EEG for neurological prognostication after cardiac arrest has evolved over several decades. Since the introduction of standardized EEG terminology by the American Clinical Neurophysiology Society (ACNS), several classification systems have been developed to improve prognostic interpretation in post-ROSC patients. Among these, the Westhall classification proposed in 2016 is commonly used by categorizing EEG findings into highly malignant, malignant, and benign patterns based on standardized EEG features from ACNS terminology.[4,8-12]

Highly malignant EEG patterns include suppressed background without discharges, suppressed background with continuous periodic discharges, and burst-suppression with or without discharges. Malignant patterns include abundant periodic discharges, electrographic seizures, discontinuous or low-voltage background activity, reversed anterior–posterior gradient, and absent EEG reactivity. The absence of malignant features defines benign EEG patterns.[8-10]

The International Liaison Committee on Resuscitation (ILCOR) recommends the modified Rankin Scale (mRS) for neurological prognostication after ROSC; however, the Cerebral Performance Category (CPC) scale is more commonly used in post-ROSC studies. CPC classifies outcomes into five categories: CPC 1 indicates full recovery or no significant neurological deficit; CPC 2 indicates moderate disability with preserved limited independence; CPC 3 indicates severe disability requiring assistance with daily activities; CPC 4 indicates a persistent vegetative state or severe disability requiring full support; and CPC 5 indicates death.[6,13]

Given the high risk of HIE in post-ROSC patients, understanding specific EEG patterns is important for clinical decision-making. Meanwhile, the use of EEG for prognostication in critically ill patients, including those after ROSC, remains limited in Indonesia. Through this case series, the authors aim to provide clinical insight into the importance of neurological prognostication in post-ROSC patients using EEG recordings.

CASE REPORT

Case 1

A 68-year-old man presented with decreased consciousness after severe dyspnea, which led to oxygen desaturation (43%), respiratory arrest, and subsequent cardiac arrest. Cardiopulmonary resuscitation was performed for 15 minutes until ROSC was achieved. His medical history included an ischemic stroke in 2019 with residual left-sided weakness and tracheostomy dependence. After ROSC, the patient developed seizures characterized by upward eye deviation and subtle left facial twitching. Additional comorbidities included hypertension for more than 10 years, recurrent strokes (brainstem hemorrhagic stroke in April 2023 and ischemic stroke in April 2024), and bilateral renal angiomyolipomas treated with embolization. Since April 2023, the patient had been bedridden and fully dependent on home care assistance. EEG was performed on the seventh day after ROSC. The EEG findings are presented in **Figure 1** and **Table 1.**

Following the latest hospitalization, the patient continued to have subtle seizures consisting of twitching at the right corner of the mouth without generalized convulsions. The patient's level of interaction after treatment was relatively preserved. Current antiseizure medications included diazepam 30 mg once daily, clonazepam 1 mg nightly, and levetiracetam 500–750 mg daily. Follow-up EEGs were performed three times, with the latest showing abnormal background slowing, low-voltage activity (attenuation and suppression), and bilateral frontal focal slowing.

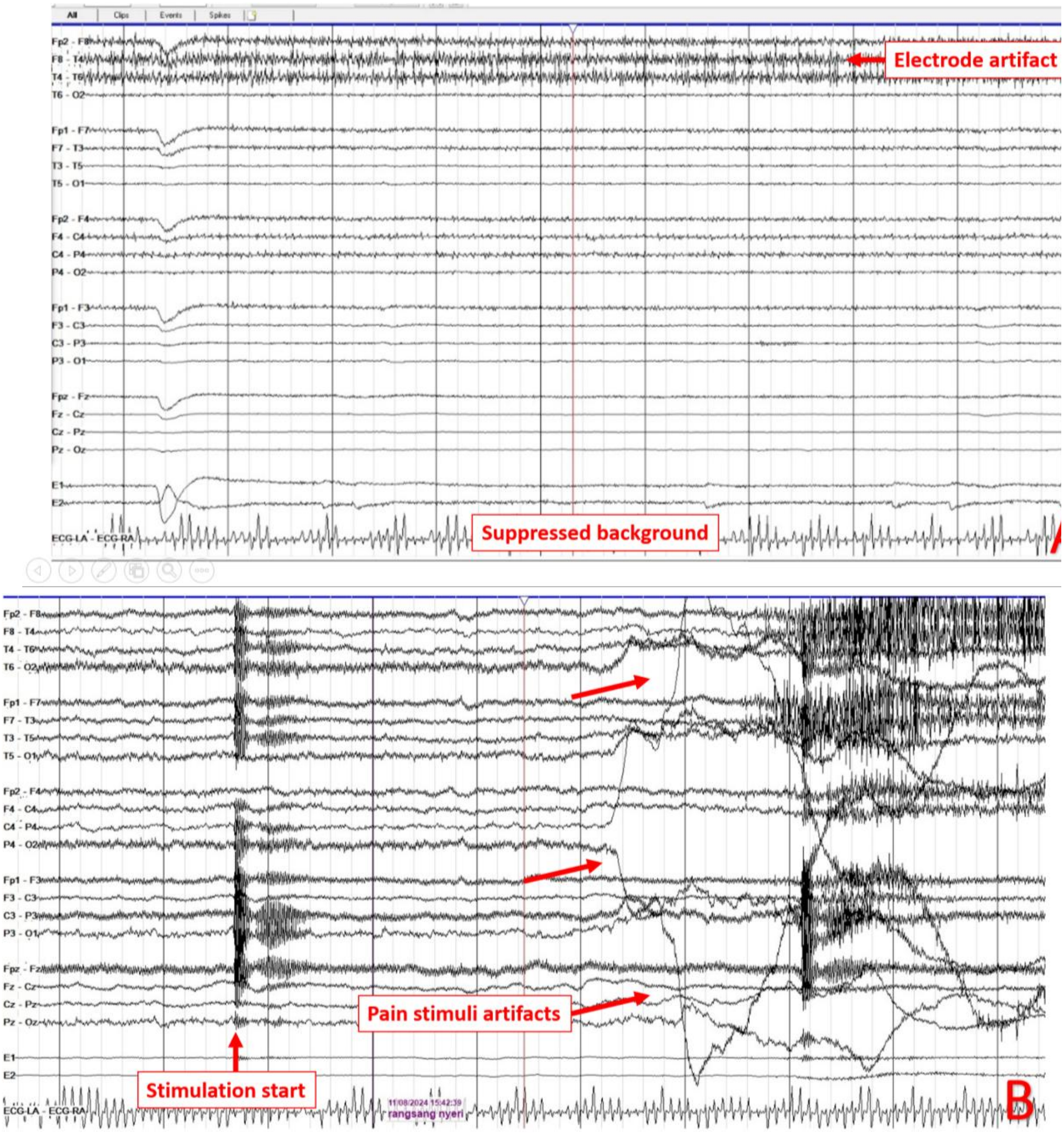


Figure 1. (a) EEG showing background suppression with an amplitude of 2 μV. (b) No brain-origin background reactivity was observed during painful stimulation. Timebase: 10 sec/page; low-frequency filter: 1 Hz; high-frequency filter: 70 Hz; notch filter: 50 Hz; sensitivity: 2 μV/mm.

Case 2

A 44-year-old man with a history of recurrent ROSC was referred after experiencing 11 episodes of cardiac arrest within 24 hours during hospitalization at a previous hospital. The patient had initially been admitted with a diagnosis of unstable angina pectoris and had undergone 26 days of ICU treatment. After discharge, he was brought to RSCM because his nasogastric tube became dislodged and he developed agitation. No seizures were observed before or after ROSC. During hospitalization, the patient's consciousness gradually improved, and he became able to respond to the examiner. EEG was performed approximately 1 month after ROSC (**Table 1**). The EEG findings are presented in **Figure 2.** The patient was not receiving any antiseizure medication.

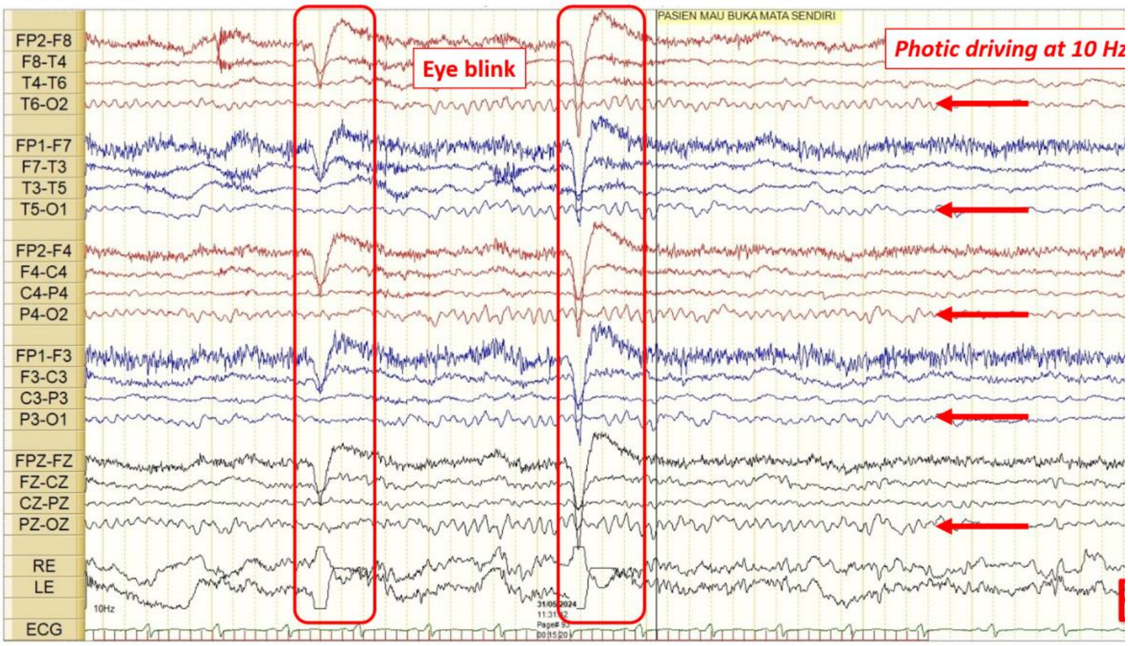


Figure 2. (a) Generalized slowing was observed. (b) Photic driving response was present during photic stimulation. Paper speed: 30 mm/sec; high-cut filter: 70 Hz; low-cut filter: 1 Hz; notch filter: on; sensitivity: 3 µV/mm.

Case 3

A 59-year-old woman experienced cardiac arrest on the second day of hospitalization at RSCM. She had initially presented with dyspnea for 2 days before admission and a 3-month history of abdominal pain. A retroperitoneal tumor suspicious for renal malignancy was suspected. During cardiac arrest, resuscitation was performed, and ROSC was achieved. Four days after ROSC, the patient developed episodes of upward eye deviation, lower limb stiffening, and subtle lip movements. These episodes partially improved after administration of 2 mg midazolam, although her level of consciousness remained unchanged. Antiseizure treatment included valproic acid at 30 mg/kgBW, which was later switched to topiramate because of elevated transaminase levels. EEG was performed on day 12 after ROSC, with findings shown in **Table 1**. The patient did not survive due to worsening complications after one month of hospitalization. The EEG findings are shown in **Figure 3**.

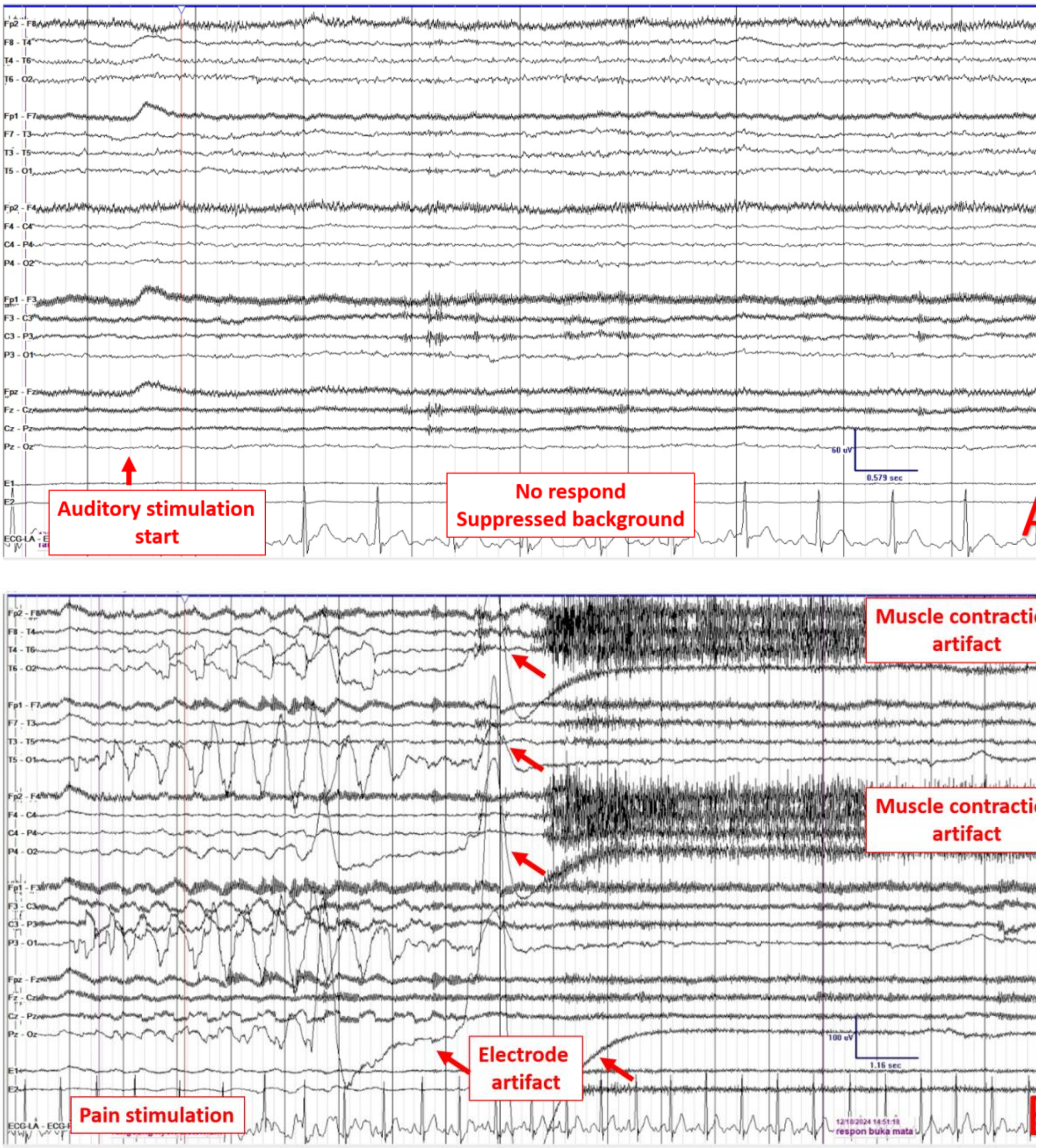
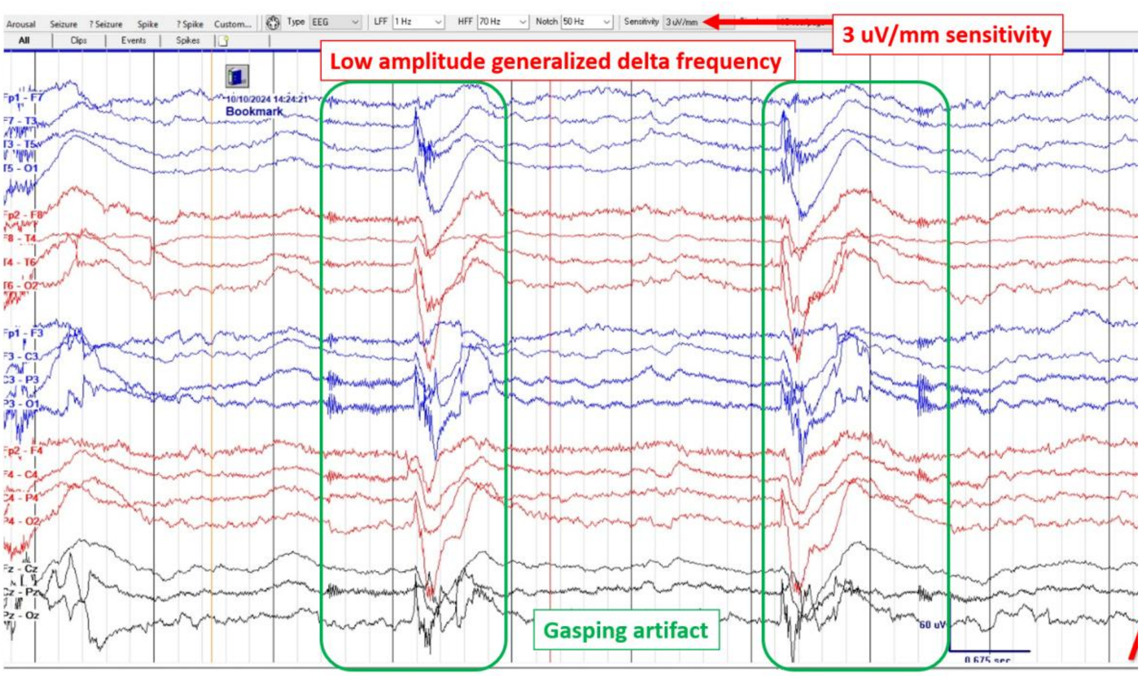


Figure 3. (a) Suppressed background rhythm with an amplitude up to 6 μV. (b) During painful stimulation, no brain-origin EEG reactivity was observed; however, prominent muscle

contraction artifacts were seen over the bilateral frontocentral regions. Timebase: 10 sec/page; low-frequency filter: 1 Hz; high-frequency filter: 70 Hz; notch filter: 50 Hz; sensitivity: 3 μV/mm.

Case 4

A 30-year-old woman experienced cardiac arrest following massive hemorrhage during cesarean section surgery at an outside hospital. Cardiopulmonary resuscitation (CPR) was performed, although the duration was unknown. ROSC was achieved, and the patient was treated in the ICU before being referred to RSCM for further management because bleeding persisted until the fourth day after ROSC. No seizures were observed during the clinical course. EEG was performed approximately 3 weeks after ROSC, with findings shown in Table 1. During EEG recording, the patient was unresponsive and exhibited gasping respiration. No antiseizure medication was administered. The patient did not survive after 21 days of ICU hospitalization.



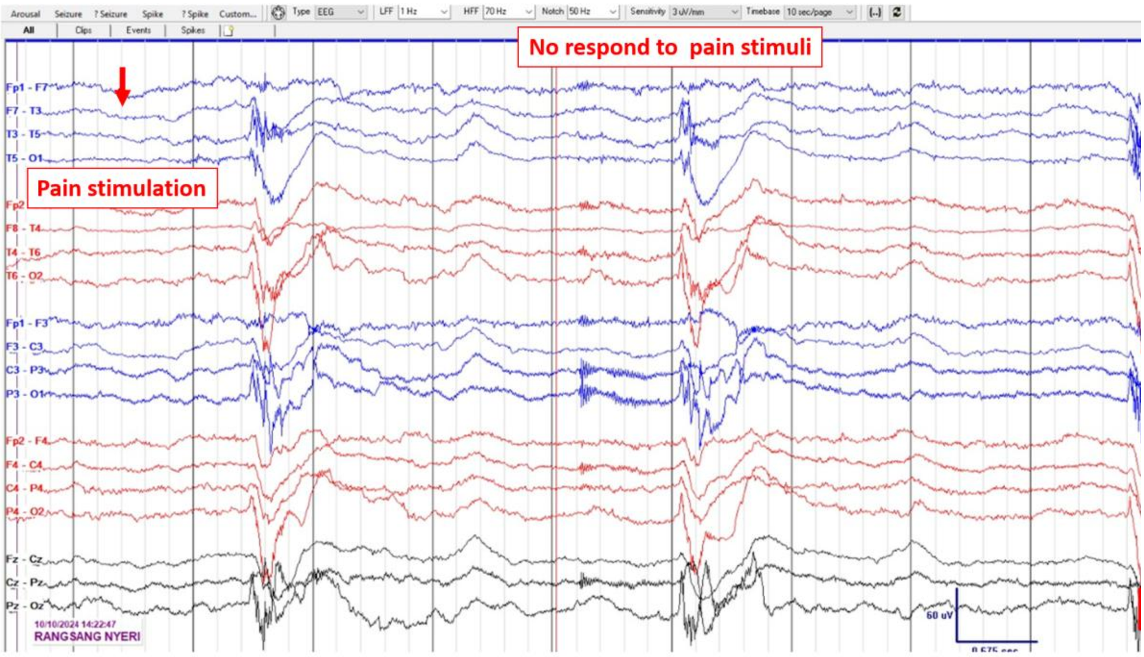


Figure 4. (a) Background activity showed low-amplitude delta slowing at 3–4 Hz (12 µV). (b) No EEG changes were observed during painful stimulation. Paper speed: 30 mm/sec; high-cut filter: 70 Hz; low-cut filter: 1 Hz; notch filter: on; sensitivity: 3 µV/mm.

Case 5

A 69-year-old woman was referred from an outside hospital after desaturation followed by cardiac arrest, requiring 45 minutes of resuscitation before ROSC was achieved. After ROSC, the patient was treated in the ICU for approximately 3 weeks before transfer to RSCM. Following referral, EEG was performed because of intermittent shivering-like movements associated with EEG waveform changes, which resolved after administration of midazolam. EEG was performed on day 20 after ROSC, with findings summarized and shown in **Figure 5** and **Table 1**. The patient had been treated with levetiracetam at the previous hospital and continued on 1000 mg twice daily due to suspected seizure activity. Levetiracetam was later tapered off after nonconvulsive status epilepticus (NCSE) was excluded. The patient was subsequently designated do-not-resuscitate (DNR) and did not survive after a total hospitalization of 1.5 months, entirely in the ICU.

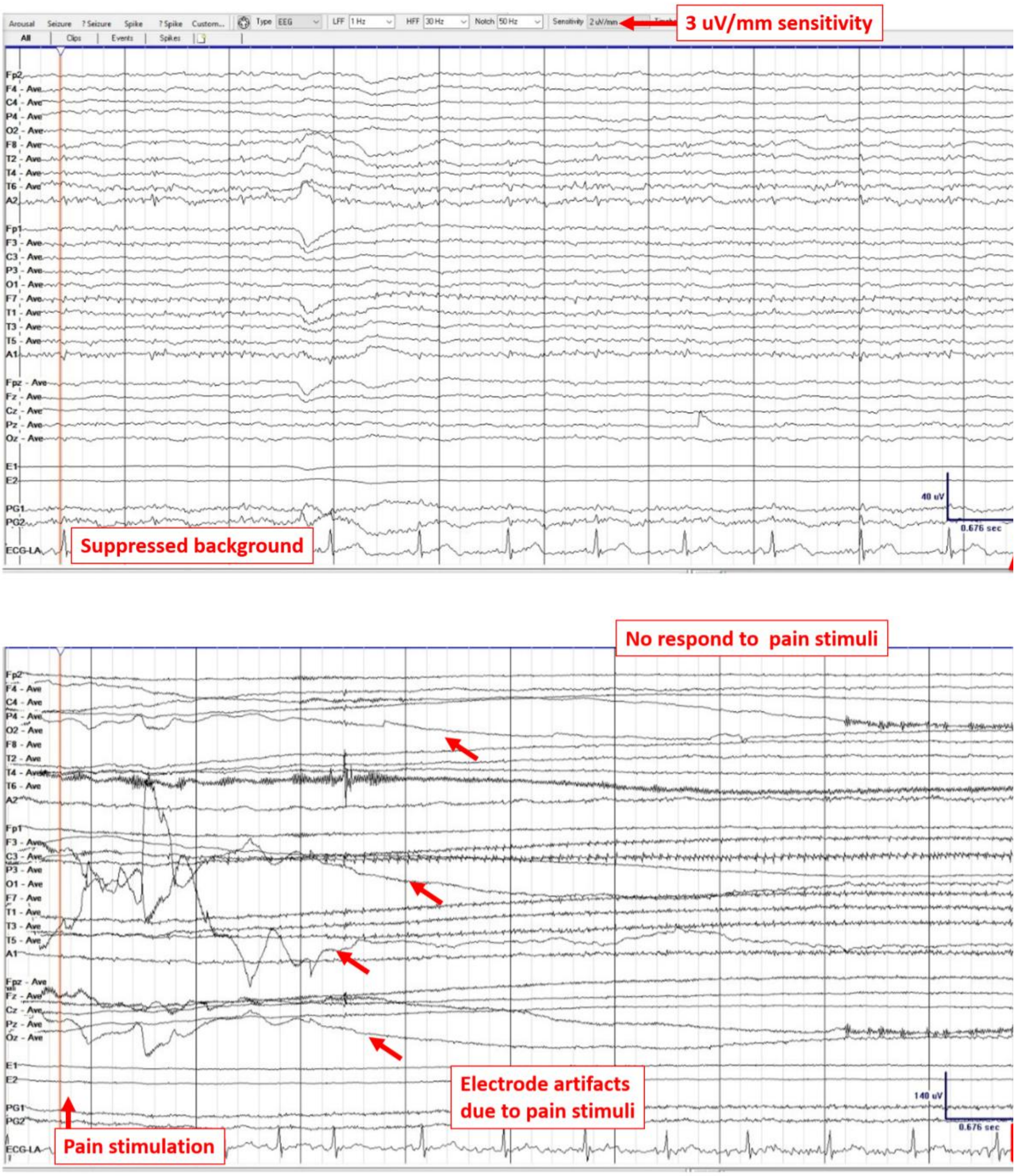


Figure 5. (a) Suppressed background rhythm with an amplitude of 2.36 µV. (b) No brain-origin EEG response was observed during painful stimulation. Timebase: 10 sec/page; high-frequency filter: 70 Hz; low-frequency filter: 1 Hz; notch filter: 50 Hz; sensitivity: 7 µV/mm.

Case 6

A 55-year-old woman underwent EEG after previously experiencing cardiac arrest and ROSC at an outside hospital. She had been hospitalized there for approximately 2.5 months before being transferred to RSCM. ROSC was achieved after 23 minutes of resuscitation. EEG was performed for prognostic evaluation because the patient remained inadequately responsive despite relatively normal metabolic parameters. The patient was eventually discharged with a tracheostomy. At discharge, she exhibited spontaneous eye opening and awareness of her surroundings. However, responses were minimal, limited to eye contact with the examiner during stimulation testing performed as part of the EEG examination (details shown in **Table 1**). No. antiseizure medication was administered. The EEG findings are presented in **Figure 6.**

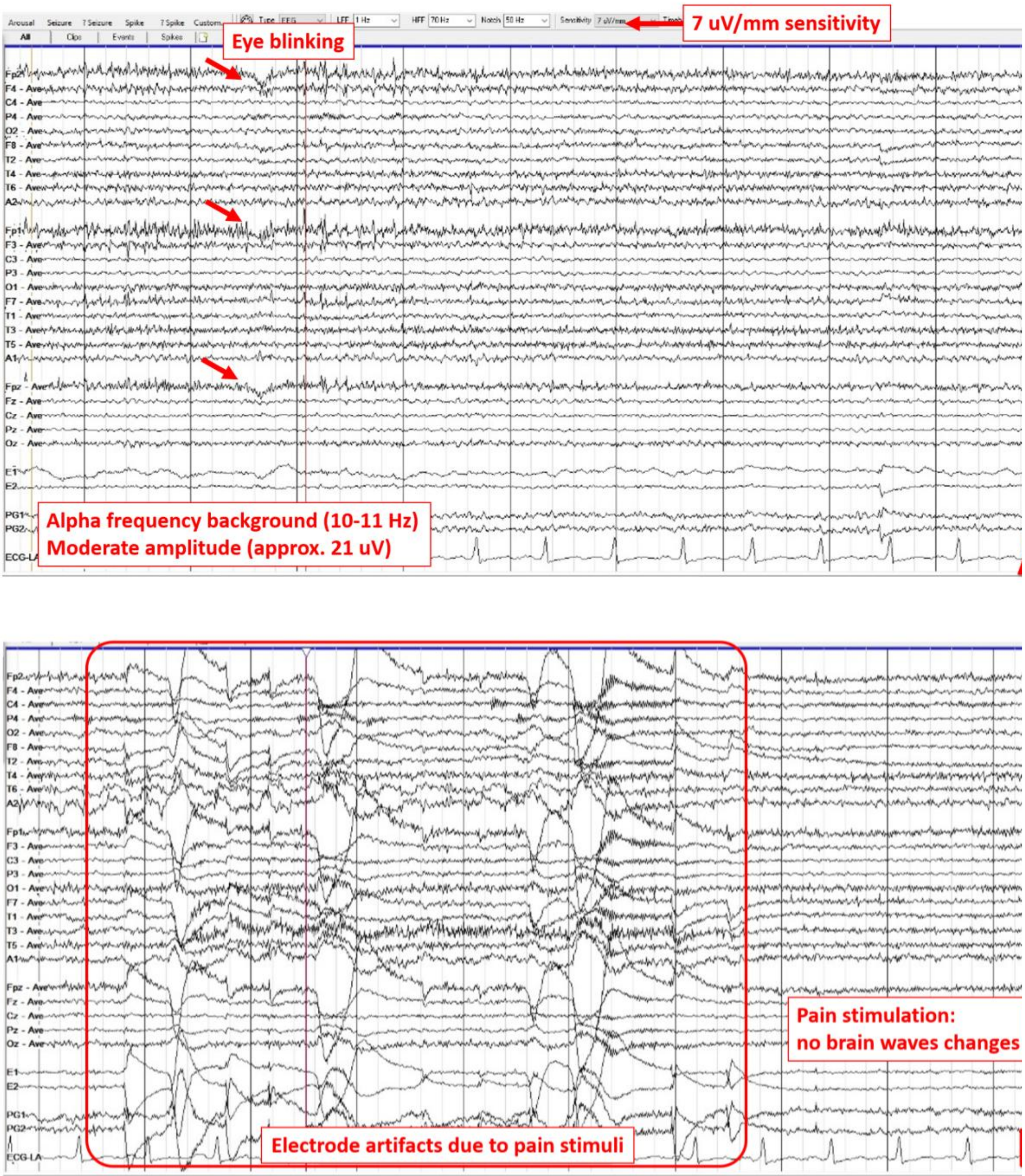


Figure 6. (a) Background activity consisted of symmetric bilateral alpha waves at 10–11 Hz with an amplitude of 21 μV. Eye-opening and eye-closing reactivity was difficult to assess. (b) During painful stimulation, no EEG changes indicative of brain activity were observed; however, the patient responded clinically with slight flexion of both arms. Timebase: 10 sec/page; low-frequency filter: 1 Hz; high-frequency filter: 70 Hz; notch filter: 50 Hz; sensitivity: 7 μV/mm.

Table 1. Post-ROSC Patient Characteristics and EEG Findings

Case	1	2	3	4	5	6
Age / Sex	68 / M	44 / M	59 / F	30 / F	69 / F	55 / F
GCS during EEG	E3 M4 Vtrach	E3–4 M6 Vtrach	E2 M1 Vett	E1 M1 Vett	E1 M2 Vtrach	E4 M5 Vtrach
EEG Timing after ROSC	>24 h	>24 h	>24 h	>24 h	>24 h	>24 h
ICU Stay	21 days	>30 days	30 days	21 days	>30 days	>30 days
CPC Score	CPC 4	CPC 3	CPC 5	CPC 5	CPC 5	CPC 4
EEG Follow-up	Yes	No	No	No	No	No
Background Amplitude	<2 µV	21 µV	6 µV	12 µV	2.36 µV	21 µV
Background Frequency	Theta 4–5 Hz	Theta–alpha 6–8 Hz	Delta 2–3 Hz	Delta 3–4 Hz	Theta 4 Hz	Alpha 10–11 Hz
Symmetry	Symmetric	Symmetric	Symmetric	Symmetric	Symmetric	Symmetric
EEG/Clinical Reactivity	No eye-opening/closing reactivity. No background change or burst after stimulation	Eye-opening/closing reactivity present. No background change after stimulation	No eye-opening/closing reactivity. No background change after stimulation	No eye-opening/closing reactivity. No background change after stimulation	No eye-opening/closing reactivity. No EEG change after stimulation, but minimal clinical response to pain	Eye-opening/closing reactivity difficult to assess. No background change after stimulation
Burst Suppression	(-)	(-)	(-)	(-)	(-)	(-)
Periodic Discharges	(-)	(-)	(-)	(-)	(-)	(-)
Electroclinical Inactivity	(+)	(-)	(+)	(-)	(-)	(-)
Epileptiform Pattern	(-)	(-)	(-)	(-)	(-)	(-)
Slowing Pattern	General slowing	Bilateral frontotemporal delta slowing, left predominance	General slowing	General slowing	General slowing	General slowing
EEG Conclusion	ECI	Bilateral frontotemporal slowing	ECI	General slowing	Continuous suppression with minimal response to pain stimulation	Alpha coma
EEG Severity Classification	Highly malignant	Benign	Highly malignant	Benign	Highly malignant	Benign

DISCUSSION

To our knowledge, reports regarding EEG-based prognostication post-ROSC remain limited in Indonesia. Most published studies on post-ROSC EEG prognostication are large-cohort studies from Europe and North America, while detailed case-based reports from Southeast Asia remain scarce. This case series highlights the practical role of EEG in predicting neurological outcomes among critically ill post-ROSC patients.[7,13] This case series also demonstrates a broad spectrum of EEG abnormalities, ranging from benign to highly malignant patterns, including electroclinical inactivity (ECI), continuous suppression, generalized slowing, and alpha coma.

Highly malignant EEG patterns include suppressed background without discharges, suppressed background with continuous periodic discharges, and burst-suppression with or without discharges. Malignant patterns include abundant periodic discharges, electrographic seizures, discontinuous or low-voltage background activity, reversed anterior–posterior gradient, and absent EEG reactivity. The absence of malignant features defines benign EEG patterns.[8,10]

Among the six patients, four showed low-voltage background activity in the form of suppression (Cases 1, 3, and 5) or attenuation (Case 4). Suppressed background activity (<10 μV) is recognized as an indicator of poor neurological outcome. However, it is important to note that EEG may become isoelectric or suppressed within 10–40 seconds after cardiac arrest and can persist during the first 24 hours; therefore, suppression should not be used alone to predict poor prognosis.[6,9,11]

Current guidelines from the European Resuscitation Council (ERC) and the European Society of Intensive Care Medicine (ESICM) recommend a multimodal approach for neurological prognostication at 72 hours after ROSC, incorporating clinical examination, electrophysiological studies, biomarkers such as neuron-specific enolase (NSE), and neuroimaging.[6,14,15]

In this series, all EEG recordings were obtained more than 24 hours after ROSC, and none were obtained within the recommended 24–72-hour prognostic window. Therefore, findings such as suppression or electroclinical inactivity (ECI) in these patients may more reliably indicate poor neurological outcomes. Previous studies have shown that absence of EEG improvement within the first 24 hours is strongly associated with poor prognosis. In contrast, recovery toward continuous physiological rhythms within the first 12 hours is generally associated with more favorable neurological outcomes.[7,9,10]

None of the six patients demonstrated burst-suppression or discontinuous background activity. Continuous EEG background activity is generally considered a favorable prognostic sign after ROSC. According to the American Clinical Neurophysiology Society (ACNS), discontinuity refers to alternating periods of attenuation or suppression with higher-voltage activity. Nevertheless, discontinuity alone cannot fully predict the extent of brain injury.[11]

Assessment of EEG reactivity can be performed using auditory, visual, and tactile stimulation by evaluating changes in EEG amplitude or frequency. In all six cases, no clinically significant EEG reactivity was observed. Previous large studies reported that the absence of EEG reactivity has a specificity of approximately 82% and a sensitivity of 73% for predicting poor neurological outcomes.[5,6,11,16-18]

In our series, EEG findings ranged from benign to highly malignant patterns according to the Westhall classification. Highly malignant patterns, in the form of ECI and continuous suppression, consistently correlated with poor neurological outcomes (CPC 4–5). Similarly, previous cohort studies have demonstrated that highly malignant EEG patterns are strongly associated with poor outcomes after cardiac arrest. Nolan et al. (2021) reported that highly malignant EEG patterns demonstrated approximately 42% sensitivity and nearly 100% specificity for predicting poor neurological outcomes (CPC 3–5). Several other studies have also shown that the absence of EEG reactivity, suppressed background activity, and persistent discontinuity are associated with poor prognosis.[5,11,13,16-18]

In contrast, benign EEG patterns in our patients were still associated with relatively unfavorable outcomes (CPC 3–5), which differs somewhat from larger cohort studies, where benign EEG patterns are more commonly associated with favorable neurological recovery (CPC 1–2). This discrepancy may reflect differences in the severity of systemic illness, prolonged ICU treatment, delayed EEG acquisition, and other confounding clinical factors within our patient population.

Limitations

An important limitation of this series is the delayed timing of EEG recordings, as all EEG examinations were performed more than 3 days after ROSC. Other confounding factors, including preexisting neurological disease, metabolic abnormalities, structural lesions, duration of ICU care, and delayed EEG acquisition, may also have affected the results. However, interpretation of EEG reactivity still shows considerable interobserver variability, limiting its consistency in clinical practice. Furthermore, this report represents a small case series and therefore cannot fully represent the broader post-ROSC population

CONCLUSION

In summary, this case series supports prior findings that highly malignant EEG patterns, particularly ECI and continuous suppression, are strongly associated with poor neurological outcomes after ROSC. Although benign EEG patterns may indicate a relatively better prognosis, neurological outcomes remain influenced by systemic conditions and overall disease severity. These findings support EEG as a valuable bedside tool for assessing recovery potential and guiding clinical management in post-cardiac arrest patients, particularly when integrated into a multimodal prognostic approach. Further studies with larger sample sizes and standardized EEG timing are needed to better clarify the prognostic value of EEG in post-ROSC patients.

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AUTHORS CONTRIBUTION

The authors performed data collection, EEG interpretation, and manuscript preparation. All authors reviewed and approved the final manuscript.

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Case Series: EEG Patterns and Neurological Outcomes Following Return of Spontaneous Circulation (ROSC)

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CASE REPORT

Case Series: EEG Patterns and Neurological Outcomes Following Return of Spontaneous Circulation (ROSC)

Serial Kasus: Pola EEG dan Hubungannya dengan Luaran Pasien Pasca-Kembalinya Sirkulasi Spontan (ROSC)

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ABSTRACT

Return of spontaneous circulation after cardiopulmonary resuscitation is often followed by hypoxic-ischemic brain injury, which may affect neurological recovery. Electroencephalography (EEG) is commonly used to evaluate brain function and prognosis in these patients. EEG patterns can be classified into benign, malignant, and highly malignant categories, which reflect the severity of brain injury. Objective of this study was to evaluate the relationship between EEG patterns and clinical outcomes in patients after return of spontaneous circulation. This case series included six patients who underwent EEG examination more than 24 hours after cardiac arrest. EEG findings were classified according to the Westhall classification and compared with clinical outcomes using the Cerebral Performance Category (CPC) scaler The Results were Four patients showed highly malignant EEG patterns, including electrocerebral inactivity or continuous suppression, and all had poor outcomes (CPC 4–5). Two patients with benign EEG patterns had relatively better outcomes (CPC 3–4). No patient achieved good neurological recovery (CPC 1–2). Low EEG reactivity was observed in all cases, and amplitudes below 10 μV were mostly found in patients with CPC 5. Highly malignant EEG patterns were strongly associated with poor neurological outcomes after return of spontaneous circulation. EEG may be useful as part of a multimodal approach for prognostic evaluation in post-cardiac arrest patients.

Keywords: CPC; EEG; Encephalopathy; ROSC.

ABSTRAK

LKembalinya sirkulasi spontan setelah resusitasi jantung paru sering diikuti oleh cedera otak hipoksik-iskemik yang dapat memengaruhi pemulihan neurologis. Elektroensefalografi (EEG) sering digunakan untuk menilai fungsi otak dan prognosis pada pasien-pasien ini. Pola EEG dapat diklasifikasikan menjadi kategori jinak, ganas, dan sangat ganas yang mencerminkan derajat cedera otak. Tujuan artikel ini adalah Mengevaluasi hubungan antara pola EEG dan luaran klinis pada pasien pasca-kembalinya sirkulasi spontan. Serial kasus ini mencakup enam pasien yang menjalani pemeriksaan EEG lebih dari 24 jam setelah henti jantung. Temuan EEG diklasifikasikan berdasarkan klasifikasi Westhall dan dibandingkan dengan luaran klinis menggunakan skala Cerebral Performance Category (CPC). Hasilnya adalah empat pasien menunjukkan pola EEG sangat ganas (*electrocerebral inactivity* atau supresi kontinu) dan seluruhnya memiliki luaran buruk (CPC 4–5). Dua pasien dengan pola EEG jinak menunjukkan luaran yang relatif lebih baik (CPC 3–4). Tidak ada pasien dengan CPC 1 atau 2. Reaktivitas EEG rendah ditemukan pada seluruh kasus, dan amplitudo di bawah 10 µV terutama ditemukan pada pasien dengan CPC Pola EEG sangat ganas berhubungan kuat dengan luaran neurologis buruk setelah kembalinya sirkulasi spontan. EEG dapat bermanfaat sebagai bagian dari pendekatan multimodal dalam evaluasi prognosis pasien pasca-henti jantung.

Kata Kunci: CPC; EEG; Encephalopati ROSC.

INTRODUCTION

Return of spontaneous circulation (ROSC) after cardiopulmonary resuscitation (CPR) marks the beginning of a complex recovery process in cardiac arrest patients and is frequently followed by hypoxic-ischemic encephalopathy (HIE), a major cause of poor neurological outcomes. To assess neurological prognosis in comatose patients after ROSC, the American Heart Association (AHA) recommends electroencephalography (EEG) as one of the prognostic tools. EEG allows direct evaluation of brain activity and may help predict neurological recovery, with its prognostic value considered optimal around 24 hours after cardiac arrest, while serial monitoring may provide additional information.[1-7]

The use of EEG for neurological prognostication after cardiac arrest has evolved over several decades. Since the introduction of standardized EEG terminology by the American Clinical Neurophysiology Society (ACNS), several classification systems have been developed to improve prognostic interpretation in post-ROSC patients. Among these, the Westhall classification proposed in 2016 is commonly used by categorizing EEG findings into highly malignant, malignant, and benign patterns based on standardized EEG features from ACNS terminology.[4,8-12]

Highly malignant EEG patterns include suppressed background without discharges, suppressed background with continuous periodic discharges, and burst-suppression with or without discharges. Malignant patterns include abundant periodic discharges, electrographic seizures, discontinuous or low-voltage background activity, reversed anterior–posterior gradient, and absent EEG reactivity. The absence of malignant features defines benign EEG patterns.[8-10]

The International Liaison Committee on Resuscitation (ILCOR) recommends the modified Rankin Scale (mRS) for neurological prognostication after ROSC; however, the Cerebral Performance Category (CPC) scale is more commonly used in post-ROSC studies. CPC classifies outcomes into five categories: CPC 1 indicates full recovery or no significant neurological deficit; CPC 2 indicates moderate disability with preserved limited independence; CPC 3 indicates severe disability requiring assistance with daily activities; CPC 4 indicates a persistent vegetative state or severe disability requiring full support; and CPC 5 indicates death.[6,13]

Given the high risk of HIE in post-ROSC patients, understanding specific EEG patterns is important for clinical decision-making. Meanwhile, the use of EEG for prognostication in critically ill patients, including those after ROSC, remains limited in Indonesia. Through this case series, the authors aim to provide clinical insight into the importance of neurological prognostication in post-ROSC patients using EEG recordings.

CASE REPORT

Case 1

A 68-year-old man presented with decreased consciousness after severe dyspnea, which led to oxygen desaturation (43%), respiratory arrest, and subsequent cardiac arrest. Cardiopulmonary resuscitation was performed for 15 minutes until ROSC was achieved. His medical history included an ischemic stroke in 2019 with residual left-sided weakness and tracheostomy dependence. After ROSC, the patient developed seizures characterized by upward eye deviation and subtle left facial twitching. Additional comorbidities included hypertension for more than 10 years, recurrent strokes (brainstem hemorrhagic stroke in April 2023 and ischemic stroke in April 2024), and bilateral renal angiomyolipomas treated with embolization. Since April 2023, the patient had been bedridden and fully dependent on home care assistance. EEG was performed on the seventh day after ROSC. The EEG findings are presented in **Figure 1** and **Table 1.**

Following the latest hospitalization, the patient continued to have subtle seizures consisting of twitching at the right corner of the mouth without generalized convulsions. The patient's level of interaction after treatment was relatively preserved. Current antiseizure medications included diazepam 30 mg once daily, clonazepam 1 mg nightly, and levetiracetam 500–750 mg daily. Follow-up EEGs were performed three times, with the latest showing abnormal background slowing, low-voltage activity (attenuation and suppression), and bilateral frontal focal slowing.

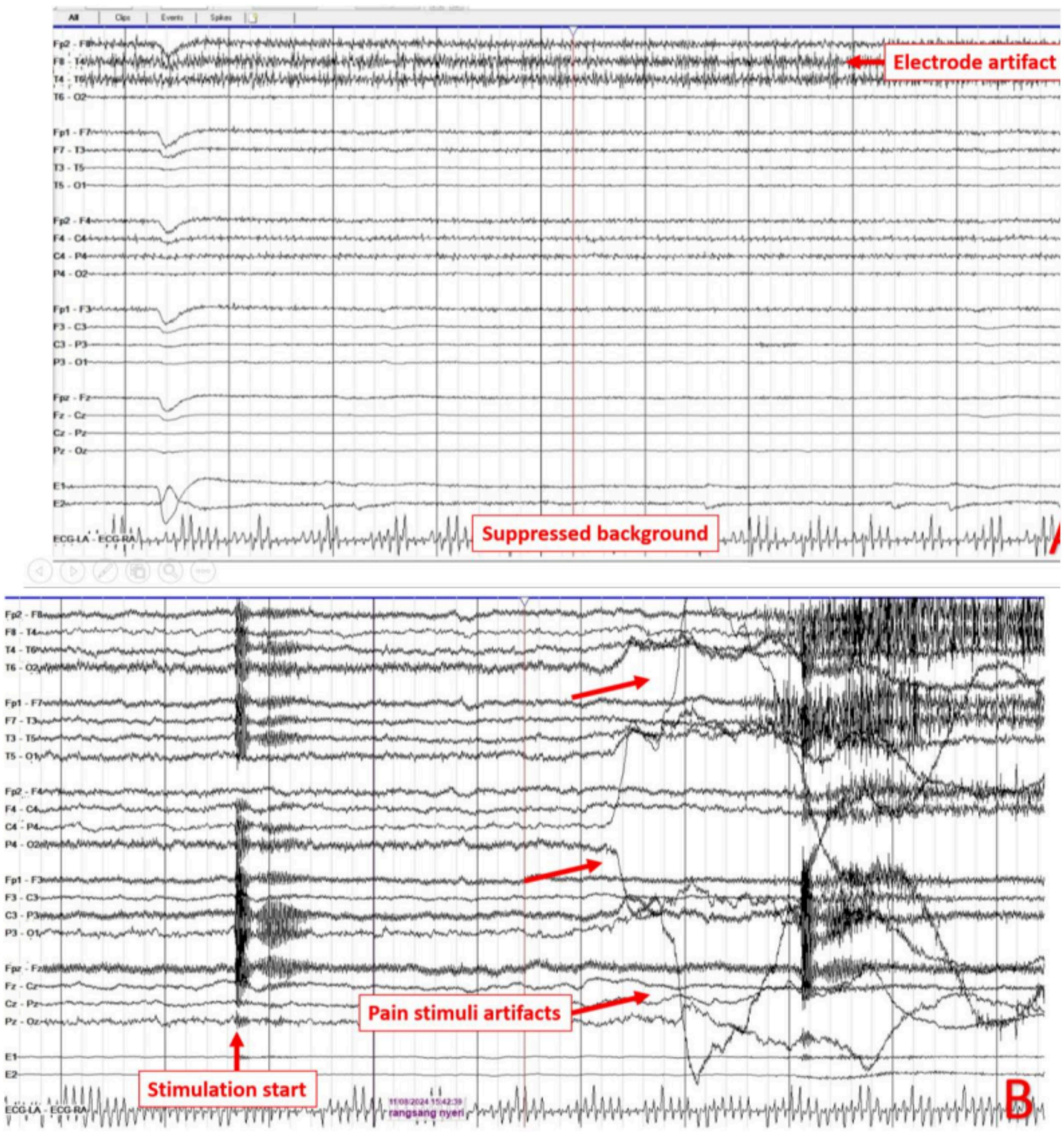


Figure 1. (a) EEG showing background suppression with an amplitude of 2 μV. (b) No brain-origin background reactivity was observed during painful stimulation. Timebase: 10 sec/page; low-frequency filter: 1 Hz; high-frequency filter: 70 Hz; notch filter: 50 Hz; sensitivity: 2 μV/mm.

Case 2

A 44-year-old man with a history of recurrent ROSC was referred after experiencing 11 episodes of cardiac arrest within 24 hours during hospitalization at a previous hospital. The patient had initially been admitted with a diagnosis of unstable angina pectoris and had undergone 26 days of ICU treatment. After discharge, he was brought to RSCM because his nasogastric tube became dislodged and he developed agitation. No seizures were observed before or after ROSC. During hospitalization, the patient's consciousness gradually improved, and he became able to respond to the examiner. EEG was performed approximately 1 month after ROSC (**Table 1**). The EEG findings are presented in **Figure 2**. The patient was not receiving any antiseizure medication.

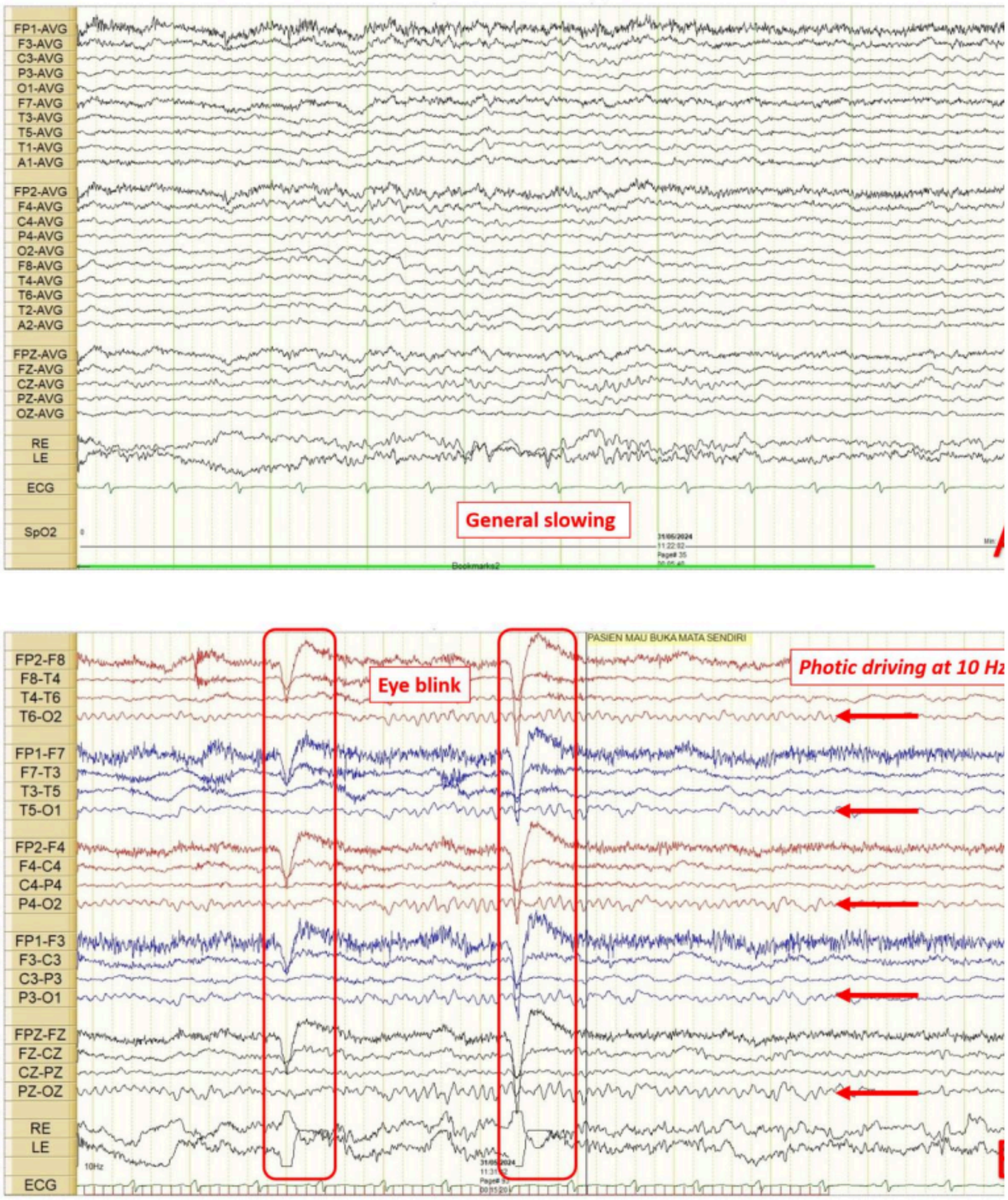


Figure 2. (a) Generalized slowing was observed. (b) Photic driving response was present during photic stimulation. Paper speed: 30 mm/sec; high-cut filter: 70 Hz; low-cut filter: 1 Hz; notch filter: on; sensitivity: 3 µV/mm.

Case 3

A 59-year-old woman experienced cardiac arrest on the second day of hospitalization at RSCM. She had initially presented with dyspnea for 2 days before admission and a 3-month history of abdominal pain. A retroperitoneal tumor suspicious for renal malignancy was suspected. During cardiac arrest, resuscitation was performed, and ROSC was achieved. Four days after ROSC, the patient developed episodes of upward eye deviation, lower limb stiffening, and subtle lip movements. These episodes partially improved after administration of 2 mg midazolam, although her level of consciousness remained unchanged. Antiseizure treatment included valproic acid at 30 mg/kgBW, which was later switched to topiramate because of elevated transaminase levels. EEG was performed on day 12 after ROSC, with findings shown in **Table 1**. The patient did not survive due to worsening complications after one month of hospitalization. The EEG findings are shown in **Figure 3**.

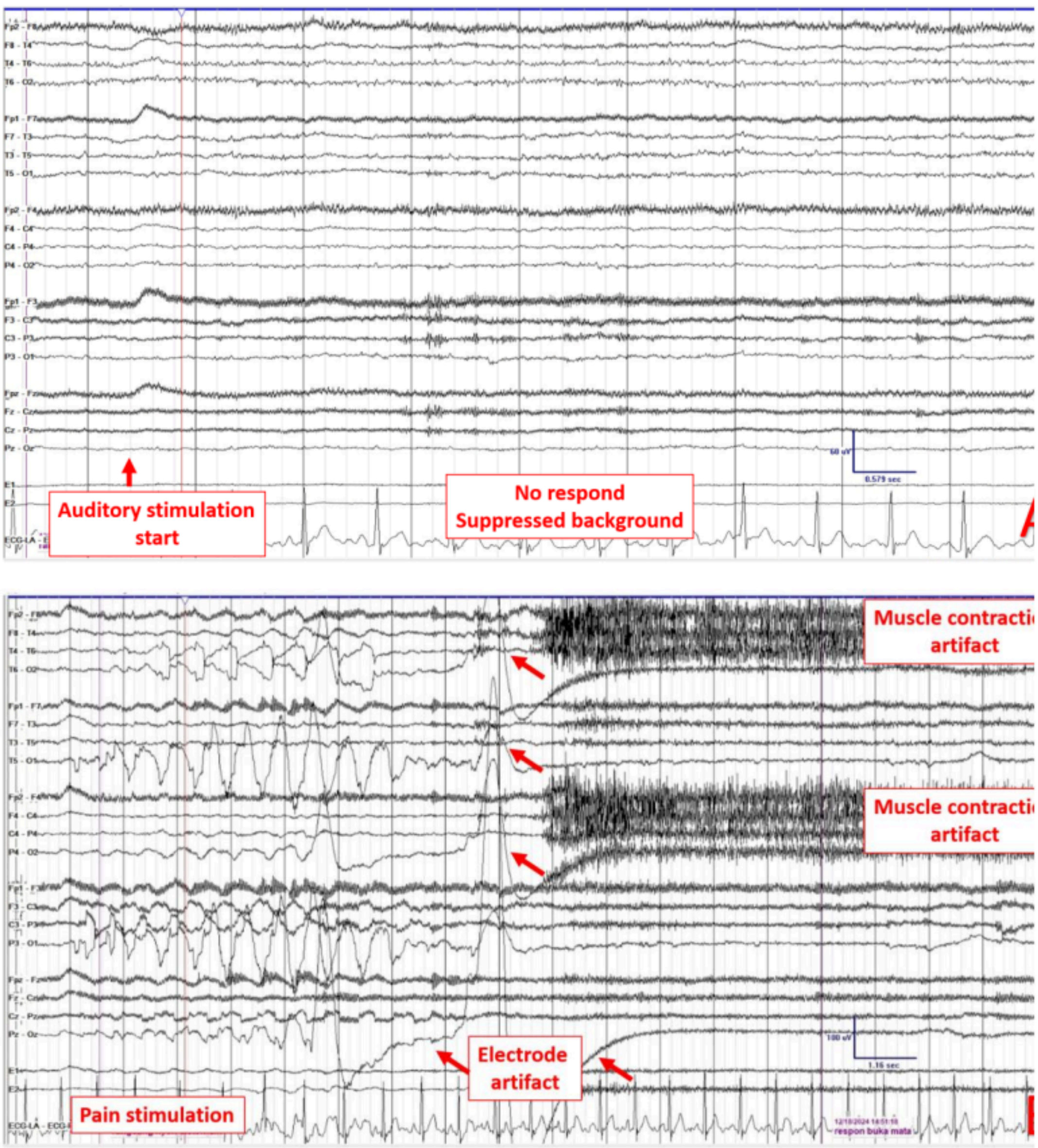
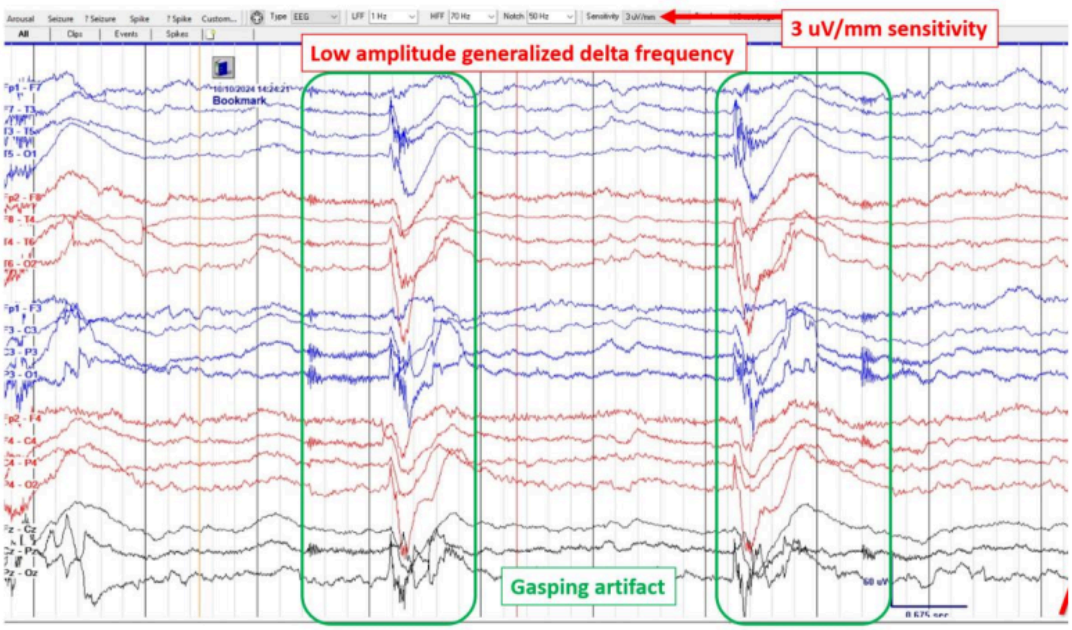


Figure 3. (a) Suppressed background rhythm with an amplitude up to 6 μV. (b) During painful stimulation, no brain-origin EEG reactivity was observed; however, prominent muscle

contraction artifacts were seen over the bilateral frontocentral regions. Timebase: 10 sec/page; low-frequency filter: 1 Hz; high-frequency filter: 70 Hz; notch filter: 50 Hz; sensitivity: 3 μV/mm.

Case 4

A 30-year-old woman experienced cardiac arrest following massive hemorrhage during cesarean section surgery at an outside hospital. Cardiopulmonary resuscitation (CPR) was performed, although the duration was unknown. ROSC was achieved, and the patient was treated in the ICU before being referred to RSCM for further management because bleeding persisted until the fourth day after ROSC. No seizures were observed during the clinical course. EEG was performed approximately 3 weeks after ROSC, with findings shown in Table 1. During EEG recording, the patient was unresponsive and exhibited gasping respiration. No antiseizure medication was administered. The patient did not survive after 21 days of ICU hospitalization.



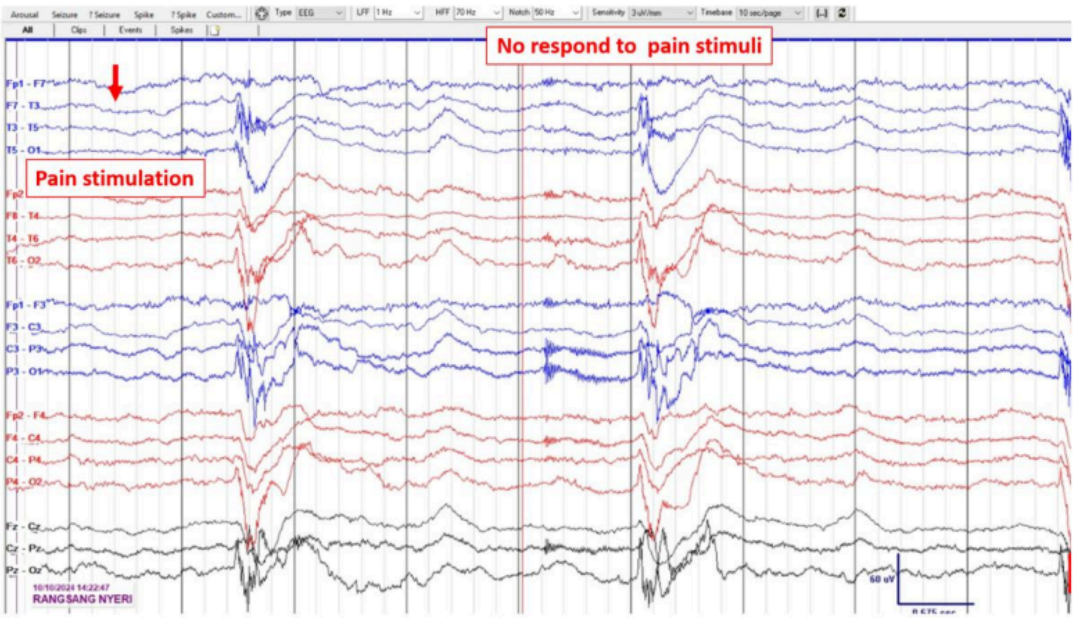


Figure 4. (a) Background activity showed low-amplitude delta slowing at 3–4 Hz (12 μV). (b) No EEG changes were observed during painful stimulation. Paper speed: 30 mm/sec; high-cut filter: 70 Hz; low-cut filter: 1 Hz; notch filter: on; sensitivity: 3 μV/mm.

Case 5

A 69-year-old woman was referred from an outside hospital after desaturation followed by cardiac arrest, requiring 45 minutes of resuscitation before ROSC was achieved. After ROSC, the patient was treated in the ICU for approximately 3 weeks before transfer to RSCM. Following referral, EEG was performed because of intermittent shivering-like movements associated with EEG waveform changes, which resolved after administration of midazolam. EEG was performed on day 20 after ROSC, with findings summarized and shown in **Figure 5** and **Table 1**. The patient had been treated with levetiracetam at the previous hospital and continued on 1000 mg twice daily due to suspected seizure activity. Levetiracetam was later tapered off after nonconvulsive status epilepticus (NCSE) was excluded. The patient was subsequently designated do-not-resuscitate (DNR) and did not survive after a total hospitalization of 1.5 months, entirely in the ICU.

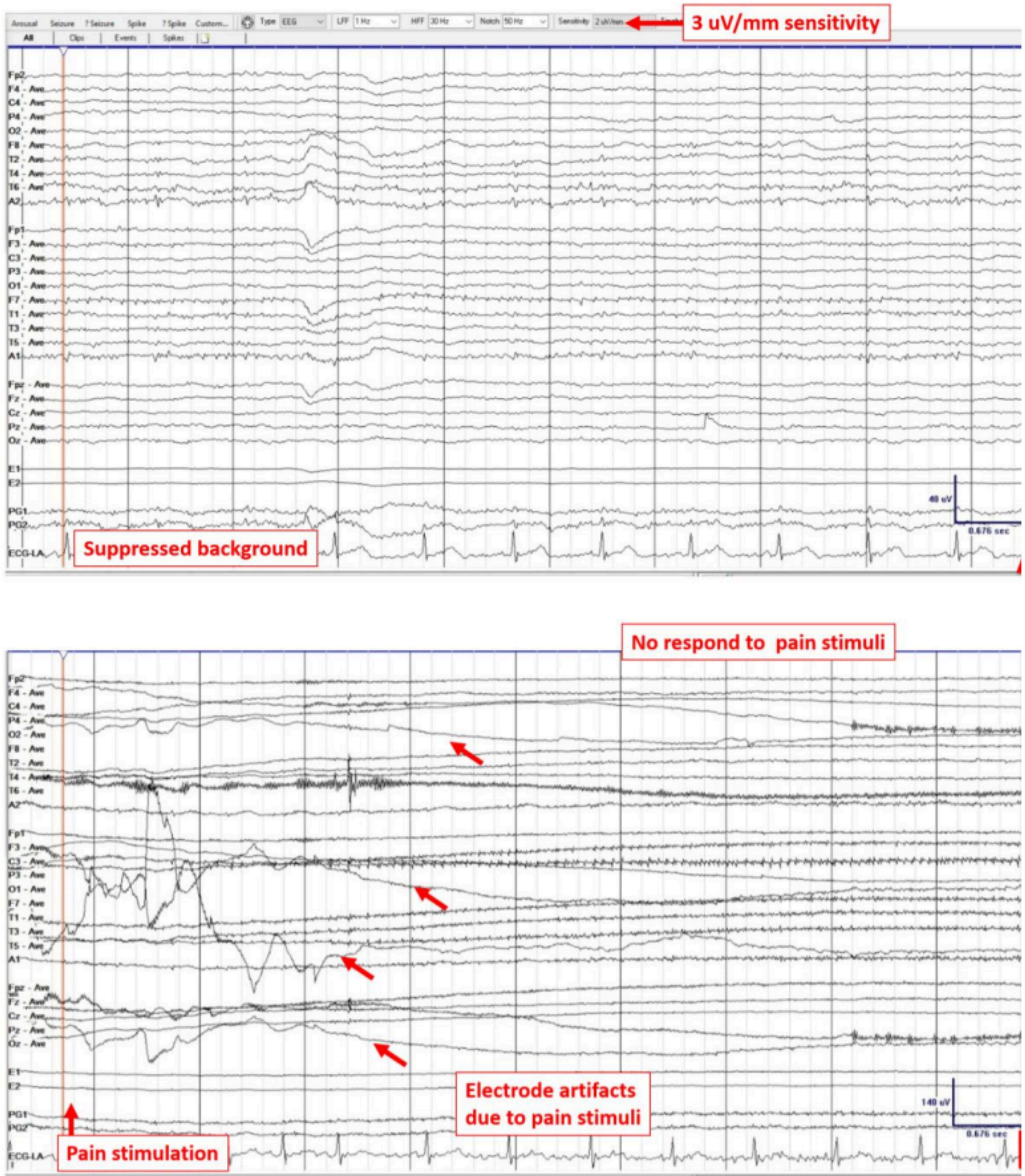


Figure 5. (a) Suppressed background rhythm with an amplitude of 2.36 μV. (b) No brain-origin EEG response was observed during painful stimulation. Timebase: 10 sec/page; high-frequency filter: 70 Hz; low-frequency filter: 1 Hz; notch filter: 50 Hz; sensitivity: 7 μV/mm.

Case 6

A 55-year-old woman underwent EEG after previously experiencing cardiac arrest and ROSC at an outside hospital. She had been hospitalized there for approximately 2.5 months before being transferred to RSCM. ROSC was achieved after 23 minutes of resuscitation. EEG was performed for prognostic evaluation because the patient remained inadequately responsive despite relatively normal metabolic parameters. The patient was eventually discharged with a tracheostomy. At discharge, she exhibited spontaneous eye opening and awareness of her surroundings. However, responses were minimal, limited to eye contact with the examiner during stimulation testing performed as part of the EEG examination (details shown in **Table 1**). No. antiseizure medication was administered. The EEG findings are presented in **Figure 6.**

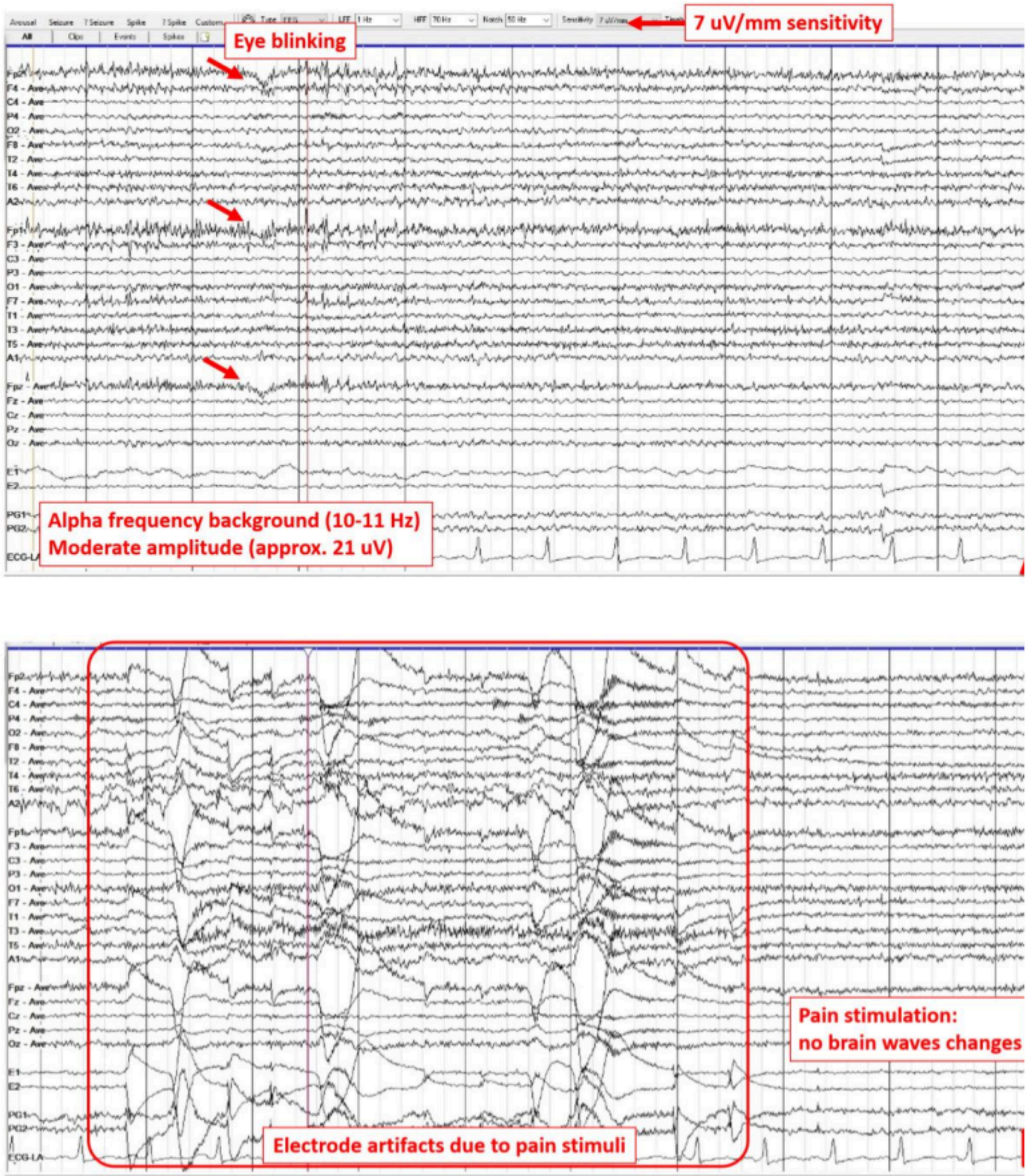


Figure 6. (a) Background activity consisted of symmetric bilateral alpha waves at 10–11 Hz with an amplitude of 21 μV. Eye-opening and eye-closing reactivity was difficult to assess. (b) During painful stimulation, no EEG changes indicative of brain activity were observed; however, the patient responded clinically with slight flexion of both arms. Timebase: 10 sec/page; low-frequency filter: 1 Hz; high-frequency filter: 70 Hz; notch filter: 50 Hz; sensitivity: 7 μV/mm.

Table 1. Post-ROSC Patient Characteristics and EEG Findings

Case	1	2	3	4	5	6
Age / Sex	68 / M	44 / M	59 / F	30 / F	69 / F	55 / F
GCS during EEG	E3 M4 Vtrach	E3–4 M6 Vtrach	E2 M1 Vett	E1 M1 Vett	E1 M2 Vtrach	E4 M5 Vtrach
EEG Timing after ROSC	>24 h	>24 h	>24 h	>24 h	>24 h	>24 h
ICU Stay	21 days	>30 days	30 days	21 days	>30 days	>30 days
CPC Score	CPC 4	CPC 3	CPC 5	CPC 5	CPC 5	CPC 4
EEG Follow-up	Yes	No	No	No	No	No
Background Amplitude	<2 µV	21 µV	6 µV	12 µV	2.36 µV	21 µV
Background Frequency	Theta 4–5 Hz	Theta–alpha 6–8 Hz	Delta 2–3 Hz	Delta 3–4 Hz	Theta 4 Hz	Alpha 10–11 Hz
Symmetry	Symmetric	Symmetric	Symmetric	Symmetric	Symmetric	Symmetric
EEG/Clinical Reactivity	No eye-opening/closing reactivity. No background change or burst after stimulation	Eye-opening/closing reactivity present. No background change after stimulation	No eye-opening/closing reactivity. No background change after stimulation	No eye-opening/closing reactivity. No background change after stimulation	No eye-opening/closing reactivity. No EEG change after stimulation, but minimal clinical response to pain	Eye-opening/closing reactivity difficult to assess. No background change after stimulation
Burst Suppression	(-)	(-)	(-)	(-)	(-)	(-)
Periodic Discharges	(-)	(-)	(-)	(-)	(-)	(-)
Electroclinical Inactivity	(+)	(-)	(+)	(-)	(-)	(-)
Epileptiform Pattern	(-)	(-)	(-)	(-)	(-)	(-)
Slowing Pattern	General slowing	Bilateral frontotemporal delta slowing, left predominance	General slowing	General slowing	General slowing	General slowing
EEG Conclusion	ECI	Bilateral frontotemporal slowing	ECI	General slowing	Continuous suppression with minimal response to pain stimulation	Alpha coma
EEG Severity Classification	Highly malignant	Benign	Highly malignant	Benign	Highly malignant	Benign

DISCUSSION

To our knowledge, reports regarding EEG-based prognostication post-ROSC remain limited in Indonesia. Most published studies on post-ROSC EEG prognostication are large-cohort studies from Europe and North America, while detailed case-based reports from Southeast Asia remain scarce. This case series highlights the practical role of EEG in predicting neurological outcomes among critically ill post-ROSC patients.[7,13] This case series also demonstrates a broad spectrum of EEG abnormalities, ranging from benign to highly malignant patterns, including electroclinical inactivity (ECI), continuous suppression, generalized slowing, and alpha coma.

Highly malignant EEG patterns include suppressed background without discharges, suppressed background with continuous periodic discharges, and burst-suppression with or without discharges. Malignant patterns include abundant periodic discharges, electrographic seizures, discontinuous or low-voltage background activity, reversed anterior–posterior gradient, and absent EEG reactivity. The absence of malignant features defines benign EEG patterns.[8,10]

Among the six patients, four showed low-voltage background activity in the form of suppression (Cases 1, 3, and 5) or attenuation (Case 4). Suppressed background activity (<10 μV) is recognized as an indicator of poor neurological outcome. However, it is important to note that EEG may become isoelectric or suppressed within 10–40 seconds after cardiac arrest and can persist during the first 24 hours; therefore, suppression should not be used alone to predict poor prognosis.[6,9,11]

Current guidelines from the European Resuscitation Council (ERC) and the European Society of Intensive Care Medicine (ESICM) recommend a multimodal approach for neurological prognostication at 72 hours after ROSC, incorporating clinical examination, electrophysiological studies, biomarkers such as neuron-specific enolase (NSE), and neuroimaging.[6,14,15]

In this series, all EEG recordings were obtained more than 24 hours after ROSC, and none were obtained within the recommended 24–72-hour prognostic window. Therefore, findings such as suppression or electroclinical inactivity (ECI) in these patients may more reliably indicate poor neurological outcomes. Previous studies have shown that absence of EEG improvement within the first 24 hours is strongly associated with poor prognosis. In contrast, recovery toward continuous physiological rhythms within the first 12 hours is generally associated with more favorable neurological outcomes.[7,9,10]

None of the six patients demonstrated burst-suppression or discontinuous background activity. Continuous EEG background activity is generally considered a favorable prognostic sign after ROSC. According to the American Clinical Neurophysiology Society (ACNS), discontinuity refers to alternating periods of attenuation or suppression with higher-voltage activity. Nevertheless, discontinuity alone cannot fully predict the extent of brain injury.[11]

Assessment of EEG reactivity can be performed using auditory, visual, and tactile stimulation by evaluating changes in EEG amplitude or frequency. In all six cases, no clinically significant EEG reactivity was observed. Previous large studies reported that the absence of EEG reactivity has a specificity of approximately 82% and a sensitivity of 73% for predicting poor neurological outcomes.[5,6,11,16-18]

In our series, EEG findings ranged from benign to highly malignant patterns according to the Westhall classification. Highly malignant patterns, in the form of ECI and continuous suppression, consistently correlated with poor neurological outcomes (CPC 4–5). Similarly, previous cohort studies have demonstrated that highly malignant EEG patterns are strongly associated with poor outcomes after cardiac arrest. Nolan et al. (2021) reported that highly malignant EEG patterns demonstrated approximately 42% sensitivity and nearly 100% specificity for predicting poor neurological outcomes (CPC 3–5). Several other studies have also shown that the absence of EEG reactivity, suppressed background activity, and persistent discontinuity are associated with poor prognosis. [5,11,13,16-18]

In contrast, benign EEG patterns in our patients were still associated with relatively unfavorable outcomes (CPC 3–5), which differs somewhat from larger cohort studies, where benign EEG patterns are more commonly associated with favorable neurological recovery (CPC 1–2). This discrepancy may reflect differences in the severity of systemic illness, prolonged ICU treatment, delayed EEG acquisition, and other confounding clinical factors within our patient population.

Limitations

An important limitation of this series is the delayed timing of EEG recordings, as all EEG examinations were performed more than 3 days after ROSC. Other confounding factors, including preexisting neurological disease, metabolic abnormalities, structural lesions, duration of ICU care, and delayed EEG acquisition, may also have affected the results. However, interpretation of EEG reactivity still shows considerable interobserver variability, limiting its consistency in clinical practice. Furthermore, this report represents a small case series and therefore cannot fully represent the broader post-ROSC population

CONCLUSION

In summary, this case series supports prior findings that highly malignant EEG patterns, particularly ECI and continuous suppression, are strongly associated with poor neurological outcomes after ROSC. Although benign EEG patterns may indicate a relatively better prognosis, neurological outcomes remain influenced by systemic conditions and overall disease severity. These findings support EEG as a valuable bedside tool for assessing recovery potential and guiding clinical management in post-cardiac arrest patients, particularly when integrated into a multimodal prognostic approach. Further studies with larger sample sizes and standardized EEG timing are needed to better clarify the prognostic value of EEG in post-ROSC patients.

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AUTHORS CONTRIBUTION

The authors performed data collection, EEG interpretation, and manuscript preparation. All authors reviewed and approved the final manuscript.

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