Clinical Neurophysiology Practice 5 (2020) 147–151

Contents lists available at ScienceDirect

Clinical Neurophysiology Practice

journal homepage: www.elsevier.com/locate/cnp

Research paper

Prognostic significance of specific EEG patterns after cardiac arrest in a Lisbon Cohort

Beatriz Guedes [a,d,*], Manuel Manita [a], Ana Rita Peralta [b,c,d], Ana Catarina Franco [b,c,d], Luís Bento [e], Carla Bentes [b,c,d]

[a] Área de Neurociências, Unidade de Neurofisiologia Clínica, Hospital de São José, Centro Hospitalar Universitário de Lisboa Central, Lisboa, Portugal
[b] Laboratório EEG/Sono – Unidade de Monitorização Neurofisiológica, Departamento de Neurociências e Saúde Mental, Hospital de Santa Maria - Centro Hospitalar Universitário de Lisboa Norte, Lisboa, Portugal
[c] Centro de Referência para Epilepsia Refratária (from the European Reference Network-EpiCARE), Hospital de Santa Maria - Centro Hospitalar Universitário de Lisboa Norte, Lisboa, Portugal
[d] Faculdade de Medicina da Universidade de Lisboa, Lisboa, Portugal
[e] Área de Urgência e Cuidados Intensivos, Unidade de Urgência Médica, Hospital de São José, Centro Hospitalar de Lisboa Central, Lisboa, Portugal

ARTICLE INFO

Article history:
Received 5 February 2020
Received in revised form 10 June 2020
Accepted 5 July 2020
Available online 30 July 2020

Keywords:
Cardiac Arrest
Outcome
EEG Pattern
Highly Malignant
Malignant
Benign

ABSTRACT

Objective: To evaluate if EEG patterns considered highly malignant are reliable predictors not only of poor neurological outcome but also reliable predictors of death.
Methods: Retrospectively, EEGs from Cardiac Arrest (CA) patients of two teaching hospitals in Lisbon were classified into 3 groups: highly malignant, malignant, and benign groups. Outcome was assessed at 6 months after CA by CPC (Cerebral Performance Categories) scale. We evaluated the accuracy of these patterns to predict poor neurological outcome and death.
Results: We included 106 patients for analysis. All patients with a highly malignant EEG ($n = 37$) presented a poor neurological outcome. Those patterns were also associated with death. Malignant EEG patterns were not associated with poor neurological outcome. Benign EEG patterns were associated with good neurological recovery ($p < 0.0001$).
Conclusion: Highly malignant EEG patterns were strongly associated with poor neurological outcome and can be considered to be predictors of death.
Significance: This study increased the knowledge about the value of EEG as a tool in outcome prediction of patients after cardiac arrest.

1. Introduction

Cardiac arrest (CA) is a common reason for prolonged hospitalization in Intensive Care Units around the world (Wnent et al., 2015). Among individuals who survive to hospital admission, the prognosis is mainly related to the severity of anoxic brain injury (Peberdy et al., 2010). Several predictors, including neurophysiological ones, have been used to predict the outcome of these patients. Specifically, electroencephalogram (EEG) has been one of the most frequently used diagnostic tools in this setting, probably because it is not excessively expensive, and it is accessible in most of hospitals (Friberg et al., 2015). However, there has been controversy about which EEG features should be used to safely identify a poor neurological outcome, due to inconsistent definitions of certain EEG patterns and the use of therapeutic hypothermia and sedative drugs modifying brain activity during EEG recording (Sandroni et al., 2014). Recently, specific EEG patterns, classified according to the most recent terminology for EEG in intensive care (Hirsch et al., 2013), were proposed as predictors of poor neurological outcome and defined as highly malignant (Westhall et al., 2016). Furthermore, malignant, and benign EEG patterns were also classified by Westhall and collaborators.

In the present study, we aimed to evaluate if highly malignant EEG patterns are reliable predictors of poor neurological outcome in a different cohort of patients. A secondary objective of this study was to evaluate the prognostic value of malignant and benign EEG

* Corresponding author at: Centro Hospitalar Universitário de Lisboa, Central Unidade de Neurofisiologia Clínica, Rua José António Serrano, 1150-199 Lisboa, Portugal.

E-mail address: beatriz.guedes@chlc.min-saude.pt (B. Guedes).

https://doi.org/10.1016/j.cnp.2020.07.001
2467-981X/

patterns. In a *Post Hoc* analysis, we also aimed to evaluate if EEG patterns considered to be highly malignant are reliable predictors of death.

2. Materials and methods

2.1. Ethical approval, patients' management, and data selection

We retrospectively analyzed EEGs of patients who suffered an out or in-hospital CA between January 2014 and July 2018 from two teaching hospitals in Lisbon (Portugal), namely Hospital de São José and Hospital de Santa Maria. This study was approved by the ethics committees from the hospitals stated.

Patients were selected according to the EEG request. The words "Paragem cadiorrespiratória", "PCR", or "Anóxia Cerebral" had to be in the EEG request form to include the patient in the study. Both units used similar TTM protocols. All causes of cardiac arrest were included.

The protocols used for withdrawal of life-sustaining therapy (WLST) in both units follow the European Guidelines (Sandroni et al., 2014). Both intensive care units follow the recommendation to use multimodal variables to establish prognosis in these patients. The EEG data was never used alone for WLST decisions. Patients with sedation were also included. The protocol for sedation is variable in both units and usually includes propofol and/or midazolam and at times is associated with fentanyl. Sedation was recorded as a variable whenever any of these medications were ongoing during EEG recording.

2.2. EEG analysis

All EEGs were reviewed by two qualified viewers. Both reviewers were blind to the outcome. Information present in the EEG form was accessible, but included only the possible cause for CA, sedation/antiepileptic drug, mental status, and presence of myoclonus or other subtle motor signs of status epilepticus.

The classification was made according to the most recent standardized EEG terminology for classification in Intensive care units from the American Clinical Neurophysiology Society (ACNS) (Hirsch et al., 2013). This classification takes into account the background activity, the presence of rhythmic or periodic patterns, and the reactivity. An EEG was considered reactive if any change in amplitude or frequency, including attenuation of activity, was present after any sound or pain stimulus. Both sound and pain stimulus were present in all our recordings. Only EEGs performed 48–100 h after CA were included for analysis, as the prognostic value of the EEG patterns is dependent on time between the CA and the EEG recording (Jørgensen and Malchow-Møller, 1981).

After the EEGs' review and classification, they were divided into three groups: a highly malignant group (with suppressed background activity, continuous periodic discharges on a suppressed background, or burst-suppression pattern), a malignant group (with abundant rhythmic or periodic patterns, absence of reactivity to sound and pain stimuli or reactive in SIRPIDS only, low voltage background activity, reverse anterior-posterior gradient, presence of at least one electrographic seizure, and discontinuous background activity) and a benign group (with absence of highly malignant and malignant features) (Westhall et al., 2016).

2.3. Outcome measurement

The neurological outcome was assessed by an independent observer 6 months after CA and classified using the Cerebral Performance Categories Scale (CPC). Two outcome groups were defined: a primary outcome group and, in a *Post Hoc* analysis, a secondary outcome group. The primary outcome concerns neurological function and the secondary outcome concerns death. In our primary outcome group, CPC1-2 values were classified as good neurological recovery (individuals with complete recovery and individuals with moderate disability but with independence in daily life activities, with or without associated symptoms) and CPC3-5 values were considered as poor neurological outcome (individuals with severe disability, conscious but completely dependent in daily life, individuals in coma, or individuals deceased). The secondary prognostic group was divided into survival (CPC1-4) and death (CPC 5).

2.4. Statistical analyses

The association of the proposed EEG patterns (highly malignant, malignant, and benign) with the primary and secondary outcome was calculated by a chi-square test. The accuracy of this association was measured by calculating sensitivity and specificity values. Confidence Intervals at 95% and p-values were calculated. SPSS Statistics version 24 was used.

3. Results

3.1. Cohort description

Patients included for analysis had a mean age of 62 (±13.9) years old, 82 (77.4%) had more than 50 years old, 17 (16.9%) patients had a functional dependency (mRS $\geq$3) prior to CA. The most common cause of cardiac arrest was acute myocardial infarction, which was present in 37 (34.9%) patients. Table 1 describes Cardiac Arrest etiology.

3.2. Outcome measurements

Six months after CA, 79 (74.5%) patients had a poor neurological outcome and 70 (66.1%) died. Patients with good and poor neurological outcomes had similar demographic and clinical characteristics (Table 2). Patients that died were more frequently from out of the hospital CA, but otherwise the other demographic and clinical characteristics were similar (Table 3).

3.2.1. Highly malignant EEG

EEG patterns considered to be highly malignant were present in 37 (34.9%) patients and all these patients presented a poor neurological outcome [specificity 100% (CI 87.2% –100%) and sensitivity 46.8% (CI 35.5% –58.40%)]. The distribution of highly malignant EEG patterns and patients neurological outcome can be observed in Table 4.

Table 1
Cardiac arrest etiology.

All included patients (n = 106)	
CA Cause	
Airway obstruction (%)	8 (7,5)
Acute Myocardial Infarction (%)	37 (34,9)
Aortic Stenosis (%)	1 (0,9)
Acute Pulmonary Edema (%)	1 (0,9)
Dysrhythmia (%)	11 (10,4)
Hemorrhagic Shock (%)	2 (1,9)
Hipoxemia (%)	9 (8,5)
Myocardiopathy (%)	1 (0,9)
Myocarditis (%)	1 (0,9)
Pulmonary Embolism (%)	2 (1,9)
Septic Shock (%)	2 (1,9)
U/N (%)	31 (29,2)

n-number of patients; U/N-unknown.

Table 2
Comparison of patientś characteristics and management between neurological outcome groups.

Variables	Good neurological outcome	Poor neurological outcome (CPC 3–5)	p-Value
Age, mean (±SD)	61.15 (13.60)	62.80 (14.70)	0.595
Age > 50	18/27 (66.7%)	61/79 (77.2%)	0.952
Male Gender	20/27 (74.1%)	56/79 (70.9%)	0.751
In hospital CA	4/27 (14.8%)	27/79 (34.2%)	0.056
TTM (33ºC or 36ºC)	24/27 (88.9%)	71/79 (89.9%)	0.885
Sedation	24/27 (88.9%)	61/79 (77.2%)	0.189
Previous mRS ≥ 3	3/27 (11.1%)	14/79 (17.7%)	0.419
GCS3 at 72 h	23/27 (85.2%)	60/79 (61.9%)	0.315
Time to EEG, mean (±SD)	71.99 (15.41)	71.42 (16.70)	0.838

Table 3
Comparison of patients' characteristics and management between vital outcome groups.

Variables	Alive (CPC 1–4)	Dead (CPC 5)	p-Value
Age, mean (±SD)	60.72 (13.14)	63.23 (14.18)	0.379
Age > 50	28/36 (77.8%)	54/70 (77.1%)	0.941
Male Gender	26/36 (72.2%)	50/70 (71.4%)	0.932
In hospital CA	5/36 (13.8%)	26/70 (37.1%)	**0.013**
TTM (33ºC or 36ºC)	30/36 (83.3%)	26/70 (37.1%)	0.128
Sedation	30/36 (83.3%)	65/70 (92.9%)	0.560
Previous mRS ≥ 3	3/36 (8.3%)	55/70 (78.6%)	0.121
GCS3 at 72 h	30/36 (83.3%)	14/70 (20.0%)	0.367
Time to EEG, mean (±SD)	60.72 (13.14)	53/70 (75.7%)	0.379

Table 4
Distribution of highly malignant EEG patterns and patientś neurological outcome.

EEG description	No. (%) (n = 106)	Poor Neurological Outcome (CPC 3–5)	Good Neurological Recovery (CPC 1–2)
Highly malignant EEG patterns, n (%)	**37 (34.9%)**	**37 (100%)**	**0 (0%)**
Suppressed Background, n	17	17 (100%)	0 (0%)
Suppressed Background with continuous Periodic Discharges, n	13	13 (100%)	0 (0%)
Burst-Suppression Background, n	7	7 100%)	0 (0%)

EEG- Electroencephalogram; n-number of patients

In the post-hoc analysis highly malignant pattern group, 32 (86.5%) patients died, and an association between those patterns and death ($p = 0.001$) was found. With regard to the prognostic accuracy of these patterns to predict death, the sensitivity and specificity was 45.7% (CI 33.7% −58.1%) and 86.1% (CI 70.5% −95.3%), respectively. The distribution of highly malignant EEG patterns and patient's vital outcome can be observed in Table 5.

3.2.2. Malignant EEG

Malignant EEG patterns were present in 39 (36.8%) patients, 29 (74.4%) of which presented a poor neurological outcome. We did not find an association between these patterns and poor neurological outcome (p = 0.976). Regarding the prognostic accuracy, sensitivity and specificity were 63.0% (CI 42.4%–80.6%) and 36.7% (CI 26.1%–48.3%), respectively. Further, we did not find an association between the presence of at least two malignant characteristics and poor neurological outcome (p-value: 0.125). The distribution of malignant EEG and patientś neurological outcome can be observed in the Table 6.

3.2.3. Benign EEG

Benign EEG patterns were present in 30 (28.3%) patients, and 17 (56.7%) had a good neurological recovery. An association between these EEG patterns and a good neurological recovery was found (p < 0.0001). With regard to the accuracy of these patterns to identify good neurological recovery, sensitivity and specificity was 63.0% (CI 42.4%–80.6%), and 83.5% (CI 73.5%–90.9%), respectively.

4. Discussion

In this study, 34.9% of patients had a highly malignant EEG pattern and all post-cardiac arrest patients with this neurophysiological characteristic had a poor neurological outcome. Furthermore, this EEG pattern was associated with death in this group. Therefore, we documented the importance of a standardized EEG analysis in the assessment of post-cardiac arrest prognosis.

As postulated, our results are in line with those of Westhall and collaborators (Westhall et al., 2016). These authors had previously found that highly malignant EEG patterns predict an unfavorable outcome in half of their patients, with no false positives. Furthermore, in both series (ours and Westhall et al., 2016), these EEG patterns showed a limited sensitivity (46.8% in our series) for poor neurological outcome. Many patients with poor neurological outcome did not present any EEG characteristic from the highly malignant pattern group, and we speculate that other factors can account for this observation, such as medical complications during admission or comorbidities.

Although we found a high specificity for the highly malignant pattern group, a recent study showed a slightly lower specificity of 91% (95% CI: 83%–97%) (Beuchat et al., 2018). However, these authors scored EEGs performed in the first 24 h, and this can account for the false positives detected. This reinforces the recommendation of prognostication 3–5 days after CA from the European guidelines (Sandroni et al., 2014). In another study with a cohort of 204 patients, 44 had a highly malignant EEG pattern which also

Table 5
Distribution of highly malignant EEG patterns and patientś vital outcome.

EEG description	No. (%) (n = 106)	Death (CPC 5)	Survive (CPC 1–4)	p-Value
Highly malignant EEG patterns, n (%)	**37 (34.9%)**	**32 (86.5%)**	**5 (13.5%)**	0.001
Suppressed Background, n	17 (16.1%)	14 (82.4%)	3 (17.6%)	–
Suppressed Background with continuous Periodic Discharges, n	13 (12.3%)	11 (84.6%)	2 (15.4%)	–
Burst-Suppression Background, n	7 (6.6%)	7 (100%)	0 (0%)	–

EEG-Electroencephalogram; n-number of patients.

Table 6
- Distribution of malignant EEG patterns and patienťs neurological outcome.

EEG description	No. (%) (n = 106)	Poor Neurological Outcome (CPC 3–5)	Good Neurological Recovery (CPC 1–2)	p-Value
Malignant EEG patterns, n (%)	**39 (36.8%)**	**29 (74.4%)**	**10 (25.6%)**	0.976
Abundant rhythmic or periodic pattern, n	14	9 (64.3%)	5 (35.7%)	–
Abundant SW discharges, n	1	0 (0%)	1 (100%)	–
Discontinuous background, n	7	4 (57.1%)	3 (42.9%)	–
Low voltage background, n	17	15 (88.2%)	2 (11.8%)	–
Reversed Anterior-Posterior gradient, n	3	3 (100%)	0 (0%)	–
Unreactive background, or reactive, only in SIRPIDS, n	18	15 (83.3%)	3 (16.7%)	–

EEG-Electroencephalogram; n-number of patients; SIRPIDS-Stimulus Induced Rhythmic Periodic Ictal Discharges; SW-Spike and- Wave or Sharp-and-Wave Discharge.

predicted a bad functional outcome with 98% specificity. In this study, one of the patients with good outcome had a burst-suppression pattern. The authors attributed the presence of this pattern to sedation (Backman et al., 2018). In the study by Beuchat et al (2018), sedation may also account for the lower specificity, as EEG were performed earlier in the course of the CA. In future it would be useful to better characterize this specific pattern and take sedation into account.

Regarding malignant EEG patterns, those were presented in almost 40% of our patients but the presence of at least one of these characteristics was not associated with poor neurological outcome. These findings are also consistent with Westhall and collaborators (Westhall et al., 2016). However, we could not support their findings of an association between the presence of at least two malignant characteristics with poor neurological outcome.

Regarding specific characteristics from the malignant EEG pattern group, EEG reactivity deserves close observation. Our results show that almost 17% of patients with unreactive EEG or EEG only reactive with SIRPIDS had a good neurological recovery. Therefore, this characteristic is not always associated with poor neurological outcome as previously stated (Crepeau et al., 2013, Rossetti and Bleck, 2014). In fact, Bouwes and collaborators (Bouwes et al., 2012) previously described in their study three patients without EEG reactivity after rewarming that had a favorable outcome. This discrepancy might also be related with the interpretation problems associated with EEG reactivity. It has been demonstrated that even among experts, agreement in EEG interpretation is only fair for reactivity findings (Westhall et al., 2015). Recently, an international consensus statement and recommendations on EEG reactivity testing and interpretation in patients after CA was proposed for testing patients after CA (Admiraal et al., 2018). These authors proposed a method for testing patients after CA and concluded that it is important for clinical prospective studies to evaluate the agreement in EEG interpretation and to clearly define the prognostic value of this neurophysiological hallmark (Admiraal et al., 2018).

Another important EEG feature deserving our comment is the presence of abundant rhythmic and periodic patterns in 13% of our patients. It is known that these patterns might be related with an ictal state and status epilepticus (Beniczky et al, 2013; Leitinger et al., 2015; Osman et al., 2018) or an ictal-interictal continuous state (Osmanet al., 2018). More than 1/3 of our patients with this EEG pattern had a good neurological recovery. Although status epilepticus has been associated with poor neurological outcome in post cardiac arrest patients (Sandroni et al., 2014), the percentage of patients fulfilling status epilepticus criteria was not quantified in our series. Also, it is not clear whether treating status epilepticus or even rhythmic and periodic patters not fulfilling status epilepticus criteria prevents additional brain damage and improve outcome. However, our results suggest that recovery can occur in a significant percentage of these patients and argue in favor of their intensive treatment until recovery or until other predictors of a poor neurological outcome arise, as proposed by Elmer and collaborators in 2016 (Elmer et al., 2016).

Another interesting feature of our work was the evaluation of benign EEG patterns as possible good prognostic biomarkers after cardiac arrest. In our group of patients with these EEG features, 55.7% showed a good neurological recovery; however, this is a low percentage compared to Westhall et al. study (93%) (Westhall et al., 2016). This can possibly be justified by difference in the definition of outcome. In Westhall series, they consider the best scored achieved in 6 months, as it is a prospective study, and we considered the score at 6 months, which justifies the difference and compromises the comparison.

An important caveat of our study is the fact that we only evaluated patients that clinically required EEG. In this design, patients that die before arriving to the hospital or in the first hour after CA are not included. The same happens to patients with fast complete recovery. We are not able to estimate the percentage of CA patients that are being evaluated with EEG because CA in not systematically registered. Nonetheless, all patients with persistent mental status abnormalities are submitted to EEG in both ICU units from which patients were recruited. Our data is therefore clinically meaningful as it represents the usual population with CA submitted to EEG.

In summary, this study adds clinical evidence to the current clinical practice of requesting an EEG in the prognostication of cardiac arrest patients. It also reinforces the standard practice that EEG should not be taken by itself in this outcome prediction.

Moreover, the accuracy of a prognostic model can be improved. In the future, it would be useful to replicate this study in a prospective way, combining other clinical, neurophysiological, and ancillary test predictors and including other Intensive Care Units and/or Hospitals. This would allow access to larger samples and to subgroup analyses. Further, other EEG analysis such as quantitative EEG can be explored as biomarkers in this prognostication, and the type of EEG recording (continuous vs spot EEG) remains to be defined for better prediction. The effect of status epilepticus and its treatment in the outcome of post cardiac arrest patients is also an important research topic.

5. Conclusion

In our cohort of post-cardiac arrest patients:

- Highly malignant EEG patterns were associated with poor neurological outcome.
- Highly malignant EEG patterns were predictors of death.

- Malignant EEG patterns were not associated with a poor neurological outcome.
- Benign EEG patterns were associated with good neurological recovery.

Overall, this study increases the knowledge of the value of EEG as a tool in outcome prediction of patients after cardiac arrest. A comprehensive, multimodal, standardized, and multicentric approach to post cardiac arrest prognostication is recommended.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank all the staff: EEG technicians, nurses, and medical residents that work in the Intensive Care Units and Neurophysiology Departments of Hospital de São José and Hospital de Santa Maria - CHULN for their support in this work. Also, a special acknowledgement to Dr. João Miguel Ribeiro, Head of Serviço de Medicina Intensiva do HSM-CHLN for his encouragement and facilitation of this FMUL Neurosciences Master Project.

References

Admiraal, M.M., van Rootselaar, A.F., Horn, J., 2018. International consensus on EEG reactivity testing after cardiac arrest: Towards standardization. Resuscitation 131, 36–41.

Backman, S., Cronberg, T., Friberg, H., Ullén, S., Horn, J., Kjaergaard, J., Hassager, C., Wanscher, M., Nielsen, N., Westhall, E., 2018. Highly malignant routine EEG predicts poor prognosis after cardiac arrest in the Target Temperature Management trial. Resuscitation 131, 24–28.

Beniczky, S., Hirsch, L.J., Kaplan, P.W., Pressler, R., Bauer, G., Aurlien, H., Brøgger, J.C., Trinka, E., 2013. Unified EEG terminology and criteria for nonconvulsive status epilepticus. Epilepsia 54, 28–29.

Beuchat, I., Solari, D., Novy, J., Oddo, M., Rossetti, A.O., 2018. Standardized EEG interpretation in patients after cardiac arrest: Correlation with other prognostic predictors. Resuscitation 126, 143–146.

Bouwes, A., van Poppelen, D., Koelman, J.H., Kuiper, M.A., Zandstra, D.F., Weinstein, H.C., Tromp, S.C., Zandbergen, E.G., Tijssen, M.A., Horn, J., 2012. Acute posthypoxic myoclonus after cardiopulmonary resuscitation. BMC Neurol. 12, 63.

Crepeau, A.Z., Rabinstein, A.A., Fugate, J.E., Mandrekar, J., Wijdicks, E.F., White, R.D., et al., 2013. Continuous EEG in therapeutic hypothermia after cardiac arrest: prognostic and clinical value. Neurology 80, 339–344.

Elmer, J., Torres, C., Aufderheide, T.P., Austin, M.A., Callaway, C.W., Golan, E., Herren, H., Jasti, J., Kudenchuk, P.J., Scales, D.C., et al., 2016. Association of early withdrawal of life-sustaining therapy for perceived neurological prognosis with mortality after cardiac arrest. Resuscitation 102, 127–135.

Friberg, H., Cronberg, T., Dünser, M.W., Duranteau, J., Horn, J., Oddo, M., 2015. Survey on current practices for neurological prognostication after cardiac arrest. Resuscitation 90, 158–162.

Hirsch, L.J., LaRoche, S.M., Gaspard, N., Gerard, E., Svoronos, A., Herman, S.T., Mani, R., Arif, H., Jette, N., Minazad, Y., et al., 2013. American clinical neurophysiology society's standardized critical care EEG terminology: 2012 version. J. Clin. Neurophysiol. 30, 1–27.

Jørgensen, E.O., Malchow-Møller, A., 1981. Natural history of global and critical brain ischaemia Part I: EEG and neurological signs during the first year after cardiopulmonary resuscitation in patients subsequently regaining consciousness. Resuscitation 9, 133–153.

Leitinger, M., Beniczky, S., Rohracher, A., Gardella, E., Kalss, G., Qerama, E., Höfler, J., Hess Lindberg-Larsen, A., Kuchukhidze, G., Dobesberger, J., et al., 2015. Salzburg consensus criteria for non-convulsive status epilepticus – approach to clinical application. Epilepsy Behav. 49, 158–163.

Osman, G.M., Araújo, D.F., Maciel, C.B., 2018. Ictal interictal continuum patterns. Curr. Treat. Options Neurol. 20, 15.

Rossetti, A.O., Bleck, T.P., 2014. What's new in status epilepticus? Intensive Care Med. 40, 1359–1362.

Sandroni, C., Cariou, A., Cavallaro, F., Cronberg, T., Friberg, H., Hoedemaekers, C., Horn, J., Nolan, J.P., Rossetti, A.O., Soar, J., 2014. Prognostication in comatose survivors of cardiac arrest: An advisory statement from the European Resuscitation Council and the European Society of Intensive Care Medicine. Intensive Care Med. 40, 1816–1831.

Westhall, E., Rosén, I., Rossetti, A.O., van Rootselaar, A.-F., Wesenberg Kjaer, T., Friberg, H., Horn, J., Nielsen, N., Ullén, S., Cronberg, T., 2015. Interrater variability of EEG interpretation in comatose cardiac arrest patients. Clin. Neurophysiol. 126, 2397–2404.

Westhall, E., Rossetti, A.O., van Rootselaar, A.-F., Wesenberg Kjaer, T., Horn, J., Ullén, S., Friberg, H., Nielsen, N., Rosén, I., Åneman, A., et al., 2016. Standardized EEG interpretation accurately predicts prognosis after cardiac arrest. Neurology 86, 1482–1490.

Wnent, J., Masterson, S., Gräsner, J.-T., Böttiger, B.W., Herlitz, J., Koster, R.W., Rosell Ortiz, F., Tjelmeland, I., Maurer, H., Bossaert, L., 2015. EuReCa ONE – 27 Nations, ONE Europe, ONE Registry: a prospective observational analysis over one month in 27 resuscitation registries in Europe – the EuReCa ONE study protocol. Scand. J. Trauma Resusc. Emerg. Med. 23, 7.