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Rhythmic electrographic discharges during deep hypothermic circulatory arrest

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HIGHLIGHTS

- Periodic sharp transients during deep hypothermic circulatory arrest (DHCA) are very common.
- Rhythmic electrographic discharges during DHCA do not appear to require therapeutic intervention.
- These findings have implications for the interpretation of EEG monitoring in patients in deep hypothermic states.

ABSTRACT

Objective: The main objective of this study is to examine the prevalence and timing of rhythmic electrographic discharges and periodic sharp transients during aortic arch repair surgeries using DHCA as detected by continuous intraoperative encephalogram (EEG) and correlate it with outcome.
Methods: Electronic medical records and the intraoperative EEGs of 32 patients who underwent aortic arch reconstruction with DHCA were reviewed. Preoperative patient characteristics, intraoperative data, and postoperative outcomes were examined. EEGs were graded based on the frequency of sharp transients (grade 0–2) and/or the presence of rhythmic electrographic discharges (grade 3).
Results: Periodic sharp transients were seen in 30/32 cases. Grade 1 and grade 2 activations were more prominent during cooling at nasopharyngeal temperature of 23.9 ± 4.01 °C (mean ± SDV). Rhythmic electrographic discharges occurred in seven patients and were exclusively seen during cooling at nasopharyngeal temperatures below 28 °C except in one case during rewarming at nasopharyngeal temperatures of 22 °C. No patient with rhythmic discharges developed postoperative clinical neurologic deficit or seizures.
Conclusions: Periodic sharp transients occurred in almost all cases during induction of deep hypothermia. This activity was not associated with postoperative neurologic deficit.
Significance: Clinical neurophysiologists, technicians and surgeons need to be aware that low amplitude periodic sharp transients and rhythmic electrographic discharges are common during DHCA, yet have no apparent clinical significance.

1. Introduction

Deep hypothermic circulatory arrest (DHCA) is currently used to prevent cerebral injury and enable the surgeons a bloodless operative field during proximal aortic surgeries (Stecker, 2007). Recent refinements in cerebral protection using selective antegrade cerebral perfusion and retrograde cerebral perfusion have further decreased the risk of cerebral injury during extended periods of DHCA (Hayashida et al., 2007). Even with these measures, there is still an increased risk for cerebral metabolic deficit and ischemic injury during these procedures (Mizrahi et al., 1989). The presence of periodic sharp transients and rhythmic electrographic discharges during DHCA has not been considered to have

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negative implications with respect to clinical outcome. However, in the context of therapeutic hypothermia following cardiac arrest in which milder degrees of hypothermia are achieved, the presence of electrographic seizures correlates with poor neurologic outcome (Glass et al., 2014; Rothman et al., 2014).

The primary role of intraoperative EEG during complex cardiac surgeries using DHCA is to determine when electrocerebral silence (ECS) has been achieved (Stecker, 2007). Additionally, intraoperative EEG may be used to detect abnormalities related to inadequate cerebral perfusion, embolic phenomenon, and epileptiform activities since EEG is sensitive to acute real time changes in brain physiology (Stecker, 2007). Little data exists on the prevalence of electrographic discharges during surgeries involving DHCA in adults. Moreover, previous studies have not attempted to grade these based on the frequency of sharp transients and/or the presence of rhythmic electrographic discharges. As such, our aim was to examine the prevalence and timing of periodic sharp transients and rhythmic electrographic discharges in adult patients undergoing aortic arch repair surgery using DHCA. The second goal of this study was to define and grade EEG changes occurring at specific temperature points of cooling and rewarming.

2. Methods

2.1. Patients

Cases were identified through a query of our electronic EEG report system. 32 patients were then randomly selected from a core group of 132 patients who underwent ascending aorta and/or aortic arch reconstructive surgery using DHCA between 2012 and 2014. Preoperative patient characteristics including gender, age, body surface area, presenting symptoms, indications for surgery, history of prior cardiothoracic surgery, as well as comorbidities such as hypertension, diabetes mellitus, stroke, and coronary artery disease were identified from the electronic medical record. Intraoperative data including rate of cooling and rewarming, concentration of hemoglobin, inhalational anesthesia, serum sodium, potassium, calcium, arterial blood gases, oxygen saturation, and blood glucose levels as well as nasopharyngeal and core temperatures during circulatory arrest were obtained. Moreover, the extent of surgery, cardiopulmonary bypass time (CBP), aortic cross clamp time, DHCA time, type of selective perfusion were recorded (for details of the operative technique, please refer to the Supplementary Material). Finally, each chart was reviewed to quantify the duration of postoperative hospital stay as well as for the presence postoperative neurologic outcome graded using the cerebral performance category (CPC) and modified Rankin score (MRS). Briefly, the CPC is a five category scale (CPC 1–5) with CPC 1 representing a good cerebral performance while CPC 5 connotes death. Evidence suggests that subjects with a CPC of 1 or 2 (moderate disability) will have a good functional outcome (Hypothermia after cardiac arrest study group, 2002). The MRS consists of 7 categories (grades 0–6), with grade 0 representing perfect health without symptoms while grade 6 signifying death. In general a MRS score of 3 or lower (slight or no disability and preserved ability to look after own affairs without assistance) is considered indicative of good functional outcome (Banks and Marotta, 2007). All pertinent clinical data were collected by an author who was blinded to the EEG categorization (A.M.F).

2.2. Intraoperative EEG monitoring

Digital 21-channel recordings were acquired using the International 10–20 system for electrode placement and reviewed with standard montages. Preoperative baseline EEGs were recorded at least for 30 min. The EEG was continuously monitored throughout the procedure, including during induction of anesthesia, institution of cardiac bypass, initiation of deep hypothermia and restoration of normothermia. All EEG recordings were reviewed in their entirety, using a low-frequency filter setting of 1.0 Hz and high-frequency filter setting of 70 Hz. Tracings were reviewed at 15 mm/s, with a sensitivity of 2 μV/mm. Review at high sensitivity was important as the amplitude of the discharges was low. Recordings were visually analyzed for periods of voltage attenuation, sharp wave transients, and abnormal background. The EEGs during cooling and rewarming were graded either "grade 0", "grade 1", "grade 2", or "grade 3" with grade 0 indicating no epileptiform activity of any kind, grade 1 indicating a rate of sharp transients occurring at <7 per 15 s epoch, grade 2 indicating >7 per 15 s epoch, and grade 3 comprising records which showed rhythmic electrographic discharges. Electrographic discharge was defined as rhythmic discharges lasting a minimum of 10 s showing a clear onset, offset, and evolution of frequency, distribution, and amplitude. EEGs were independently reviewed and graded by an experienced electroencephalographer (J.W.B) who was unaware of the details of clinical characteristics of the cohort. Representative EEG tracings for each grade are shown in Fig. 1.

2.3. Statistical analysis

Patient characteristics were reported as mean for discrete variables. The relationship of duration of DHCA times, bypass time, rate of cooling, length of hospital stay, concentration of inhalational anesthesia with the occurrence of electrographic seizure was investigated. Potential predictors of the occurrence of an electrographic seizure were also evaluated. In addition, a relationship between intraoperative hemoglobin concentration, ABG levels, and various electrolyte events and the occurrence of seizure was explored. For further analysis, patients were divided into two groups: group A consisted of those who had either grade 0, grade 1 or grade 2 EEGs activation while group B included cases with grade 3 patterns. Patients' demographics and other baseline characteristics, as well as the intraoperative variables between the two groups were compared using Wilcoxon rank-sum test or chi-square or Fisher's exact test as appropriate. Chi-square test was used to determine whether there was significant association between the EEG grades (0–3) and postoperative neurologic outcome as measured by the CPC as well as to determine whether there is a significant difference between CPC scale at admission and discharge. McNemar's test was used to compare the rate of occurrence of the three grades of EEG patterns during cooling and rewarming. All tests were 2-sided and p values <0.05 were considered statistically significant. Statistical analysis was performed using SAS Version 9.3 (SAS Inc., Cary, NC).

2.4. Standard protocol approvals, registrations, and patient consents

This study was approved by the Mayo Clinic Institutional Review Board.

3. Results

3.1. Patients and surgical characteristics

Patients' demographics and other baseline characteristics, as well as the intraoperative variables are summarized in Tables 1 and 2. The mean duration of circulatory arrest was 27.15 min [range, 14–72 min]. Most of the patients were male (78.1%) and 80% presented with symptoms attributable to aortic pathology, including back pain, anterior chest pain, and syncope. All cases