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Case Report

Intraoperative 16-Channel Electroencephalography and Bilateral Near Infrared Spectroscopy Monitorization in Aortic Surgery

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Abstract

Transient neurologic dysfunction is common after aortic surgery. Major causes of postoperative complications followed by cardiac surgery are due to hypoperfusion states such as selective cerebral perfusion, embolic debris during cardiopulmonary bypass and ulcerated plaque emboli originated from carotid arteries. Neurologic complications prolong periods of intensive care unit and hospital stay, worsens quality of life and unfortunately they are an important cause of morbidity. Anaesthesia during a carotid and aortic surgery constitutes of providing adequate brain perfusion pressure, attenuating cerebral metabolism by anaesthetic agents and monitoring the cerebral metabolic supply and demand relationship during the intraoperative period. We present a monitoring approach with an intraoperative 16-channel electroencephalography and bilateral near infrared spectroscopy during redo aneurysm of the sinus of Valsalva surgery.

Keywords: Intraoperative neuromonitoring, electroencephalography, aortic surgery, cardiac anaesthesia, near infrared spectroscopy

Introduction

After aortic surgery, the incidence of stroke is reported to be 2–33%, and the incidence of temporary neurological dysfunction is reported to occur at rates reaching up to 35% (1, 2). In open-heart surgery, perioperative neurological complications can result from factors such as embolism associated with thromboembolic residues of the hypoperfused heart, ulcerated plaque embolisms arising from the carotid artery and low flow in selective cerebral perfusion. In cardiopulmonary bypass (CPB), providing appropriate perfusion pressure is important because cerebral blood flow depends on collateral circulation, especially during selective perfusion. The administration of anaesthesia in aortic and carotid surgery involves keeping cerebral perfusion pressure at proper levels, decreasing cerebral metabolic requirements with anaesthetic drugs and monitoring this requirement–supply relationship. As various surgical strategies and intraoperative neuromonitoring techniques have developed in recent years, it is intended to reduce neurological complications that occur after aortic surgery (4).

In this paper, the use of intraoperative 16-channel electroencephalography (EEG) and bilateral near-infrared spectroscopy (NIRS) was presented in a patient operated on due to Valsalva sinus aneurysm for the second time.

Case Presentation

The repair of a Valsalva sinus aneurysm was planned under elective conditions for a 47-year-old male patient with complaints of dysarthria, dysphagia and aphagia sequelae, who had a previous history of aortic valve replacement and supracoronary aortic graft interposition surgery due to type 1 dissection and one year after the operation, a cerebrovascular event (pontine infarct) because of not having regularly used coumadin. Moreover, he had a history of hypertension and allergy to penicillin. His bilateral carotid Doppler examination revealed minimal plaque and intimal thickness on the right and left sides. In his preoperative echocardiograph, a mechanical aortic valve, 6.5-cm ascending aorta and normal ejection fraction were observed. For premedication, the patient was administered 0.15 mg kg^{-1} oral diazepam on the night before surgery and 0.1 mg kg^{-1} i.m. morphine 30 min before surgery. Two peripheral venous routes and left radial artery cannulation were performed in the operating room. Five-channel electrocardiography, invasive arterial blood pressure measurement and pulse oximeter monitoring were conducted before induction. Before the patient was anaesthetised NIRS pallets (Equanox, Nonin

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Medical) were applied to the bilateral forehead region. Silver electrodes were then pasted onto the Fp1, Fp2, F7, F8, C3, C4, T3, T4, T5, T6, P3, P4, A1, A2, O1 and O2 regions of the patient, and he was attached to a Nicolet One EEG (Viasys Healthcare) device. The numerical values of spectral edge frequencies (SEFs) were also monitored in addition to the visual monitoring of beta, alpha, theta and delta waves. Baseline values were measured. During the operation (Figure 1) and antegrade selective cerebral perfusion (ASCP) (Figure 2), EEG and NIRS data were continuously monitored. Following preoxygenation, induction was slowly performed with 10 μg kg^{-1} fentanyl (B. Braun Melsungen, Germany), 0.1 mg kg^{-1} midazolam (Roche Ltd, Basel, Switzerland) and 1 mg kg^{-1} lidocaine without decreasing the mean arterial pressure. After providing muscle relaxation with 0.6 mg kg^{-1} rocuronium (Schering-Plough Tıbbi Ürünler Tic. A.Ş. Istanbul, Turkey), endotracheal intubation was performed in suitable conditions. The maintenance of anaesthesia was enabled with intermittent fentanyl–rocuronium intravenous (iv) boluses and 1–2% sevoflurane. The respiratory rate was adjusted so as to obtain 50% FiO_2, a breath volume of 6–8 mL kg^{-1} and $PaCO_2$ of 35–45 mmHg after intubation. Central vein catheterisation was performed from the left internal jugular vein. Considering the baseline value of activated coagulation time (ACT) before CPB, 30000 U of heparin was administered for anticoagulation. ACT before CPB was kept at 400–450 min. During the administration of anaesthesia, blood gases, ACT, urinary frequency, blood glucose level and haemodynamic parameters were monitored, and necessary interventions were conducted. After right axillary artery and arterial two-stage vein cannulation, CPB was started, and the patient was brought down to 28°C. Following the use of antegrade and retrograde cardioplegia after the placement of a cross-clamp, an aortotomy was performed above the previous graft. Coronary ostia were prepared and Valsalva sinuses were resected to the aortic root. Because the old mechanical aortic valve appeared functional, it was left in its place. A Dacron graft and mechanical aortic valve ring were anastomosed onto the aortic root together. Coronary ostia were then re-implanted onto the button-shaped graft. Propofol (5 mg kg^{-1}) was administered before low output. After entering into low output (10 mL kg^{-1} min^{-1}) with ASCP, a distal anastomosis was performed using an open technique in such a way that hemiarch replacement could be conducted. Following air removal, the cross-clamp was removed, and warming was initiated. Low output (ASCP), cross-clamp and CPB lasted for 24 min, 88 min and 162 min, respectively. At the end of CPB, the effect of heparin was reversed with protamine in the ratio of 1:1. After a 5-h operation, the patient was taken to the intensive care unit with endotracheal tube. He was extubated at the postoperative 8th hour. After being followed-up in the intensive care unit for 2 days, he was discharged from the hospital without any new neurological event on the postoperative 7th day. The values of rSO_2 that were obtained during the operation are presented in Table 1 and Figure 3. In the EEG

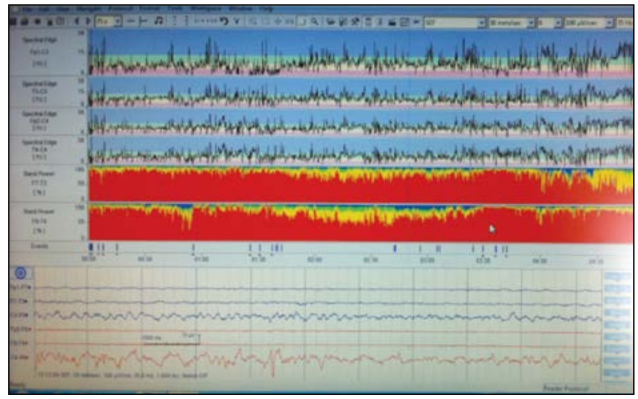

Figure 1. EEG during the entire operation
EEG: electroencephalography

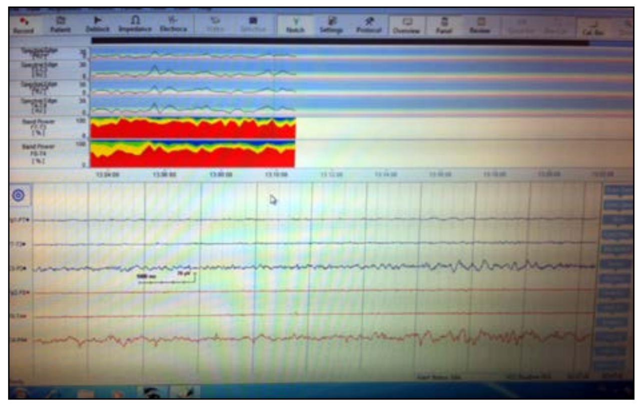

Figure 2. EEG during the period of ASCP
ASCP: antegrade selective cerebral perfusion; EEG: electroencephalography

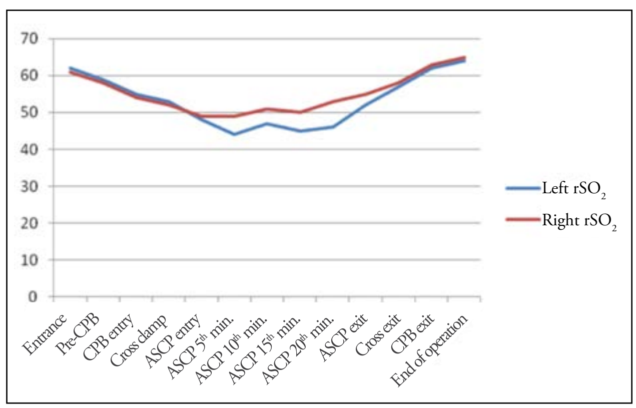

Figure 3. Bilateral rSO_2 values.
CPB: cardiopulmonary bypass; ASCP: antegrade selective cerebral perfusion.

trend, the percentage values of beta, alpha and theta waves were lower and those of delta waves were higher in the left hemisphere than in the right hemisphere, which was perfused by ASCP. Bilateral SEFs of the patient are given in Table 2. Written informed consent was obtained from the patient for his data to be used in a case report.

Discussion

Electroencephalography was first included in intraoperative neuromonitoring as a method for recording electrical activity

Table 1. Bilateral rSO_2 values

NIRS	Entrance	Pre -CPB	CPB entry	Cross clamp	ASCP entry	ASCP 5 min	ASCP 10 min	ASCP 15 min	ASCP 20 min	ASCP exit	Cross exit	CPB exit	End of Operation
Leftr SO_2%	62	59	55	53	48	44	47	45	46	52	57	62	64
Right rSO_2%	61	58	54	52	49	49	51	50	53	55	58	63	65

NIRS: near-infrared spectroscopy; CPB: cardiopulmonary bypass; ASCP: antegrade selective cerebral perfusion

Table 2. Bilateral EEG spectral edge frequency (SEF)

SEF	Entrance	Pre -CPB	CPB entry	Cross clamp	ASCP entry	ASCP 5 min	ASCP 10 min	ASCP 15 min	ASCP 20 min	ASCP exit	Cross exit	CPB exit	End of Operation
Left	15.6	14.8	13.8	13.8	9.8	8.0	7.5	6.6	5.9	7.2	12.9	13.8	14.4
Right	15.4	14.2	13.6	13.7	10.9	9.6	9	9.5	9.6	11	13.7	14.2	14.1

EEG: electroencephalography; SEF: spectral edge frequency; CPB: cardiopulmonary bypass; ASCP: antegrade selective cerebral perfusion

from the scalp in 1960 and then it began to be used in carotid endarterectomies and large-vessel surgeries (5, 6). It is generally used for evaluating the degree of cerebral perfusion, monitoring the depth of anaesthesia and determining the efficiency of hypothermia for neuroprotection. To understand and interpret raw EEG signals requires expertise because these signals can be subjective and open to comment even in experienced hands. Therefore, EEG signals are converted to be mathematically definable using the fast Fourier transform (FFT) method. FFT is not an EEG signal but a frequency spectrum of regular sine-wave activity and this processed datum can be transferred to the user as SEF. As the percentage values of beta, alpha, theta and delta waves and the values of SEFs are numerical, they are more practical in terms of evaluation. Therefore, instead of mixed waveforms that can vary from person to person and are followed only visually, an easier evaluation can be performed with SEFs. In the case presented here, SEFs, which were symmetrical in the beginning, displayed mild lateralisation with the onset of ASCP. The difference between hemispheres increased in the later periods of ASCP and after ASCP the values began to be symmetrical again. While selective perfusion was being applied to the right side, SEFs of the right hemisphere were observed to be higher than those of the left side.

In the first published series about the use of unilateral ASCP in aortic surgery, because distal perfusion was provided through the femoral artery in addition to cerebral perfusion, a CPB flow of 30–50 mL kg^{-1} min^{-1} was implemented at lower body temperatures (22–26°C). No major neurological event was detected in this first small series (7). In the study by Hagl et al. (8), conducted in 2001, the superiority of antegrade cerebral perfusion over other cerebral protection techniques (total circulatory arrest and retrograde cerebral perfusion) was proven with regard to neurological results. With the increased belief in providing cerebral perfusion in this way and the development of neuromonitoring techniques, despite clinical differences, selective cerebral perfusion with moderate hypothermia and a flow of 10 mL kg^{-1} min^{-1} has become more common in clinical practice since the late 1990s (9). In order to shorten the time of CPB (reduction of cooling-down and warming times) and to avoid the undesired effects of hypothermia, interventions began to be applied with moderate hypothermia (26–28°C), but there is no adequate evidence for the reliability of the procedure at higher temperatures. On the other hand, in studies conducted with large series of cases, it was found that the rate of permanent neurological defects after procedures that were performed with the ASCP technique varied between 2% and 4% (8, 10, 12).

During unilateral ASCP, low-flow cerebral perfusion provided from the right carotid artery through the right axillary artery reaches the left hemisphere with a fully functional Willis circle. The prevalence of an incomplete Willis polygon has been found to occur at rates of up to 50% in some series, and this situation accounts for 15% of cerebral perfusion disorders (13, 14). During intervention, after the desaturation of the contralateral hemisphere has been rapidly determined with NIRS and EEG, the left carotid artery can be cannulated, and in addition, left cerebral perfusion can be provided. Therefore, the early detection of perfusion deficiency is important and improves neurological prognosis (15). In our patient who underwent aortic surgery, perfusion sufficiency and contralateral hemisphere difference were evaluated with two monitors during the entire surgery and especially during ASCP. The basal measurements of the patient were primarily evaluated due to his history of a previous cerebrovascular event. EEG electrodes do not give information on brain stem localisation because the O1-O2 region, which is the lowest region where they are placed, exhibits occipital lobe activity. On the other hand, rSO_2 values obtained by NIRS correspond only to the frontal region. Accordingly, it is not expected that EEG and NIRS will reveal any pathological finding of a previous pontine infarct. However, pathological conditions in other cortical regions of the brain can be seen as locally impaired symmetry and abnormal waveforms. Data obtained via NIRS can give information only about the perfusion of the frontal region. Therefore, using more than one neurological monitoring technique (EEG, NIRS, transcranial Doppler ultrasound, evoked potentials, etc.) during the intraoperative period enables the more reliable evaluation of global and local electrical activity, perfusion and acute pathologies of the brain.

In this patient, as SEFs and rSO_2 values were within normal intervals and both hemispheres were symmetrical, changes observed during the operation were determined to belong to the intraoperative period. During ASCP, lower SEFs and rSO_2 values were found in the left hemisphere. The rate of difference in NIRS values between the hemispheres did not exceed 30%, but the values of rSO_2 were below 50% during the ASCP period. The absence of apparent pathological hemisphere differences suggested that the Willis polygon was relatively functional. In parallel with rSO_2 values, SEFs were observed to be lower in the left hemisphere during ASCP. Owing to the suppression of SEFs with the administration of propofol, in addition to 28ºC hypothermia in ASCP, cerebral metabolic activity was reduced. Therefore, bilateral SEFs were below the level of 14 Hz, which was determined to be an adequate level of anaesthesia (16). In this way, poor blood flow (10 mL kg^{-1} min^{-1}) during the ASCP period was enabled to meet the decreased metabolic activity.

Conclusion

Acute cerebral ischaemia can be detected in a short time by intraoperative EEG monitoring. The severity of ischaemia and changes in frequency and amplitude are correlated with each other (17-19). This close relationship between cerebral blood flow and EEG enables dynamic, valuable and continuous monitoring during the intraoperative period. In contrast to frontal regional perfusion evaluated via NIRS, it is possible to obtain information about all cortical regions of the brain using multiple-channel EEG. It is not surprising that there can be similar obstructive pathologies in the Willis polygon of patients with aortic and carotid atherosclerosis. Therefore, in patients who will undergo important vascular surgery, as in our case, a global evaluation is more valuable for postoperative neurological prognosis than the evaluation of a restricted region via NIRS. However, using EEG in the intraoperative period causes some difficulties. In the operating room, the use of 16-channel EEG as a trend monitor is difficult due to some disadvantages, including the time-consuming placement of electrodes and the recording of artefacts at times such as when electrode cables are in contact with the operating table and the patient. However, making multiple-channel EEG more functional by a method adapted to intraoperative period conditions with fewer artefacts and its usage in combination with NIRS will contribute to the prevention of neurological morbidity in aortic surgery.

Informed Consent: Written informed consent was obtained from patient who participated in this case.

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