Bispectral index and detection of acute brain injury during cardiac surgery

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EDITOR:

Stroke, encephalopathy and cognitive disorders following cardiac surgery remain devastating problems as a result of macro- or micro-embolic phenomena or global cerebral hypoperfusion [1]. Besides, more sophisticated neuromonitoring systems (i.e. raw electroencephalogram (EEG), evoked potential, near infra-red spectroscopy), the bispectral index (BIS) derived from a single channel frontal EEG may serve as a simple and less-expensive tool, which affords the unique opportunity to gauge the hypnotic level while detecting cortical dysfunction [2]. Herein, we report a case of severe depression of the BIS index and discuss a multimodal approach for early diagnosis of neurological dysfunction.

A 62-yr-old female with an aneurysm of the ascending aorta and stable aortic insufficiency was scheduled for elective valve replacement and aortic prosthetic graft insertion. The patient was chronically treated for diabetes, hyperlipidaemia and hypertension. Four weeks previously, she had suffered a stroke associated with atrial fibrillation. Preoperative cardiac investigations demonstrated normal ventricular function, patent coronary arteries and a 50% stenosis on the left carotid artery with a hypoplastic right vertebral artery. At arrival in the operating room – in addition to standard equipment – a 4-electrodes BIS sensor was placed on the forehead and connected to the AXP-2000 monitoring system (software version 4.0; Aspect Medical, Newton, MA, USA). After intrathecal injection of 0.7 mg morphine, general anaesthesia was induced and maintained with a propofol infusion targeted to BIS values between 40 and 60. After endotracheal intubation and mechanical lung ventilation, transoesophageal echocardiography (TOE) demonstrated the absence of patent foramen ovale and intracardiac thrombi, whereas the ascending aorta appeared free from calcification, atheromatous plaque, intimal flap or false lumen suggestive of dissection. After heparinization, normothermic cardiopulmonary bypass (CPB) was instituted with cannula inserted in the right subclavian artery and the right atrium. After aortic cross-clamping, myocardial protection was accomplished by antegrade infusion of hyperkalaemic blood solution; 2 min later, haemodynamic and blood parameters were unchanged, but the BIS value abruptly decreased from 40 to 0 along with a steep increase in the burst suppression index to 100% (Fig. 1). While any cause of technical artefacts was excluded, the infusion of propofol was slightly decreased and the surgeons were asked to verify the position of the cannulas. Using a transthoracic 4–8 MHz echographic probe at the right temporal acoustic window, colour and pulsed Doppler failed to demonstrate blood flow in the middle and anterior cerebral arteries. While the subclavian arterial cannula was slightly withdrawn, direct puncture of the innominate artery revealed a non-pulsatile pressure value equal to the monitored radial pressure (55–60 mmHg).

Although the BIS index persisted at 'near-zero' values with the raw EEG resembling a flat line (burst suppression ratio of 100), the surgeons completed the intervention (aortic cross-clamp time of 60 min) by inserting a 24-mm St Jude stentless valve and a 24-mm collagen impregnated Dacron graft. After ventricular de-airing, the patient was weaned from CPB without pharmacological support. Postoperatively, no clinical sign of awakening was noticed and magnetic resonance imaging documented severe and diffuse cortical lesions consistent with anoxic encephalopathy. The patient remained in a persistent coma and active life support was withdrawn on the eleventh postoperative day. Autopsy examination confirmed global brain ischaemic injuries and documented a common origin of right and left carotid arteries.

Although BIS index is not designed as a tool for neurological monitoring during cardiac surgery, the sudden and sustained decrease in BIS concurrent with a flat EEG line in our case was highly suspicious for global ischaemic-induced cortical dysfunction at the time of aortic cross-clamping. Among likely causes leading to severe brain damage, one should consider malposition of the subclavian cannula (advanced too proximally) and/or disruption of atheromatous plaque due to a 'sandblasting' effect generated by a high-velocity flow pattern at the orifice of the CPB cannula. Intraoperative TOE and autopsy ruled out arterial

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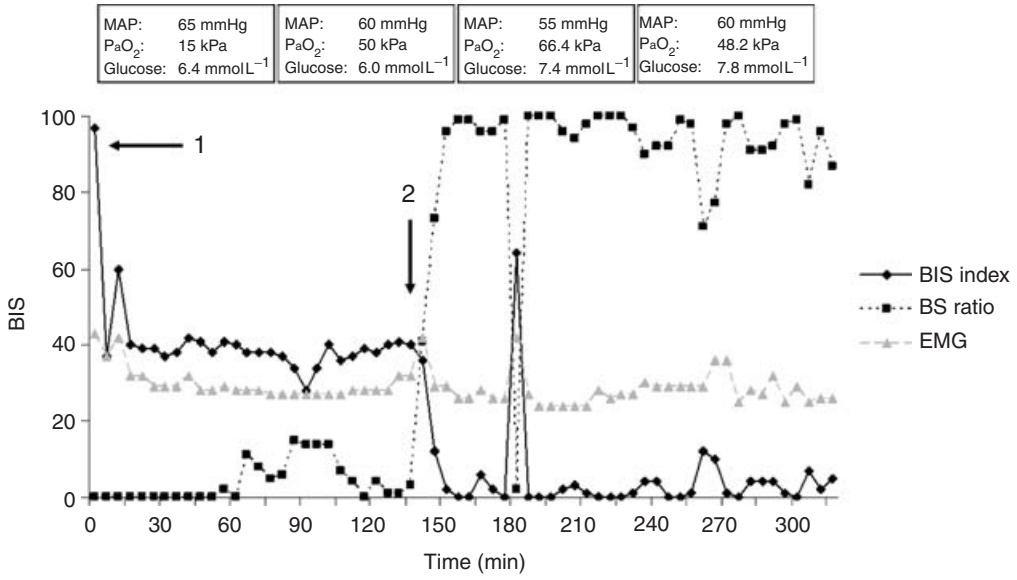

Figure 1.
Changes in the BIS, the BS ratio and the EMG activity from the start of anaesthesia (arrow 1) throughout the surgical procedure, including the aortic cross-clamping (arrow 2); the averaged values of MAP, PaO_2 and glucose blood concentration are indicated for the corresponding pre-incision, pre-bypass, bypass and post-bypass periods. (BIS: bispectral index; BS: burst suppression; EMG: electromyographic; MAP: mean arterial pressure; PaO_2: arterial oxygen pressure).

dissection and macro-embolization. Importantly, flow collateralization through the left carotid artery was ineffective given the common origin of both carotid arteries and flow collateralization through the basilar trunk was also limited by a hypoplastic vertebral artery and impairment of cerebral autoregulation associated with chronic vascular disease (hyperlipidaemia, diabetes, hypertension, stroke).

Anecdotal reports have indicated that intraoperative events unrelated to anaesthetic depth may produce a sustained drop in BIS values (e.g., cerebral ischaemia or hypoperfusion, gas embolism, uncontrolled haemorrhage), whereas a subsequent increase in BIS values provided confirmation of brain activity regained during cardiopulmonary resuscitation [3–5]. In line with these observations, the usefulness of BIS monitoring as an index of neurological dysfunction has been demonstrated in critically ill patients: BIS values are good predictors of neurological outcome and tightly correlate with other scoring systems such as the Glasgow coma score and clinical sedation/agitation scales [6,7].

Considering the effectiveness of BIS monitoring as an early warning sign of perioperative stroke, the observation of a sudden and sustained low BIS value combined with an elevated burst suppression ratio warrants a stepwise approach involving: (1) exclusion of technical artefacts (e.g. low transcutaneous impedance values, contact of the 4-lead probe on the skin forehead, good signal quality index), (2) assessment of potential causes of decreased metabolic brain activity (e.g. anaesthetic/sedative overdose, hypothermia, hypoglycaemia) and (3) measurement of cerebral blood flow by transcranial Doppler ultrasounds. In most operating theatres, the availability of the echocardiographic machine coupled with the 2–4 MHz transthoracic probe allows the direct visualization and estimation of cerebral blood flow at the temporal and occipital windows by application of Doppler flow colour and pulsed Doppler modalities.

Given the increasing prevalence of high-risk neurological patients, intraoperative application of BIS, – eventually supplemented by transcranial ultrasound –, might improve patient safety and deserves further clinical trials.

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Work stress in medical anaesthesiology trainees

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EDITOR:

Recent reports of human errors indicate the importance of assessing work stress and improving the working environment in order to reduce errors. It is natural to assume that medical trainees have a large burden of stress during their training period. It has recently been reported that the concentration of salivary amylase may reflect the degree of working stress [1], and a kit that enables simple measurement of amylase concentration has been developed [2]. We therefore tried to measure salivary amylase concentrations in medical trainees of the Department of Anaesthesiology in order to determine stress factors.

Twelve medical trainees who had initially received training in Sapporo Medical University Hospital after graduation from medical school were enrolled in this study. None of the medical trainees had a history of neurological or psychiatric disorders; none of them were taking any medication that affects autonomic nervous and endocrine systems, and none of them had any tendency towards gingival bleeding. Two studies were conducted: Study 1 was carried out to find how individual stress changes within 1 day (07:00, 12:00, 15:00, 19:00), and Study 2 was carried out to determine whether stress reaction differed depending on the type of surgery (abdominal or neck/face surgery at 30 min before the operation, 60 min after the operation and just after the end of operation). The timing of salivary sampling was blinded and randomized, and the surgical cases of which the medical trainees took charge were also randomized. The concentrations of salivary amylase were measured by the use of a kit for simplified measurement, COCORO Meter^{TM} (Nipro Co., Osaka, Japan) [3]. A disposable probe was inserted into the sublingual region for 20 s, and the concentration of amylase was then measured in the kit, measurement time taking approximately 10 s. This automated system for analysing salivary amylase activity using a dry-chemistry system was made by the fabrication of a disposable teststrip equipped with built-in collecting and reagent papers and an automatic saliva transfer device [3]. Differences in measured concentrations in each group and between groups were compared using the Kruskal–Wallis test with Fisher's *post hoc* test. $P < 0.05$ was considered significant.

In Study 1, the concentrations of salivary amylase at 07:00 varied: eight medical trainees showed very low concentrations of amylase (less than 30 kU L^{-1}) while four trainees showed concentrations over 100 kU L^{-1}. The time course of the amylase activity was therefore divided into two groups depending on the morning concentrations (Fig. 1). The amylase concentrations in the trainees who showed low concentrations in the morning tended to increase during the day, but there was no statistical significance (Fig. 1a, $n = 8$; $P = 0.056$). The amylase concentrations in the trainees who showed high concentrations (over 100 kU L^{-1}) in the morning significantly decreased at 12:00 (Fig. 1b, $n = 4$; $P = 0.038$), but there was no change in the amylase concentrations after that time. There were no significant differences in the amylase concentrations between these groups after 12:00. Interestingly, all of the trainees who showed amylase concentrations

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