ORIGINAL ARTICLE

HSR Proceedings in Intensive Care and Cardiovascular Anesthesia 2011; 3(1): 47-58

Impact of bispectral index monitoring on postoperative delirium in patients undergoing aortic surgery

G. Santarpino, R. Fasol, J. Sirch, B. Ackermann, S. Pfeiffer, T. Fischlein

Cardiac Surgery Unit, Klinikum Nuernberg, Nuernberg, Deutschland

HSR Proceedings in Intensive Care and Cardiovascular Anesthesia 2011; 3(1): 47-58

ABSTRACT

Background: Bispectral index monitoring can facilitate anesthesia care. We evaluated the association of Bispectral index with postoperative neurological outcome and delirium in patients undergoing aortic surgery.
Methods: From 2006 to 2009, 292 consecutive patients undergoing aortic surgery were retrospectively reviewed. Patients were classified into 5 groups according to Bispectral index reduction: Group I (≤15%), Group II (15-20%), Group III (20-25%), Group IV (25-30%), and Group V (>30%).
Results: The number of patients in each group was : 52 (17.8%), Group I; 125 (42.8%), Group II;68 (23.3%), Group III; 33 (11.3%), Group IV; 14 (4.8%), Group V. The incidence of delirium and neurological events was higher in Group IV and Group V(90.9% and 18.2% in Group IV, and 71% and 79% in Group V; both $p < 0.001$). Only Group V showed a longer intensive care unit stay compared to Group I (13.5 ± 10.3 vs 5.4 ± 6.6 days; $p = 0.002$), Group II (7.3 ± 8.6 days, $p = 0.005$) and Group III (6.7 ± 6.5 days, $p = 0.015$). Group V also showed a longer intubation time compared to Group I (228 ± 211 vs 73 ± 112 hours; $p = 0.008$) and Group II (105 ± 177 hours, $p = 0.002$).
Conclusion: Our data suggest a higher incidence of neurological deficits in patients with a Bispectral index reduction of >25% from baseline. Explanations for these findings are speculative with regard to the underlying mechanisms, and larger studies are warranted to clarify these issues.

Keywords: *aortic surgery, bispectral index monitoring, cerebral complications, delirium*

INTRODUCTION

The reduction in cardiac morbidity/mortality following cardiac surgery has focused the attention on central nervous system complications, especially in elderly patients with severe comorbidity and neurological dysfunction (1). Although considerable information on neurological outcome in coronary patients is available (2), neurological risk and cerebral protection techniques are an issue of debate since many years (3-5).
In ascending aortic arch surgery, cerebral oximetry has been demonstrated to confirm the adequacy of cerebral perfusion and oxygenation.
With individual catheters for selective cerebral perfusion, acute changes may indicate catheter migration, obstruction, or dislodgment (6, 7). Any asymmetrical decline should prompt a thorough assessment to determine sufficient cerebral flow. If unilateral selective cerebral perfusion from the right axillary is used for cerebral protection, cerebral oximetry of the contralat-

Corresponding author:
Giuseppe Santarpino, MD
Cardiac Surgery Unit, Klinikum Nuernberg
Klinikum Sued, Breslauer Strasse 201
90471 Nuernberg, Deutschland
e.mail: g.santarpino@libero.it

eral hemisphere may indicate the need for an additional catheter in the left common carotid artery in patients without sufficient collaterals (8, 9). Cerebral oximetry may not detect cerebral embolic events (10). Transcranial Doppler is more sensitive in detecting embolic events and confirming cerebral blood flow, but is more operator-dependent and may not be available in emergent situations (11).
Bispectral index (BIS) monitoring systems allow to access processed EEG information as a measure of the effect of certain anesthetics. The clinical impact of BIS monitoring has been demonstrated in a variety of randomized controlled trials that reveal the potential for BIS monitoring to facilitate improvements in anesthesia care (12-14). The predictive value of BIS as a monitor for awareness has been partially clarified (15), but much remains to be elucidated regarding postoperative delirium (16-18).
The aim of this study was to evaluate the role of BIS in postoperative neurological outcome of patients undergoing aortic surgery, with special reference to motor function and delirium.

METHODS

Study patients

From December 2006 to December 2009, 292 consecutive adult patients undergoing aortic surgery were retrospectively reviewed from the clinical and hospital records. The study population was divided into subgroups according to BIS reduction and type of surgery in order to limit the uneven distribution of patients in each group due to retrospective data collection. All patients underwent replacement of the ascending aorta, combined with aortic arch or valve replacement or coronary artery bypass grafting in some cases, for elective, urgent or emergency indications in hypothermic circulatory arrest or using selective cerebral perfusion, if necessary. A separate subgroup analysis was made for aortic dissection patients undergoing elective ascending and aortic arch aneurysm operations.

Anesthesia

The anesthetic technique was standardized for all patients. After induction using intravenous propofol at an initial dose of 1.5-2.5 mg/kg followed by a continuous 2-4 mg/kg/h infusion combined with remifentanyl administration (25 ng/kg/min), neuromuscular blockade was achieved with cisatracurium (0.2 mg/kg). Lungs were ventilated to normocapnia with an air-oxygen mixture (45–50%). The alpha-stat method was used for blood gas management.
Before deep hypothermic circulatory arrest, methylprednisolone sodium succinate (1000 mg) was adminstered, and the head was packed in ice to maintain low brain temperature.
BIS was measured at the frontal lobe of the left hemisphere after skin preparation with disinfectant alcohol and slight rubbing by using a BIS monitoring system and a BIS sensor (Aspect Medical Systems, Cambridge, MA; BIS version 3.0 rev. 0.5). BIS measurements were taken before anesthesia induction and recorded every 15 s thereafter. Following induction of anesthesia, baseline BIS value was recorded (baseline BIS).
For each individual patient, a ratio between the baseline BIS value and the minimum BIS value recorded during surgery was determined (baseline value-minimum value/baseline value x 100). According to the BIS values derived from this ratio, patients were classified into five groups according to BIS reduction: Group I ≤15%, Group II 15-20%, Group III 20-25%, Group IV 25-30%, and Group V >30%. During surgery, only episodes lasting >15 min with the

most pronounced reduction in BIS value were entered in the records. Since several artifacts and clinical conditions may impact the displayed BIS value, the time interval was arbitrarily set to >15 min to minimize the rate of false positives (19). BIS was considered to be reduced when the anesthesiologist's and surgeon's attempts failed to restore normal values (approximately 40 to 60 during maintenance) over this time interval, by adopting strategies aimed at improving cerebral protection via pharmacological agents or topical cerebral cooling, or modifying selective cerebral perfusion (see below).

Surgical technique and cardiopulmonary bypass

Cardiopulmonary bypass (CPB) and surgical technique were standardized for all patients. CPB was established using a double-staged venous cannula placed in the right atrium. Cerebral perfusion was established through the right axillary artery or brachiocephalic artery in patients with or without aortic dissection, respectively. Body perfusion was maintained via the femoral artery. Distal ascending aorta or aortic arch was used for ascending aneurysms. Myocardial protection was always achieved with antegrade/retrograde blood cardioplegia according to the protocol of Calafiore et al. (20). In patients undergoing hypothermic circulatory arrest, cooling was limited to 20°C rectal temperature. In this patient subset, the lowest BIS value at any time during surgery was documented in the anesthesiology records, regardless of the lowest temperature attained. Total CPB flow was maintained at 2.6 $l/min/m^2$ during normothermia and progressively reduced to a minimum of 2.2 $l/min/m^2$. When the aortic arch was opened, the epiaortic vessels were snared with vessel loops and the left carotid artery cannulated with a retrograde cardioplegia cannula if clinical (mydriasis or anisocoria) or instrumental signs (deep fall of the BIS value with respect to post-induction plateau levels observed in the time interval between circulatory arrest and establishment of selective cerebral perfusion) were suggestive of cerebral ischemia.

Postoperative care

On admission to the intensive care unit (ICU), assisted-controlled ventilation was started in all patients to maintain pH between 7.35 and 7.45, PaCO2 between 35 and 45 mmHg, and PaO2 between 90 and 100 mmHg with an arterial oxygen saturation >95%. If patients showed signs or symptoms of neurological complications after surgery, brain computed tomography was performed.

An awake and compliant extubated patient, with stable hemodynamic parameters, and absence of bleeding indicated the discharge from the ICU to the ward. The weaning parameters were recorded from the Evita 4 Ventilator (Dräger Medical AG and Co., Lubeck, Germany).

Respiratory rate to tidal volume ratio, pressure–frequency product, PaO2 to fractional inspired oxygen concentration, and PaCO2 were recorded at the same time in the two groups 30 min after the beginning of the weaning protocol. Successful extubation was defined as the ability to maintain spontaneous breathing for 48 hours. Perioperative and ICU complications were also recorded.

Delirium was defined as a disturbance of consciousness and cognition that develops rapidly and fluctuates over time, without neurological sequelae, according to the American Psychiatric Association's (APA) Diagnostic and Statistical Manual of Mental Disorders (DSM) - IV (20). On the basis of the differential diagnosis performed by the anesthesia staff in the ICU, clinical instrumental findings showing postoperative low cardiac output, or acute renal or liver failure were not entered in the database as events associated with postoperative delirium and were not included in the statistical analysis.

Study endpoints

The primary endpoints of the study were the incidence of delirium and neurological complications with motion deficit. Mortality, non-neurological outcome, orotracheal intubation time and ICU length of stay were secondary endpoints.

Statistical analysis

Continuous variables are presented as mean ± standard deviation, and categorical variables are presented as absolute numbers and proportions.
Data were checked for normality before statistical analysis. Normally distributed continuous variables were compared using the one-way ANOVA.
Owing to the fact that patients were classified into more than two study groups, an intergroup post-hoc analysis was performed according to Bonferroni (equal variances assumed). Categorical variables were analyzed using the X2-test or Fisher's exact test.
All statistical analyses were considered significant if $p < 0.05$ and were performed with the SPSS statistical package 13.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

On the basis of BIS reduction, number of patients included in each group was as follows: 52 (17.8%) in Group I, 125 (42.8%) in Group II, 68 (23.3%) in Group III, 33 (11.3%) in Group IV, and 14 (4.8%) in Group V. The clinical characteristics as well as the, intra- and postoperative parameters of the study population are reported in *Table 1*.

Table 1 - *Clinical characteristics, intra- and postoperative parameters of the study population (292 patients).*

	Mean ± SD	Range
Age (years)	59.2 ± 13.5	19-84
EuroSCORE	10.2 ± 3.3	0-19
Height (cm)	173.1 ± 9.9	145-212
Weight (kg)	82.3 ± 18.3	49-176
NYHA class	1.1 ± 1.4	1-4
LVEF (%)	60.3 ± 11.7	19-79
Procedure time (min)	281.5 ± 117.7	90-680
CPB time (min)	167.4 ± 81.3	26-555
Cross-clamping time (min)	93.3 ± 42.6	18-277
Minimum temperature (°C)	28.4 ± 5.8	14.5-37
Intubation time (h)	108.9 ± 179.4	4-1248
ICU stay (days)	7.3 ± 8.0	1-41
Delirium		
No	239 (81.8%)	
Yes	53 (18.2%)	
No need for therapy	22 (7.5%)	
Need for therapy	31 (10.6%)	
Neurological events		
No	263 (90.1%)	
TIA	1 (0.3%)	
RIND	3 (1.0%)	
Stroke	25 (8.6%)	
Indication		
Elective	123 (42.1%)	
Urgency	37 (12.7%)	
Emergency	132 (45.2%)	
Surgical procedure		
Ascending aortas + CABG	3 (1.0%)	
Ascending aorta + AVR	178 (61.0%)	
Ascending aorta - AVR	91 (31.2%)	
With aortic arch	20 (6.8%)	
Mortality		
No	273 (93.5%)	
Yes	19 (6.5%)	

AVR = aortic valve replacement; CABG = coronary artery bypass graft; CPB = cardiopulmonary bypass; ICU = intensive care unit; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association; RIND = reversible ischemic neurological disease; TIA = transient ischemic attack.

Intergroup analysis showed no statistical differences in preoperative characteristics and intraoperative parameters among groups (*Table 2*).

Four patients with aortic arch disease (1 from Group I, 2 from Group II and 1 from Group V) underwent total aortic arch replacement using the elephant trunk technique for supra-aortic artery reimplantation. Sixteen patients (3 from Group I, 7

Table 2 - *Clinical characteristics, intra- and postoperative parameters of the study groups.*

	Group I (n = 52)	Group II (n = 125)	Group III (n = 68)	Group IV (n = 33)	Group V (n = 14)
Age (years)	59.7 ± 15.0	60.0 ± 14.3	60.2 ± 11.9	53.6 ± 11.2	58.7 ± 10.9
EuroSCORE	10.3 ± 3.2	10.2 ± 3.6	9.9 ± 2.8	10.7 ± 3.5	10.1 ± 3.2
Height (cm)	172.1 ± 9.7	172.7 ± 9.5	171.9 ± 10.2	177.8 ± 10.8	174.9 ± 8.4
Weight (kg)	80.4 ± 13.9	81.4 ± 16.7	84.6 ± 25.2	84.6 ± 14.5	81.4 ± 14.4
NYHA class	1.2 ± 1.4	1.3 ± 1.5	1.0 ± 1.3	0.7 ± 1.3	1.1 ± 1.3
LVEF (%)	63.5 ± 11.7	59.2 ± 12.8	60.7 ± 10.2	58.4 ± 10.9	61.3 ± 8.0
Procedure time (min)	272.0 ± 126	285.7 ± 115.9	268.0 ± 117.0	287.0 ± 113.2	331.0 ± 117.7
CPB time (min)	165.2 ± 94.1	165.8 ± 76.2	162.2 ± 83.2	171.6 ± 70.1	205.4 ± 89.7
Cross-clamping time (min)	95.7 ± 50.5	88.4 ± 36.8	93.4 ± 43.4	101.5 ± 44.6	108.2 ± 50.0
Minimum temperature (°C)	28.7 ± 6.0	28.5 ± 5.4	29.1 ± 5.6	26.8 ± 6.5	26.5 ± 6.6
Intubation time (h)	73.3 ± 112	105.2 ± 177.8	106.6 ± 209.4	133.5 ± 169.0	228.2 ± 211.3
ICU stay (days)	5.4 ± 6.6	7.3 ± 8.6	6.7 ± 6.5	8.7 ± 8.3	13.5 ± 10.3
Delirium					
No	49 (94%)	120 (96%)	63 (92.6%)	3 (9.1%)	4 (29%)
Yes	3 (5.8%)	5 (4%)	5 (7.4%)	30 (90.9%)	10 (71%)
No need for therapy	1 (1.9%)	1 (0.8%)	4 (5.9%)	15 (45.5%)	1 (7.1%)
Need for therapy	2 (3.8%)	4 (3.2%)	1 (1.5%)	15 (45.5%)	9 (64%)
Neurological events					
No	49 (94%)	119 (95.2%)	66 (97.1%)	27 (81.8%)	2 (14%)
TIA	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (7.1%)
RIND	0 (0%)	2 (1.6%)	1 (1.5%)	0 (0%)	0 (0%)
Stroke	3 (5.8%)	4 (3.2%)	1 (1.5%)	6 (18.2%)	11 (79%)
Indication					
Elective	22 (42%)	50 (40%)	36 (52.9%)	10 (30.3%)	5 (36%)
Urgency	10 (19%)	16 (12.8%)	6 (8.8%)	4 (12.1%)	1 (7.1%)
Emergency	20 (38%)	59 (47.2%)	26 (38.2%)	19 (57.6%)	8 (57%)
Surgical procedure					
Ascending aortas + CABG	0 (0%)	2 (1.6%)	0 (0%)	1 (3.0%)	0 (0%)
Ascending aorta + AVR	32 (61%)	72 (57.6%)	46 (67.6%)	22 (66.7%)	6 (43%)
Ascending aorta - AVR	16 (31%)	42 (33.6%)	21 (30.9%)	8 (24.2%)	4 (29%)
With aortic arch	4 (7.7%)	9 (7.2%)	1 (1.5%)	2 (6.1%)	4 (29%)
Mortality					
No	49 (94%)	116 (92.8%)	64 (94.1%)	32 (97.0%)	12 (86%)
Yes	3 (5.8%)	9 (7.2%)	4 (5.9%)	1 (3.0%)	2 (14%)

AVR = aortic valve replacement; CABG = coronary artery bypass graft; CPB = cardiopulmonary bypass; ICU = intensive care unit; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association; RIND = reversible ischemic neurological disease; TIA = transient ischemic attack.

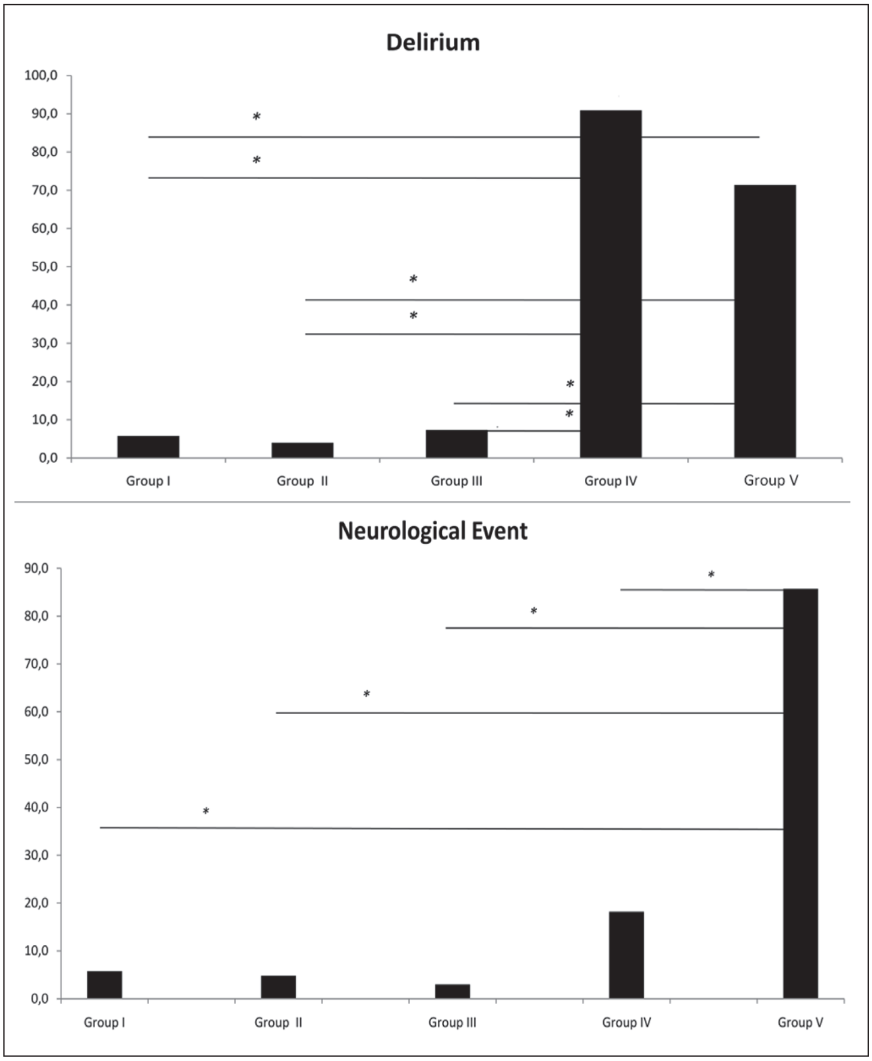

Figure 1
*Incidence of delirium and neurological events in the study population (*p < 0.001).*

from Group II, 1 from Group III, 2 from Group IV, and 3 from Group V) underwent aortic hemiarch replacement (antero-inferior portion of the aortic arch) with reattachment of the brachiocephalic branches. Among patients undergoing replacement of both the ascending aorta and aortica valve, we used the Bentall technique with coronary button reimplantation in 26, 44, 18, 8 and 2 patients from Group I, II, II, IV and V, respectively, and the Wheat technique in 6, 28, 28, 14 and 4 patients from Group I, II, III, IV and V, respectively.

Postoperative outcome analysis showed a cumulative difference in the incidence of delirium and neurological events among groups (both $p < 0.001$) (*Figure 1*).
Similarly, cumulative differences were observed in length of ICU stay and intubation time ($p = 0.003$ and $p = 0.001$, respectively). At post hoc analysis, only Group V showed a longer ICU stay compared to Group I ($p = 0.002$), Group II ($p = 0.005$) and Group III ($p = 0.015$). Group V also showed a longer intubation time compared to Group I ($p = 0.008$) and Group II ($p = 0.002$).

A total of 53 patients developed postoperative delirium; among these patients, 16 underwent elective surgery (1 in Group III, 9 in Group IV and 4 in Group V).
A total of 29 patients developed postoperative neurological events: among these patients, 5 underwent elective surgery (4 in Group V). To avoid any potential confounding effect of aortic dissection surgery, a separate subgroup analysis was made for aortic dissection patients.
All death events occurred in patients with aortic dissection (n = 19, 11.2%) ($p < 0.001$).
Dissection patients also showed a higher incidence of postoperative neurological events ($p = 0.01$) and delirium ($p = 0.007$), necessitating more frequently therapy for delirium ($p = 0.03$).
At preoperative risk factor analysis, dissection patients were similar to elective patients for prevalence of female sex, dia-

Table 3 - *Clinical characteristics, intra- and postoperative parameters of aortic dissection patients.*

	Group I (n = 52)	Group II (n = 125)	Group III (n = 68)	Group IV (n = 33)	Group V (n = 14)
Age (years)	59.5 ± 14.9	58.3 ± 15.5	57.9 ± 12.4	52.4 ± 9.2	59.3 ± 8.5
EuroSCORE	11.7 ± 2.9	11.9 ± 2.9	11.1 ± 2.1	12.0 ± 2.8	11.1 ± 1.9
Height (cm)	174.2 ± 9.9	173.5 ± 9.9	172.1 ± 10.9	179.7 ± 10.5	174.0 ± 10.5
Weight (kg)	80.5 ± 13.7	81.9 ± 17.3	86.7 ± 31.3	86.3 ± 14.7	82.0 ± 14.8
NYHA class	1.1 ± 1.5	1.3 ± 1.6	0.8 ± 1.3	0.7 ± 1.3	0.9 ± 1.3
LVEF (%)	60.8 ± 11.0	60.3 ± 9.9	59.3 ± 10.6	59.2 ± 8.3	59.1 ± 4.5
Procedure time (min)	302.6 ± 126.9	329.5 ± 114.6	330.6 ± 116.4	321.7 ± 111.1	386.7 ± 69.8
CPB time (min)	183.2 ± 103.7	194.4 ± 79.2	199.7 ± 87.4	193.1 ± 68.7	210.1 ± 81.1
Cross-clamping time (min)	100.3 ± 56.8	94.7 ± 38.3	101.7 ± 43.0	110.4 ± 48.4	126.0 ± 49.6
Minimum temperature (°C)	26.5 ± 6.0	26.1 ± 5.1	25.4 ± 5.1	25.0 ± 6.6	22.8 ± 4.6
Intubation time (h)	111.2 ± 145.9	80.1 ± 109.3	163.7 ± 279.7	155.6 ± 185.1	287.0 ± 211.4
ICU stay (days)	6.9 ± 6.8	8.0 ± 7.5	8.7 ± 7.4	9.8 ± 8.3	16.4 ± 11.0
Delirium					
No	27 (90.0%)	70 (93.3%)	28 (87%)	2 (8.7%)	3 (33.3%)
Yes	3 (10.0%)	5 (6.7%)	4 (12%)	21 (91%)	6 (66.7%)
No need for therapy	1 (3.3%)	1 (1.3%)	4 (12%)	9 (39%)	0 (0%)
Need for therapy	2 (6.7%)	4 (5.4%)	0 (0%)	12 (52%)	6 (66.7%)
Neurological events					
No	27 (90.0%)	69 (92%)	31 (97%)	18 (78%)	1 (11.1%)
TIA	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (11.1%)
RIND	0 (0%)	2 (2.7%)	0 (0%)	0 (0%)	0 (0%)
Stroke	3 (10.0%)	4 (5.3%)	1 (3.1%)	5 (22%)	7 (77.8%)
Mortality					
No	27 (90.0%)	66 (88%)	28 (87%)	22 (96%)	7 (77.8%)
Yes	3 (10.0%)	9 (12%)	4 (12%)	1 (4.3%)	2 (22.2%)

CPB = cardiopulmonary bypass; ICU = intensive care unit; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association; RIND = reversible ischemic neurological disease; TIA = transient ischemic attack.

betes, smoking habit and neurological history, but were older ($p < 0.001$) and more often affected by hypertension ($p < 0.001$) and hypercholesterolemia ($p = 0.017$).
The two groups also showed a deducible difference in intubation, procedure, CPB and cross-clamping times, length of ICU stay and body temperature (all $p < 0.001$)
Dissection patients included in the five groups did not show any statistical difference in preoperative and intraoperative parameters (*Table 3*), except for mortality ($p < 0.001$), length of ICU stay ($p = 0.022$) and intubation time ($p = 0.006$). At post hoc analysis, statistical differences were observed in length of ICU stay in Group I vs V ($p = 0.013$) and in Group II vs V ($p = 0.023$) as well as in intubation time in Group II vs V ($p = 0.01$). The incidence of neurological events was higher in Group V ($p < 0.001$), whereas the incidence of delirium was higher in Group IV ($p < 0.001$) (*Figure 2*).

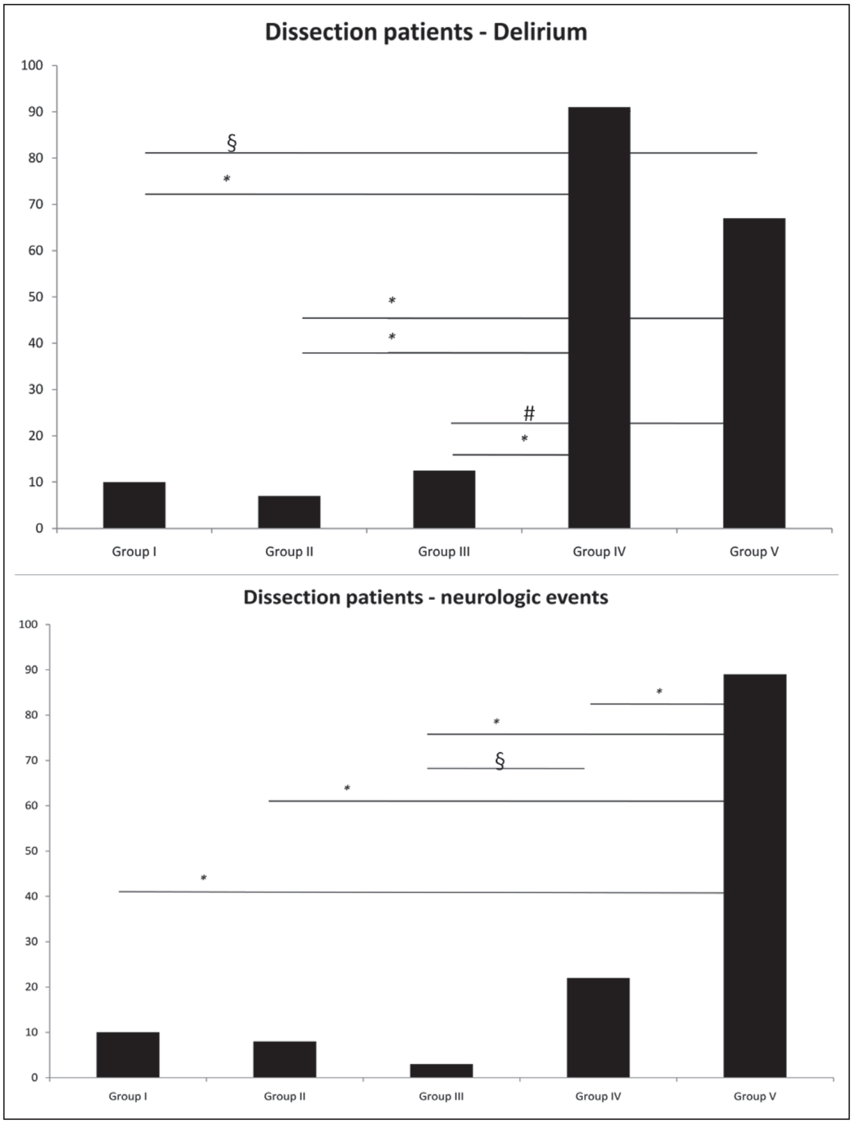

Figure 2
Incidence of delirium and neurological events in aortic dissection patients.
*(*p < 0.001; §p = 0.002; #p = 0.003).*

DISCUSSION

Central nervous system complications accounted for 2-7% of all deaths after CPB surgery in the 1970s, reaching almost 20% by the mid-1980s, and continuing to increase at the present time (2-19, 21). Postoperative neurological dysfunction is also an issue of concern, in that many factors may precipitate postoperative complications with important implications for quality of life and health economics (22-24).

Neurological injury describes a range of disorders, from incapacitating or lethal stroke or coma to encephalopathy, delirium, and neurocognitive decline (22, 25). Although stroke after cardiac surgery is an important concern for both short-term and long-term disability, more subtle neurological effects, such as delirium, are associated with increased medical costs and health care. The possibility of predicting postoperative disturbance of consciousness and cognition can facilitate the appropriate and well-time care avoiding further problems (e.g. fall out of bed, unwilling extubation, self-inflicted wounds). In addition, the development of ever more sophisticated systems for multimodal neurological monitoring has resulted in improved patient safety, and several clinical trials have been carried out with the aim of evaluating new strategies for the prevention of postoperative delirium (26, 27).

Surgical aortic patients are at high risk for postoperative central nervous system complications, because of at least two mechanisms, namely atherosclerosis/cerebral embolization and hypoperfusion. As recently demonstrated by Morimoto et al. (28), low levels of regional cerebral oxygen saturation, monitored using near-infrared spectroscopy, may also represent an important risk factor for postoperative delirium.

Many investigations have identified aortic atherosclerosis aneurysm as a factor associated with a significant increase in the risk of stroke: embolization of aortic atheroma or other debris from the surgical area is an important causal factor in neurological injury after cardiac surgery (29, 30). Low blood pressure during cardiac surgery in selective cerebral perfusion, especially with carotid disease, is associated with reduced washout of small emboli and neurological injury (31).

Moreover, in patients - as our aortic dissection patients – operated with monolateral perfusion, cerebral perfusion maybe not enough because of some variations of the circle of Willis (32). Therefore, in these patients is always recommended an intraoperative follow-up that we performed with transcranial Doppler and BIS monitoring.

More recently, the attention has focused on a refined neurological outcome. Delirium and psychosis, which may often complicate the postoperative course of type-A aortic dissection, are common manifestations of acute brain dysfunction in critically ill patients, and correlate with poor short-term outcomes and adverse sequelae (33).

Real-time readings of regional oxygen saturation using near-infrared spectroscopy during aortic surgery may allow perfusion or oxygenation abnormalities to be detected early (34). Recent studies demonstrating improved central nervous system outcomes with applied neuromonitoring in cardiac surgical patients can be understood as reflecting the optimization of central nervous system perfusion characteristics with potential amelioration of microembolic injury (35).

All these studies demonstrated the neuromonitoring capability of influencing intraoperative anesthesiology and surgical management and the risk for events following a deep reduction of BIS, but no studies show a capability for delirium predictivity. Notwithstanding this, Plaschke et al. (36). have recently demonstrated that early postoperative delirium is associated with decreased

bispectral EEG. Conversely, another study in pediatric patients has found no correlation between deep hypnosis as measured by BIS and the incidence of postoperative delirium/agitation (37).
Our data show a significant risk increase for postoperative delirium with a BIS decrease of 25-30% compared to BIS estimates during anesthesia induction time.
A BIS reduction >20% has already been demonstrated to suggest a higher risk postoperative complications and poor neurological outcome (12), with a high incidence of postoperative delirium and stroke.
In our study population, aortic dissection patients showed a higher BIS reduction than elective patients undergoing ascending aneurysm surgery. This may be explained by the fact that hypothermic arrest with selective cerebral perfusion results in decreased cerebral metabolism. Available evidence suggests an association between decreased cerebral metabolism and BIS reduction (38). Our data, however, show a similar trend in postoperative delirium and neurological events both in the whole study population and dissection patients, even though patients undergoing surgery with hypothermic circulatory arrest have a different postoperative neurological risk that those undergoing surgery with standard CPB. It can be hypothesized a stronger effect of BIS reduction rather than elective/aortic dissection procedures on postoperative risk for delirium or neurological events.
The higher mortality rate observed in Group V is correlated with the poorer neurological outcome of these patients (1-4) and, as expected, all death events occurred in aortic dissection patients.
Group IV patients showed a higher incidence of delirium but similar intubation time and length of ICU stay as compared with groups I, II and III. These data can be explained by our hospital policy: when confused patients show hemodynamic stability and an adequate respiratory status, they are transferred are as soon as possible to an intermediate care unit that provides a more familiar support.

Study limitations

Our study has several limitations.
First, the classification of our study patients into five groups according to BIS reduction is arbitrary, but it made the statistical analysis easier. The aim of our study, however, was not to determine a specific cut-off value, but to demonstrate an association between BIS reduction and development of delirium.
Second, the time interval of 15 min for considering the BIS reduction significant is not supported by the available literature. This choice was dictated by the need for a reasonably reliable index of decreased cerebral metabolism.
Third, the size of the study sample was small and the study design was retrospective. Moreover, data collection was incomplete as regards the equipment used for BIS measurements: clinical record forms only included the recorded BIS values and omitted the measuring device used. All devices, however, were manufactured by the same company (Aspect Medical Systems International, De Meern, The Netherlands).
Finally, given that 90% of the general population is left-hemisphere dominant, electrodes for BIS measurements were always placed in this position. We cannot also exclude the impact of other factors on depth of anesthesia during surgery or postoperative complications, such as different hemodynamic conditions among patients and different procedure times. Moreover, several factors that have been shown to affect the postoperative risk of stroke (e.g., carotid atherosclerosis) were not included in the statistical analysis, because of the lack of such information in the clinical record forms of patients arriving to hospital

as urgent cases. Randomized studies with larger populations are needed before any final conclusions can be drawn.

CONCLUSIONS

Our experience showed that intraoperative cerebral monitoring with BIS can predict postoperative delirium when a BIS reduction of 25-30% is observed. Several confounding factors likely affected the reported BIS values, but if these findings are confirmed by additional research, they would translate in improved quality of the care. Explanations for these findings are speculative with regard to the underlying mechanisms and larger studies are warranted to clarify these issues.

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Cite this article as: Santarpino G, Fasol R, Sirch J, Ackermann B, Pfeiffer S, Fischlein T. Impact of bispectral index monitoring on postoperative delirium in patients undergoing aortic surgery. HSR Proceedings in Intensive Care and Cardiovascular Anesthesia 2011; 3(1): 47-58

Source of Support: Nil, **Conflict of interest:** None declared.