Asymmetry of the bispectral index in lateral decubitus position during one-lung ventilation: A prospective-observational study

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Abstract

Background Use of the bispectral index (BIS) reduces cases of intraoperative awareness and deep sedation. Although non-invasive, the BIS values are often misunderstood. This study evaluated the effects of BIS readings during intra-operative positioning and ventilation. **Methods** Forty-four patients undergoing esophageal cancer surgery were enrolled. BIS sensors were applied on right and left sides. A > 10% difference in BIS reading between the two sides was defined as 'asymmetry.' **Results** Intraoperative BIS asymmetry was observed in 14 (32.6%) patients in the supine position, but 43 (100%) patients in the left lateral decubitus position. The maximum differences between BIS values were observed 15 minutes after one-lung ventilation in the left lateral decubitus position (mean 6.8 ± 4.6 , range [1-27]). **Conclusion** During one-lung ventilation in the lateral decubitus position, care should be taken when placing a BIS sensor and interpreting BIS values.

Introduction

The bispectral index (BIS) was developed to monitor patient level of consciousness under sedation and general anaesthesia.[1] Use of the BIS reduces cases of intraoperative awareness and deep sedation. The BIS is non-invasive, but the major complication is misunderstanding of the results. Generally, BIS values near 100 reflect an awoken state, 40-60 reflects a hypnotic level adequate to prevent awareness under general anesthesia in adults, and less than 40 is considered a deep hypnotic state. The combination of low blood pressure and a small low bispectral index (BIS <45) during surgery has been associated with increased postoperative mortality.[2, 3]

Several factors have been found to alter BIS readings without affecting the depth of anaesthesia. Changes in patient position also affect BIS values and might affect interpretation of the depth of anesthesia. A previous study reported BIS values were increased significantly with changing patient position from neutral to the head-down position followed by a significant decrease with resetting the patient back to neutral position.[4] Usually, the electroencephalogram (EEG) for calculation of BIS is obtained solely from the frontolateral skull, assuming that the EEG characteristics are the same on both sides. However, there is no general recommendation of a particular position for application of BIS. Also, BIS asymmetry readings have been reported as different values in left- and the right-sided BIS recordings. [5, 6]

This study was performed to investigate the incidence and possible clinical relevance of lateral differences of BIS during lateral decubitus positioning and one-lung ventilation.

Materials And Methods

After obtaining approval by the Institutional Review Board of Samsung Medical Centre, Seoul, Republic of Korea (SMC 20107-12-033), and registering in the clinical trial identifier (clinicaltrials.gov identifier NCT 03397745), 44 patients undergoing elective thoracic surgery of esophageal cancer from January 2018 to

August 2018, in a tertiary care academic centre were recruited for this study, and written informed consent was obtained from each patient.

The eligibility criteria were 20 and 80 years of age, esophageal cancer surgery (Ivor-Lewis surgery or 3-filed operation), American Society of Anesthesiologists physical status I-III. The exclusion criteria were ineligibility for BIS sensor application because of a skin problem or refusal to participate.

Anaesthesia and Monitoring

After patient arrival at the operating room, echocardiography, pulse oximetry, and non-invasive blood pressure were monitored. Measurement of BIS was performed continuously from the time of arrival until the end of surgery. A BIS electrode was placed frontolaterally on each side of the skull following the manufacturer's recommendations after cleaning the skin with 70 % ethanol (Aspect Medical System, Norwood, MA, USA). Since 'electrode one' of the BIS sensor was placed on the centre of the forehead, the left and right 'electrode one' were randomly placed above and below each other for each set of data collection.[5, 7]

Two BIS sensors were attached to two Aspect XP BIS monitors (Aspect Medical System, software version 3.2, Model A-2000, Natick, MA, USA). The BIS monitors were using two monitors, changing the actual monitors to avoid device bias switched sequentially to avoid any monitoring site and machine bias. BIS data were collected separately for the left and right cerebral hemispheres throughout surgery. A signal quality index greater than 95% was considered reliable. All BIS data were recorded automatically on the computer every 1 sec, and the average BIS values over 1 minutes for 6 time points were compared. The time points were: 1. Awake in supine position; 2. After induction in the supine position; 3. Immediately after the lateral decubitus position in the supine position; 4. 15 minutes after one-lung ventilation in the left lateral position; 5. After two-lung ventilation in the left lateral position; and 6. After surgery in the supine position

Anesthesia was induced intravenously with propofol 2 mg/kg and a continuous infusion of remifentanyl (0 – 0.2 µg/kg/min). A neuromuscular blockade was obtained for intubation with a single dose of rocuronium (0.6-1.2 mg/kg). The trachea was intubated, and the lungs were mechanically ventilated with oxygen (FiO₂ = 1.0) until the correct positioning of the tracheal tube was verified by auscultation of the lungs and measurement of end-tidal CO₂. Remifentanyl was titrated to maintain a mean blood pressure within ± 20% of the pre-anaesthesia baseline, and sevoflurane was titrated to maintain a target bispectral index of 45 ± 5. Routine clinical monitoring included measurements of train of four by neuromuscular monitoring. Fluid was infused at a rate of 3 – 5 ml/kg/h using lactated Ringer's solution. The SpO₂ was maintained over 95% during one-lung ventilation. End-tidal sevoflurane (ETsevo) were recorded.

Asymmetry

A greater than 10% deviation of average BIS value on either side (an increase or decrease) was defined as 'BIS asymmetry.' The incidence of BIS asymmetry during surgery was monitored at the 6 time points and

calculated for each patient by summarizing the number of asymmetries per patient.

Statistical analysis

We performed a power calculation that required 45 patients in each group to detect a 10% difference to obtain statistically significant results with $\alpha=0.05$ and $\beta=0.90$ in mean (SD) 40 (8) of BIS of the two sides after placing the patient in the left lateral decubitus position. Demographic data, perioperative data, and clinical outcomes between the two groups were examined with independent sample t-test or Mann–Whitney U-test for continuous variables. All the analyses were performed using SPSS (version 24, Chicago, IL, USA). A two-sided alpha of 0.05 was used for all statistical tests.

Results

Forty-four right-handed adults undergoing oesophageal cancer surgery under general anesthesia were enrolled. One patient was excluded from the study after enrolment because of peritoneal seeding. Patient characteristics are presented in Table 1. No patient showed intraoperative or postoperative clinical signs of awareness. The BIS signal quality was > 95 for all measurements.

Intraoperative BIS asymmetry was observed in 14 (32.6%) patients during supine position, but in 43 (100%) patients during left lateral decubitus position. Total intraoperative BIS asymmetry during supine position and left lateral decubitus position was 23/258 (8.9%) and 69/258 (26.7%), respectively. During episodes of BIS asymmetry, BIS was higher on the right side in 38.8% (equal 27.9%) of patients in the supine position and higher on the right side in 48.8% (equal 9.3%) of patients in the left lateral decubitus position.

Table 2 shows the baseline and intraoperative BIS values of both sides. Although there was no difference in mean BIS values, there was a significant change in the gap of BIS values from right and left sides following changes in patient position and ventilation. Figure 1 shows the gap of BIS values of the right and left sides. The maximum difference between BIS values was observed 15 min after one-lung ventilation (mean 6.8 ± 4.6 , range 1-27).

Higher ETsevo values were observed during one-lung ventilation than two-lung ventilation to maintain BIS 40-60. (Figure 2). At the end of surgery, only one patient revealed BIS asymmetry in the supine position, he showed BIS symmetry before lateral decubitus position (Figure 3).

Discussion

The main clinical relevance of our study was that, if asymmetry existed in the lateral decubitus position and the difference of BIS on the two sides increased under one-lung ventilation, confining BIS to a unilateral measurement may miss insufficient depth of anesthesia or over-sedation. We found that the BIS values from right and left sides showed large asymmetry (mean 6.8 ± 4.6 , range 1-27) during the left lateral position under one-lung ventilation.

As shown in Figure 2, ETsevo (%) for adequate depth of anesthesia (approximately BIS 45) were different between two-lung ventilation and one-lung ventilation. Also, hypotensive and hypoxic events are frequently during one-lung ventilation. Thus, assessment of the depth of anesthesia was difficult, and reliable guidelines are needed during one-lung ventilation. Usually, EEG for calculation of anaesthetic depth is obtained unilaterally from the frontolateral skull, assuming that the EEG characteristics are the same for the sides. Because humans sleep mostly bilaterally,[8] this was observed during the supine position in our study.

However, asymmetry of EEG during sleep or sedation has been observed in humans and animals.[7, 9, 10] Also, intraoperative asymmetry of the two sides was introduced in several studies.[5, 11] Fudickar et al. reported that BIS asymmetry occurred in 12% of adults during ear-nose surgery[5] and found that asymmetry was not related to the side position during surgery. This percentage was higher than that in our study (8.9%) and might be associated with unanticipated stimulation or movement during ear-nose surgery.

In our study, the right-side values in the left lateral decubitus position were higher than those of the left side. The gap was highest after 15 minutes in one-lung ventilation. We propose four reasons for this phenomenon. First, large shifts in distribution of intracranial blood might alter cerebral electrical activity and dipoles responsible for EEG wave changes.[4] Second, when the cortex moves away from the inner skull, the EEG amplitude is affected, and a lower amplitude leads to higher BIS values.[12] Third, cerebral oxygen saturation decreased in the lateral decubitus position under one-lung ventilation and contributed to change in cerebral oxygen saturation during anesthetic-induced disruption of cerebral autoregulation. [13] Fourth, electrophysiological studies support the notion that the right hemisphere is more activated during direct sensation and is dominant for cerebral activation. [12]

Although most patients showed little difference in BIS values, except 15 minutes after lateral decubitus position in one-lung ventilation, from sensors placed on the two sides of the forehead, one patient with severe (>75%) stenosis of the right carotid artery showed a large gap during the entire intraoperative phase (Figure 3). In the awake status and supine position under general anesthesia, there were low but similar BIS values (Left vs. Right 81 vs. 79 and 50 vs. 51). However, after the left lateral decubitus position, the BIS values of the right side were significantly higher than those of the left side. Bispectral index asymmetry is frequently observed in unilateral brain lesions.[7] BIS also was reported to be decreased during loss of consciousness due to sudden cerebral ischemia.[6] Our patient had high blood pressure in the awake state (systolic blood pressure 160 mmHg). A hypertensive patient with carotid artery disease may be more susceptible to low arterial blood pressure (His intraoperative systolic blood pressure was 90-120 mmHg) due to the upward shift of the cerebral autoregulation curve and impaired cerebral autoregulation distal to carotid stenosis. Also cerebral oxygen saturation in the lateral decubitus position decreased under one-lung ventilation, attributed to anaesthetic-induced disruption of cerebral autoregulation.

This study had several limitations. We could not monitor cerebral blood flow or cerebral perfusion. As such, the reason for asymmetry was unknown. In addition, we did not determine which BIS values were reliable during the lateral decubitus position under one-lung ventilation. Electrodes and monitors for bilateral measurement of EEG have recently become available, so further studies are needed to confirm the reliability of the BIS values.

During one-lung ventilation in the lateral decubitus position, anesthetic depth as measured by ETsevo (%) changed, and we found that the BIS values from the right and left sides showed asymmetry. Also, the change in cerebral oxygen saturation might have occurred in patients with cerebral disease because of disruption of cerebral autoregulation.

Care should be taken when placing a BIS sensor and interpreting BIS values in patients during the lateral decubitus position under one-lung ventilation.

List Of Abbreviations

bispectral index (BIS), End-tidal sevoflurane (ETsevo), electroencephalogram (EEG)

Declarations

Ethics approval and consent to participate:

Institutional Review Board of Samsung Medical Centre, Seoul, Republic of Korea (SMC 20107-12-033), written informed consent was obtained from each patient

Consent for publication: Not application

Availability of data and material: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: MHP and SHK designed and conducted study. Also we wrote the manuscript and approved the final manuscript.

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Tables

Table 1. The characteristics of patients

Age, yr	62.9 ± 9.1
Gender, Male(%)	36 (86.7%)
Height, cm	164.8 ± 8.6
Weight, kg	64.4 ± 11.6

Values are number (proportion) or mean (SD).

Table 2. The baseline and intraoperative bispectral index of both sides

Values are mean (SD).

	Awake in supine position	After induction in supine position	Immediately after the lateral decubitus position in the supine position	15 minutes after one-lung ventilation in the left lateral position	After two- lung ventilation in the left lateral position	After surgery in the supine position
Left	92.3±4.4	47.8±9.1	44.4±7.7	46.0±6.7	44.6±6.6	45.7±5.9
Right	92.5±4.6	47.0±8.2	44.1±9.4	44.2±7.7	45.2±7.7	45.9±6.4
p value	0.788	0.162	0.739	0.170	0.226	0.526

Figures

Figure 1

The mean (A) and difference (B) of BIS values on the right (orange line) and left (blue line) sides 1. Awake in supine position; 2. After induction in the supine position; 3. Immediately after the lateral decubitus position in the supine position; 4. 15 minutes after one-lung ventilation in the left lateral position; 5. After two-lung ventilation in the left lateral position; and 6. After surgery in the supine position.

Figure 2

The end-tidal sevoflurane during one-lung ventilation compared to two-lung ventilation 2. After induction in the supine position; 3. Immediately after the lateral decubitus position in the supine position; 4. 15 minutes after one-lung ventilation in the left lateral position; 5. After two-lung ventilation in the left lateral position; and 6. After surgery in the supine position.

Figure 3

The bispectral index on the right (orange line) and left (blue line) sides of one patient showed large asymmetry when placed in left lateral decubitus position 1. Awake in supine position; 2. After induction in the supine position; 3. Immediately after the lateral decubitus position in the supine position; 4. 15 minutes after one-lung ventilation in the left lateral position; 5. After two-lung ventilation in the left lateral position; and 6. After surgery in the supine position.