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ORIGINAL RESEARCH **PERIOPERATIVE MEDICINE**

Changes in bispectral index (BIS) with different positions during general anesthesia

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ABSTRACT

Background & Objective: Bispectral index (BIS) is used for intraoperative anesthesia depth assessment during general anesthesia (GA). This monitoring modality has been used routinely at many centers during GA, but especially during susceptible patients, in which precise depth of anesthesia is required. We aimed to compare changes of BIS in different head positions under GA, but without surgical stimulation.

Methodology: Thirty ASA physical status I patients aged 18−60 y were recruited for this prospective, observational study after ethical approval by the institutional ethical review committee. After administration of GA, patients were kept in supine position for 15 min and the BIS, signal quality index (SQI), electromyography (EMG), mean arterial pressure (MAP) and heart rate (HR) were recorded. Patients were then sequentially placed in: reverse Trendelenburg (45°), supine, Trendelenburg (45°) positions, each for 15-min duration and 3 readings were taken in each position at 5 min interval. Lastly patient was positioned back to supine position for the surgery to begin.

Results: There was a statistically significant decrease of BIS value with a change from supine position to reverse Trendelenburg position (P = 0.02) and increase in BIS value from supine to Trendelenburg position (P = 0.01). Changing of position from supine to reverse Trendelenburg was found to have a statistically significant decrease in MAP (P = 0.005), whereas changing to Trendelenburg position significantly increased MAP compared to supine position (P < 0.001). There was a positive moderate linear correlation between BIS and MAP (r = 0.513, P = 0.004).

Conclusion: A change of position from supine to reverse Trendelenburg decreases and from supine to Trendelenburg position transiently increases the BIS values.

Abbreviations: BIS - Bispectral Index; SQI - Signal Quality Index; EMG – Electromyography; MAP - Mean Arterial Pressure

Key words: Anesthesia; Anesthesia, General; Bispectral Index; Electroencephalography; Electromyography; Monitoring; Positioning

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1. INTRODUCTION

A proper depth of anesthesia is an important aspect during general anesthesia to avoid awareness or the undesirable over-sedation of the patients.[1,2] Traditionally, depth of anesthesia had long been monitored clinically by assessing autonomic parameters (Evan's score) or patient response to surgical stimuli, by measuring systolic blood pressure, heart rate (HR), sweating and tears.[3] It has been proven that hemodynamic responsiveness to noxious stimuli does not necessarily signify awareness, nor does lack of hemodynamic changes guarantee unconsciousness.[4] In October 1996, the Food and Drug Administration (Rockville, MD) approved the Bispectral Index (BIS) monitor (Aspect Medical Systems, Newton, MA) as an accepted measure of the hypnotic effect of anesthetics and sedative drugs. Since its introduction, BIS has been used to monitor the depth of anesthesia and to allow faster emergence and improved recovery.[3,5]

BIS is the processed electroencephalographic (EEG) technique to be correlated with behavioral assessment of the level of consciousness, irrespective of the hypnotic, or a combination of hypnotics, used to produce that state.[6] It is a single number calculated from EEG-derived sub-parameters. It appears to track the effect-site concentration of the anesthetic drugs and their effects on the cortical EEG. The value ranges from 0 to 100 to quantify the level of central nervous system depression, where 0 is an isoelectric EEG and 100 is fully awake state (Box 1). The monitor displays a real time EEG trace, acquired from a quadruple electrode fronto-temporal montage. The display also shows a signal quality index (SQI), which is calculated based on the impedance to electronic signal, electrode contact and other variables, and an indicator of electromyographic (EMG) interference.

Box 1: Suggested interpretation of BIS values[6]	
100−85	Awake, aware, capable of memory processing and explicit recall
85−60	Increasing sedation and impairment of memory processing. Rousable in response to stimulation
60−40	Surgical anesthesia. Decreasing probability of postoperative recall. Auditory processing and reflex movement still occur
40−0	Increasing frequency of burst suppression. BIS of 0 indicates cortical electrical silence

Spurious BIS values may lead to inappropriate drug dosages. Several factors have been found to affect the readings without affecting the depth of anesthesia.[7,8] Both EMG activity and radiofrequency interference from electrical equipment in the operating room influence the BIS algorithm. Duarte et al.[7] also studied possible reasons to produce false results from BIS readings such as the effects of different anesthetics and other drugs, interference from electrical equipment and types of monitors used.

BIS values were shown to be affected from changing the head positions as compared from supine position which is required in certain surgeries to facilitate surgical approach.[9,10] To date, there are only a limited number of studies done to show the changes in BIS values after changing head positions. However, the results were still inconclusive as the BIS readings might have been influenced by other factors including surgical stimulation.

BIS readings might be altered by physiological derangements, anesthetic medications and surgical stimulation. We aimed to compare the BIS values in different head positions without surgical stimulation, along with the SQI to determine the reliability of the BIS values produced. The EMG readings were also monitored to ensure there was no interference from the muscle activity.

2. METHODOLOGY

It was a prospective, observational study conducted over one year after approval by the Research Committee of the Department of Anesthesiology & Intensive Care, Hospital Canselor Tuanku Mukhriz (HCTM), Universiti Kebangsaan Malaysia Medical Centre (UKMMC). Further approval by the Research and Ethics Committee UKMMC (Research Code: FF-2016-317) and Medical Research and Ethics Committee (MREC), National Medical Research Register (NMRR), Ministry of Health, Malaysia (NMRR-16-196-29180) was also obtained prior to commencement of the study. Explanation and written informed consents were obtained from the patients recruited for the study.

Thirty ASA physical status I patients, aged 18−60 y, undergoing elective surgery requiring general anesthesia were enrolled into the study. Morbidly obese patients with body mass index more than 35 kg/m^2, or with history of previous head injury, cerebrovascular disease, glaucoma, retinal detachment and those taking recreational drugs, were excluded from this study. A subject was considered as drop-out if there was technical problem such as poor contact of BIS sensor, disconnection of BIS, poor SQI and excessive EMG.

The patients were fasted for at least 6 h prior to their surgery. No premedication drug was given. On arrival to the operating complex (OC), standard monitoring, electrocardiography, non-invasive blood pressure and pulse oximetry were applied. A BIS sensor (BIS™ Quatro 4 electrodes sensor) was attached across the participants' foreheads and connected to the monitor (BIS™ Medtronic-Covidien, Dublin, Ireland) to record the brain activity. The sensor consisted of four parts; No. 1 was attached at the center of forehead, 4 above the lateral end of eyebrow, 3 on the temple, between corner of eye and hairline and 2 was between 1 and 4 (Appendix 1).

After determining the baseline values for the BIS, SQI, EMG, mean arterial pressure (MAP) and HR, anesthesia was induced with fentanyl 2 µg/kg, propofol 2 mg/kg titration and rocuronium 0.6 mg/kg IV. Tracheal intubation was performed with endotracheal tube size 7.0–8.0 mm according to the patient's body size, and sevoflurane was administered in oxygen/air 50:50 to achieve a minimum alveolar concentration (MAC) of 1.2 via volume-control mode to deliver tidal volume of 6−8 ml/kg, respiratory rate 10−12 and maintaining normocapnia with end tidal carbon dioxide of 35−40 mmHg. If MAP fell more than 30% from the baseline, phenylephrine 100 µg or ephedrine 6 mg boluses were given IV.

Once a MAC of 1.2 was achieved, the BIS, SQI, EMG, MAP and HR were recorded at 0 min (supine T0) and this was repeated at 5 min intervals in supine position for 2 more readings at 5 min (supine T5) and 10 min (supine T10). The patient was then positioned to the reverse Trendelenburg position (head up 45°) and the values were recorded every 5 min for 3 readings at 10, 15 and 20 min (head up T10+5, T15 and T20). An additional 5 sec were taken to position the patient and a standardized measuring tool was used to measure the degree of tilting the operating table. The patient was then returned to supine (supine 2) position and the readings were taken at 5 min intervals for 3 readings at 20, 25 and 30 min (supine 2 T20+5, T25 and T30). The patient was then placed in Trendelenburg position (head down 45°) and the values were recorded every 5 min for 3 readings at 30, 35 and 40 min (head down T30+5, T35 and T40). These measurements were taken before any stimulation or surgical incision was made. After recording the data, surgery was allowed to proceed as planned.

Statistical Analysis

Sample size was calculated based on a previous study by Kaki and Almarakbi,[9] using power and sample size calculator program version 3.1.2 (2009). With the alpha (α) value of 0.05 and power of 80% while considering a drop-out of 20%, 30 patients were recruited.

All data were analyzed by using Statistical Package for Social Sciences (SPSS) version 23. A normality test was carried out for all dependent variables. Demographic data were analyzed and presented as frequency, percentage, mean and standard deviation.

Mean ± standard deviation (SD) range were used for descriptive analysis of BIS values, MAP and HR changes according to different head positions in different time intervals. Wilcoxon Signed Ranks Test with Bonferroni correction was used for the non-normally distributed variables of SQI and EMG and are expressed as median (interquartile range).

A paired *t-test* was conducted to test for changes in BIS values, MAP and HR between different head positions. Repeated measures Analysis of Variants (ANOVA) were used to test the changes between BIS values, MAP and HR within the same position at various time intervals. Pearson correlation coefficient was used to correlate the changes of BIS values with MAP and HR and expressed as r, whereby r 0–0.5 represents weak correlation, 0.5–0.7 moderate correlation and 0.7–1 strong correlation. Statistical significance was considered at a $P < 0.05$.

3. RESULTS

A total of 30 patients were recruited for this study and there was no drop-out from this study. Demographic and clinical characteristics are shown in Table 1.

Table 1: Demographic data

Parameter	Value
Age (y)	33.7 ± 11.4
Weight (kg)	71.6 ± 12.4
Height (cm)	166.5 ± 8.1
BMI (kg/m^2)	25.5 ± 3.5
Gender	
Male	21 (70)
Female	9 (30)
Race	
Malay	22 (73)
Chinese	4 (13.3)
Indian	2 (6.7)
Others	2 (6.7)

Data are expressed in mean ± SD, or n (%)

BIS values were at optimum readings in view of SQI at the highest (> 90) with minimal EMG interference (EMG < 30). The median values of the SQI and EMG

Table 2: Bispectral index (BIS) values, signal quality index (SQI) and electromyography (EMG) at different time points

Position	BIS values	SQI	EMG
Preoperative	95.0 ± 2.4	97.00 (89.50−99.00)	56.00 (48.75−57.25)
Supine			
Supine T0	38.1 ± 7.5	95.00 (90.00−100.00)	29.00 (28.00−34.00)
Supine T5	36.9 ± 6.3	96.00 (89.75−99.00)	29.00 (28.00−30.00)
Supine T10	37.1 ± 7.4	97.00 (92.00−99.00)	28.00 (28.00−29.25)
Head Up			
Head up T10+5	35.6 ± 6.9	97.00 (94.75−100.00)	28.00 (27.75−30.00)
Head up T15	36.9 ± 6.4	97.50 (96.25−100.00)	29.00 (28.00−29.25)
Head up T20	37.7 ± 6.9	97.00 (97.00−100.00)	29.00 (27.25−29.00)
Supine 2			
Supine2 T20+5	38.1 ± 5.8	98.00 (92.00−100.00)	28.00 (28.00−29.00)
Supine2 T25	37.7 ± 4.9	98.50 (95.00−100.00)	28.00 (28.00−29.00)
Supine2 T30	36.4 ± 4.9	97.00 (95.75−100.00)	28.00 (27.00−29.00)
Head Down			
Head down T30+5	39.1 ± 5.3	100.00 (96.50−100.00)	28.00 (27.75−29.00)
Head down T35	38.6 ± 5.7	97.00 (95.75−100.00)	28.00 (27.00−29.00)
Head down T40	36.9 ± 5.1	99.00 (97.00−100.00)	28.00 (27.00−28.00)

Data are expressed in mean ± SD, median (interquartile range) as appropriate

are indicated in Table 2. Despite changing of positions, the SQI and EMG are at their optimum values. There was no statistically significant difference in the means of BIS values of reverse Trendelenburg and Trendelenburg position when compared to T0. There was a statistically significant difference of the mean of BIS values with changing from supine position to the head up position (P = 0.02) and this value steadily returned to the baseline value after 5 min. An increase in BIS values was noticed with changing the patient to head down position and was found to be statistically significant with P = 0.01.

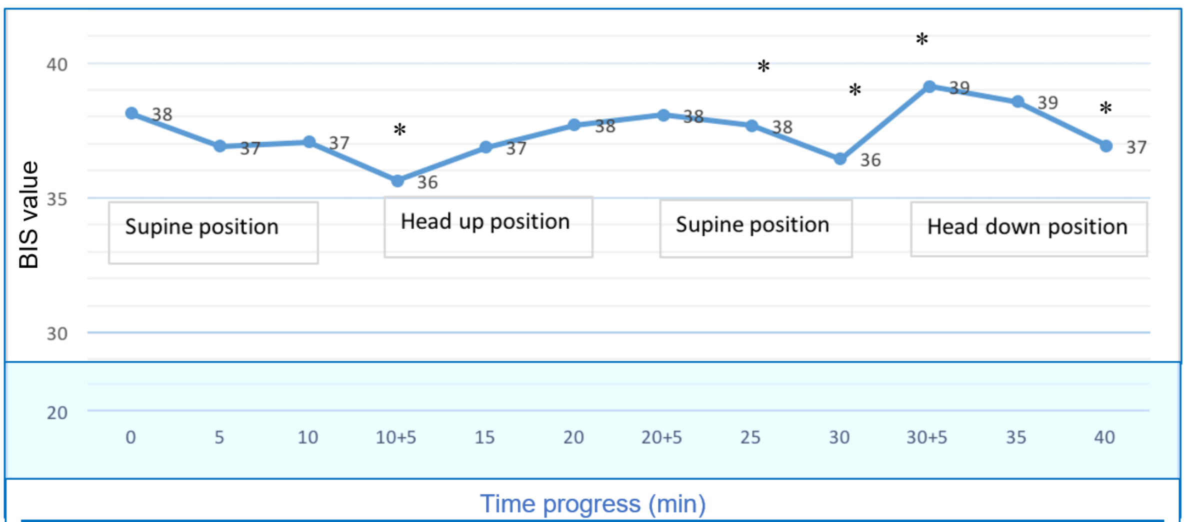

Figure 1: Changes in BIS values in different head positions at different time intervals in relation to changes in patient position; ** indicates P < 0.05 when BIS values were compared from the previous values*

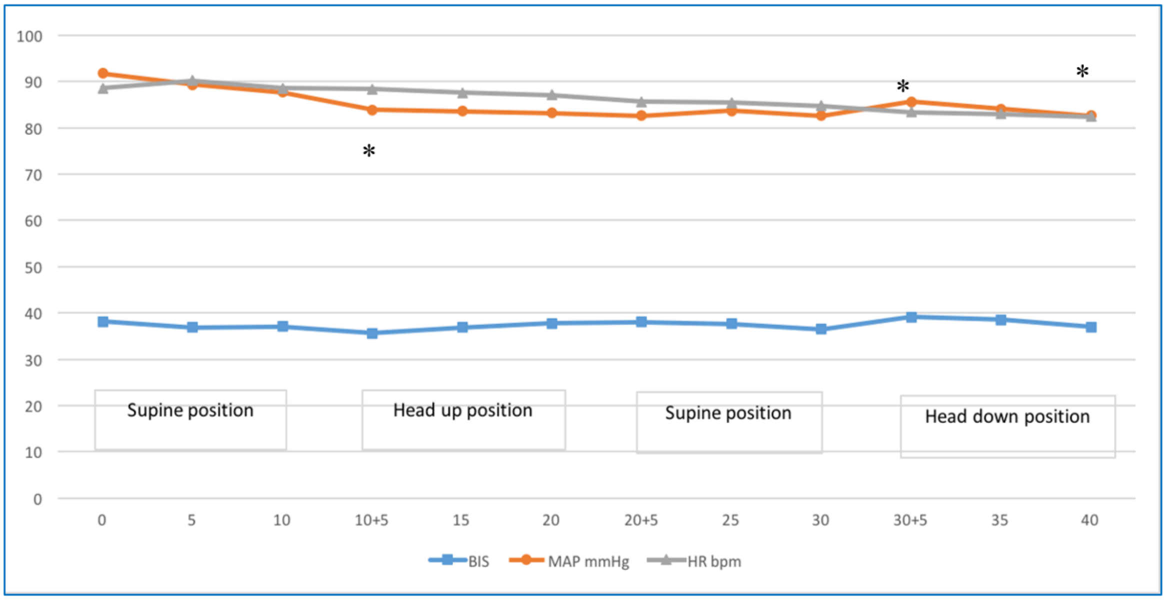

Figure 2: The relationship between changes in BIS values with HR and MAP

** indicates P < 0.05 when MAP was compared to previous MAP value*

The BIS values steadily decreased after 5 min when they were compared at the end of the head down position to the beginning of the position and it was statistically significant with P = 0.01 (Figure 1).

The concomitant changes in MAP and HR related to changes in patient's position are presented in Figure 2. There was a statistically significant decrease in MAP after tilting the patient from supine to head up position (P = 0.005), and increase in MAP when changing from supine to head down position (P < 0.001). Additionally, there was a significant positive moderate linear correlation between BIS and MAP (r = 0.513, P = 0.004). There were no statistically significant changes in HR throughout the study.

4. DISCUSSION

Experiences of awareness and recall during GA can be most distressing for the patients.[11] On the other hand, excessive depth of anesthesia is equally undesirable as it may increase morbidity and compromise patient's outcome.[2] The use of BIS monitoring with clinical assessment allows anesthesiologists to make precise decisions in terms of accurate anesthetic dosage adjustments during anesthesia.[3]

The key findings of this study were that head up position induced a transient decrease in BIS values, whereas the head down position was associated with a transient increase in BIS values without any surgical stimulation as compared from previous study done by Kaki and Almarakbi.[9] There was also a transient decrease in MAP after tilting the patient from supine to head up position and a transient increase in MAP when changing from supine to head down position. These transient effects can be attributed to the physiological changes associated with different positions, which are related to changes in the cerebral blood flow. Previous studies have demonstrated that the head down and head up positions altered cerebral blood flow as demonstrated by magnetic resonance imaging (MRI).[12-14] These distribution changes of cerebral blood were associated with changes of oxygen delivery to the brain. This might affect neuronal activity and alter cerebral electrical activity with the dipole responsible for EEG waveform changes as described by previous studies.[15–17]

The acute transient changes in BIS values after positioning from supine to head up and head down position steadily returned to the pre-position values at the subsequent time intervals. However, we did not document the time taken for the BIS values to return to the initial level. Study done by Hughson et al.[18] demonstrates that there's a decrease of cerebral blood flow from supine to tilting up position and it took 5 seconds for normal subjects to return to the baseline value. In another study, while the Trendelenburg maneuver increased the cardiac output and left ventricular preload, the effects were transient and the changes of values normalized after 10 min.[19]

While studies have shown that BIS monitoring is reliable in a wide variety of patients and positions, in certain circumstances the BIS index may not accurately reflect a patient's level of sedation. The SQI measures the reliability of the signal; higher SQI numbers indicate more reliable BIS values.[20] In this study, the values of

SQI were more than 90 despite changes of position. This shows that the BIS readings were optimal at all times.

As with any EEG signal, BIS is subject to interference and artifact and the most frequent source of unreliable BIS is from muscle activity. This muscle activity, measured as EMG can be caused by pain, twitches, seizures, eye movement or anything that results in increase in the muscle tone or in movement. Elevated EMG activity increases BIS, while subsequent administration of neuromuscular blockade drug (NMB) reduces it.[21] In designing this study, we took into consideration that muscle activity may affect the BIS values. Hence, we used the NMB to reduce interference in EMG indexes due to muscle activity.[22]

In comparison with previous studies, minimizing the effects of other factors, we standardized the known factors known to influence the BIS values such as additional drugs and surgical stimulation to obtain BIS values which best reflected at different positions. Nevertheless, this study has some limitations.

5. LIMITATIONS

The correlation between cerebral blood flow and BIS values was not evaluated which would be monitored by MRI. This can be done at centers which have hybrid ORs which incorporate MRI machine in OT. Our study was not powered to detect awareness as post anesthesia follow up would be beneficial to ascertain the occurrence of awareness due to changes of BIS values in different positions.

6. CONCLUSION

In conclusion, a change of position from supine to reverse Trendelenburg decreases and from supine to Trendelenburg position transiently increases the BIS values.

7. Trial Registry Number

National Medical Research Register (NMRR), Ministry of Health, Malaysia NMRR-16-196-29180

8. Availability of data

The numerical data generated in this study is available with the authors.

9. Conflict of interests

None declared by the authors.

10. Funding

No external or industry funding was involved in this study.

11. Authors contribution

KK: Drafting, intellectual content, data collection, analysis, writing manuscript

AI: Drafting, intellectual content, editing

RAR: Editing and final approval of the version to be published

MNM: Writing and formatting, manuscript preparation

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