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Bispectral Index Monitoring Tailors Clinical Anesthetic Delivery and Reduces Anesthetic Drug Consumption

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This study was designed to investigate whether BIS monitoring improves clinical anesthetic delivery and reduces anesthetic drug consumption in adult patients undergoing moderate surgical procedures under general anesthesia, when compared to standard clinical practice. Sixty patients were randomly assigned into two groups of 30 patients each: BIS-guided group (BIS-g) and BIS-blinded group (BIS-b). In BIS-g group sevoflurane and fentanyl were adjusted to maintain a BIS index of 50-60 during procedure and 55-70 towards end of procedure, while in the BIS-b group, the monitor display was customized to make BIS values invisible to anesthesiologist and sevoflurane and fentanyl were adjusted according to standard clinical practice and such that provides early recovery. BIS-guided anesthesia reduced total sevoflurane usage by 32% than BIS-blinded anesthesia, which consequently reduced cost by 32%. Also times to orientation, to arrival at and to discharge from PACU were shorter in BIS-g group. Results imply that BIS-guided anesthesia might improve recovery profile as it tailors clinical anesthetic delivery and reduces sevoflurane consumption.

Key words: BIS index, BIS monitor, awareness, anesthetic drug consumption, recovery time

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INTRODUCTION

Bispectral index of EEG (BIS™, Aspect MS) has been the first device widely available to quantify the hypnotic effect of an anesthetic in clinical practice (Billard and Mavoungou, 2007). Raw EEG information is obtained via a sensor placed on the patient's forehead. The BIS monitoring system processes the EEG information and calculates a number between 100 and 0 that provides a direct measure of the patient's level of consciousness. This number is known as the BIS value, whereby a value of 100 represents normal cortical electrical activity and is associated with the awake state and a value of 0 indicates cortical electrical silence (Sinha and Koshy, 2007).

However, BIS monitoring may improve aspects of anesthetic administration, but data about improving recovery process by BIS-titrated anesthetic agents have been inconsistent (Mayer *et al*., 2007). Some studies suggest that BIS-controlled anesthesia may help assess the hypnotic component of anesthesia (Katoh *et al*., 1998; Kearse *et al*., 1998), as well as reduce drug consumption and shorten recovery times when compared with a standard practice protocol (Yli-Hankala *et al*., 1999; Bannister *et al*., 2001; Guignard *et al*., 2001; Sascha *et al*., 2005; Billard and Mavoungou, 2007; Sinha and Koshy, 2007). Others were not able to show differences in the patients' recovery profiles after BIS monitored general anesthesia (Ahmad *et al*., 2003; Agarwal *et al*., 2004; Bruhn *et al*., 2005; Dahaba, 2005; Zohar *et al*., 2006).

The objective of this study was to assess effects of BIS-guided general anesthesia on recovery times and anesthetic drug consumption in patients undergoing elective moderate abdominal surgical procedures. Present hypothesis was that BIS monitoring implies faster recovery while economizing drug use.

MATERIALS AND METHODS

With ethical committee approval and written informed consent, 60 adult patients, aged 45-60 year, ASA physical status I, II, or III, scheduled for elective moderate abdominal surgical procedures, expected durations at least 2 h, were recruited. Study took place at Theodor Bilharz Research Institute during the period between January 2006 and July 2007. Non-inclusion criteria included a history of any disabling central nervous or cerebrovascular disease, hypersensitivity to opioids, substance abuse, treatment with opioids or any psychoactive medication and a body mass index >40. No patient received local anesthesia, regional block or premedication.

Patients were randomly selected and assigned into two groups of 30 patients each: BIS-blinded anesthesia group (Group BIS-b) and BIS-guided anesthesia group (Group BIS-g). IV catheter was inserted into a large forearm vein and standard monitors were applied (S/5™ monitor: Datex-Ohmeda™ Aestiva/5, D-LCC. Helsinki, Finland). After the skin of the forehead of all patients had been carefully wiped with an alcohol swab and allowed to dry, BIS® self-adhesive EEG electrode strips (Aspect Medical Systems, Newton, MA, USA) were positioned on the forehead. BIS plug-in modules were connected to the monitor (Stand alone model A-2000, Aspect Medical Systems, Newton, MA, USA). The sampling rate for raw EEG was 256 Hz. Electrode impedances were considered acceptable if <10 k (manufacturers' recommendations). BIS and BIS signal quality index, recorded at 1 min intervals were transferred to a computer hard disk using the software program Datex-Ohmeda S/5 Collect (version 4.0) for off-line analysis.

Patients received a standardized anesthetic according to the following regimen. After administration of 100% oxygen, anesthesia was induced with propofol 1-2 mg kg^{-1} IV and fentanyl 2-3 μg kg^{-1} IV. After loss of consciousness, patients received atracurium 0.5 mg kg^{-1} IV. After tracheal intubation, the lungs were mechanically ventilated with a tidal volume of 8-10 mL kg^{-1} with the ventilatory rate adjusted to maintain an end-tidal carbon dioxide 30-35 mmHg. Anesthesia was continued with sevoflurane and 50% nitrous oxide with oxygen 2 L min^{-1}. Intermittent boluses of atracurium 0.2-0.3 mg kg^{-1} IV were adjusted according to train-of-four monitoring. Fresh gas flow rate was set to 6 L min^{-1} until the difference between inspiratory and end-expiratory sevoflurane concentrations was ≤0.2%. Fresh gas flow rate was then reduced to 2 L min^{-1}. The beginning of maintenance of anesthesia was defined as this time.

In the BIS-b group, the monitor display was customized to make BIS values invisible to the attending anesthesiologist. Sevoflurane and fentanyl were adjusted according to standard clinical practice and such that provides early recovery. If the patient in this group exhibited hypertension (mean arterial blood pressure >25% above baseline) (MBP) and tachycardia (heart rate (HR) >90 beats min^{-1}), anesthesia was deepened either by increasing inspired sevoflurane concentration, or administering fentanyl 25-50 μg or labetalol 5-10 mg IV. The mode of treatment was left to anesthesiologist's discretion.

In the BIS-g group, the anesthesiologist adjusted administration of sevoflurane and fentanyl to maintain a BIS index of 50-60. If the patient in that group, exhibited hypertension or tachycardia the mode of treatment was dependent on the BIS index. If the BIS index was >60, anesthesia was deepened by increasing sevoflurave concentration until BIS index was between 50 and 60. If BIS index was already in the targeted range and the

patient exhibited hypertension or tachycardia, fentanyl 25-50 μg IV was given. If BIS index was <50, sevoflurave was decreased and patient was checked for signs of lack of analgesia (i.e., lacrimation, grimacing, movement). In case of lack of analgesia, fentanyl 25-50 μg IV was administered. But if no signs of lack of analgesia, labetalol 5-10 mg IV was administered.

Hypotension (MBP<20% below baseline) was treated with IV fluid replacement or by a decrease in sevoflurane concentration and finally, by ephedrine 3-6 mg IV or phenylephrine 20-100 μg IV. Bradycardia (HR<50 beats min^{-1}) was treated with either reducing sevoflurane or atropine 0.02 mg kg^{-1} IV.

Towards end of surgical procedure, almost 10 min before the last stitch, nitrous oxide was discontinued in both groups. The inspired concentration of sevoflurane was decreased according to usual clinical practice, in the BIS-b group. While, in BIS-g group sevoflurane concentration was adjusted to maintain a BIS index of 55-70 to facilitate recovery. Residual neuromuscular blockade was reversed with glycopyrrolate (0.01 mg kg^{-1}) and neostigmine (0.05 mg kg^{-1}) IV, 5 min prior to discontinuation of anesthetic. At the end of skin closure, which was defined as beginning of recovery period, sevoflurane was discontinued and fresh gas flow was increased to 6 L min^{-1} pure oxygen.

Postoperatively, all patients were visited on the first, second and third day and interviewed about any recall of intraoperative awareness. Patients were questioned for recall of events, hearing vague sounds, feeling surgical instruments or dressing application, or dreaming.

Data and calculations: The amount (mL) of sevoflurane used was calculated using Dion's formula: Amount of volatile anesthetic used (mL) = dialled concentration × Total fresh gas flow×duration at that concentration × Molecular weight/2.412×Density. Also total amount of propofol and fentanyl consumed during the procedure was determined. End-tidal sevoflurane was recorded in the two groups.

The times to: awakening (as determined by eye opening), tracheal extubation, orientation (to place, person and time), arrival at PACU, discharge from PACU as determined by Aldrete score >9, as well as incidence of awareness were recorded. Data were determined at 1 min intervals from discontinuation of sevoflurane, Aldrete score assessment is expressed in Table 1 and performed at 15 min interval by a research assistant blinded to group assignment, to determine readiness for discharge from PACU (Aldrete and Kroulik, 1970).

Statistical analysis: Results were expressed as Mean±SD or number (%). Comparison between numerical data of different parameters in the two groups was performed using Mann Whitney U test. Categorical data were compared using Chi-square test. The data were considered significant if $p \leq 0.05$ and highly significant if $p < 0.01$. Statistical analysis was performed with the aid of the SPSS computer program (version 11 windows).

Table 1: Aldrete score (for assessment of discharge criteria)

Variables of discharge criteria	Score
Activity	
Not moving	0
Non-purposeful movement	1
Moving limbs purposely	2
Respiration	
Apneic/needs maintenance	0
Shallow or limited	1
Deep breathing or coughing	2
Consciousness	
Unresponsive	0
Responding to stimuli	1
Fully awake	2
Hemodynamic stability	
Blood pressure >30% below baseline MAP value	0
Blood pressure 15-30% of baseline MAP value	1
Blood pressure <15% of baseline MAP value	2
O_2 Saturation	
<90%	0
90-94 %	1
≥95%	2
Total	10

RESULTS

Sixty patients were enrolled in this study. Three patients were discarded, two from BIS-b group and one from BIS-g group. The two of BTS-b group received excessive fentanyl near end of surgery and the one of BIS-g was desaturated intra-operatively, necessitating discontinuation of nitrous oxide.

Demographic data and duration of surgery and anesthesia were comparable in both groups (Table 2).

Table 3 shows that the total sevoflurane usage (mL) was 32% lower in the BIS-g group than BIS-b group (5.7±1.9 vs. 8.4±2.3, $p<0.01$). The average end tidal sevoflurane concentration (%) during surgery was lower in the BIS-g group (0.43±0.3 vs. 0.59±0.1, $p \leq 0.01$). There was no difference in the consumption of other drugs.

Table 4 shows that there was no difference in the awakening time in both groups (4.4±1.9 vs. 4.1±1.6 $p>0.05$) as well as in time to extubation (min) in both BIS-b and BIS-g groups (4.8±2.3 vs. 4.3±2.1 $p>0.05$), respectively.

Time to orientation (min) was faster in the BIS-g group than in BIS-b group (7.4±1.5 vs. 11.2±1.9), where, $p<0.01$. Time to arrival at PACU (min) was faster in BIS-g group than BIS-b group (9.4±1.9 vs. 14.1±2.8 $p<0.01$). Discharge from PACU was significantly faster in BIS-g group than BIS-b group (53.9±14.7 vs. 78.6±21.5 $p<0.01$). Patient disorientation percentage (%) after discontinuation of inhalational anesthetic agents is

Table 2: Demographic data and procedure duration in the two studied groups

Variables	BIS-b (n = 28)	BIS-g (n = 29)
Age (years)	52.1±5.2	51.6±7.4
Weight (kg)	91.4±6.5	87.6±8.2
Gender (male/female)	20/8	18/11
Duration of surgery (min)	85.8±17.4	91.7±11.3
Duration of anesth (min)	108.7±10.5	111.7±14.6

Data are expressed as Mean±SD. BIS-b: Bispectral index blinded group: BIS-g: Bispectral Index guided group

Table 3: Amount of drugs consumed intra-operative and average end-tidal sevoflurane

Anesthetic drugs	BIS-b (n = 28)	BIS-g (n = 29)
Propofol (mg)	157.90±35.8	161.70±27.5
Fentanyl (μg)	389.40±41.5	383.70±62.6
Sevoflurane (mL)	8.40±2.3	5.70±1.9**
Average end-tidal sevoflurane (%)	0.59±0.1	0.43±0.3**

Data are expressed as Mean±SD. BIS-b: Bispectral index blinded group: BIS-g: Bispectral index guided group. Average end-tidal sevoflurane concentrations (vol %). **p<0.01 = Highly significant

Table 4: Recovery times after termination of sevoflurane

Variables	BIS-b (n = 28)	BIS-g (n = 29)
Awakening (eye opening) (min)	4.4±1.9	4.1±1.6
Tracheal extubation (min)	4.8±2.3	4.3±2.1
Orientation (min)	11.2±1.9	7.4±1.5 **
Arrival at PACU (min)	14.1±2.8	9.4±1.9**
PACU discharge (min)	78.6±21.5	53.9±14.7**
Awareness	0	0

Data are expressed as Mean±SD. BIS-b: Bispectral index blinded group: BIS-g: Bispectral index guided group. PACU: Post anesthesia care unit. **p<0.01 = Highly significant

Table 5: BIS index values (average)

Timing	BIS-b (n = 28)	BIS-g (n = 29)
Pre-anesthetic (baseline)	89.4±5.6	91.7±2.7
During surgery (skin incision, completion)	41.2±7.3	52.4±3.4**
During anesthesia (induction, discontinuation)	48.1±5.4	54.9±4.5**
After discontinuation	66.5±14.3	70.4±11.2

Data are expressed as Mean±SD. BIS-b: Bispectral index blinded group: BIS-g: Bispectral index guided group. **p<0.01 = Highly significant

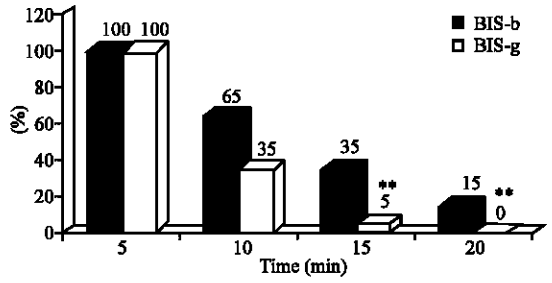

Fig. 1: Patient disorientation (%) after discontinuation of anesthesia. BIS-g: Bispectral index guided group: BIS-b: Bispectral index blinded group. **p<0.01 = Highly significant

significantly higher at 10 and 15 min post-operative, in BIS-b than BIS-g group **(p<0.01), as shown in Fig. 1.

Table 5 shows that the average BIS index values were lower in BIS-b group than BIS-g group during surgery (41.2±7.3 vs. 52.4±3.4 p<0.01) and during anesthesia (48.1±5.4 vs. 54.9±4.5 p<0.01). The BIS values showed no difference between the two groups upon discontinuation of anesthesia. None of the patients reported awareness.

DISCUSSION

This study was designed to investigate whether BIS monitoring improves clinical anesthetic delivery and reduces anesthetic drug consumption in adult patients undergoing moderate surgical procedures with general anesthesia, when compared to standard clinical practice.

The results showed that BIS monitoring reduced consumption of inhalational anesthetic sevoflurane, where total sevoflurane administered was 32% less in the BIS-g group than BIS-b group and the average end tidal sevoflurane concentration during surgery was lower in the BIS-g group. Consumption of IV anesthetics was unaffected. Although there was no difference in time to awakening, (as measured by time to eye opening) and extubation, yet time to orientation and time to arrival at and also to discharge from PACU (reaching an Aldrete score of >9) were faster in BIS-g group. Percentage of patient disorientation at 10 and 15 min after cessation of anesthesia was higher in the BIS-blinded group than the BIS-guided group. These findings as well as the fact that BIS index values were lower in BIS-b group than BIS-g group during surgery and anesthesia, imply that anesthesia was maintained at a deeper level in the BIS-b group and consumed irrelevantly larger amounts of sevoflurane anesthetic.

We did not encounter any case of awareness, in either group. Patients were questioned for recall of events, hearing vague sounds, feeling surgical instruments or dressing application, or dreaming. This might be attributed to the very low rate of incidence of awareness, which approximates 1/1000 (Sebel *et al.*, 2004), necessitating a large number of patients in order to encounter one case of awareness.

Although knowing how deeply anesthetized patients are, not just that they are unaware, may be of great value, yet, whether this benefit is worth the cost is highly dependent on the clinical situation. There are clinical situations where the BIS monitor may guide towards using additional narcotic or anti-hypertensive medications rather than simply turning up the anesthetic vapor. This change in management has several clinical implications. By using less volatile agent, emergence times may be reduced and cognitive function may return quicker. This is especially beneficial after neurosurgical procedures, requiring quick patient cooperation with examination, as well as in ambulatory cases, especially when total intravenous anesthesia is titrated.

Present results support earlier data suggesting that BIS-controlled anesthesia leads to faster emergence and improves recovery (Gan *et al*., 1997; Song *et al*., 1997; Leslie *et al*., 2005; Billard and Mavougou, 2007; Mayer *et al*., 2007; Sinha and Koshy, 2007). In other trials, times to awakening as well as consumption of anaesthetic drugs were reduced using BIS monitor (Domino *et al*., 1999; Burrow *et al*., 2001).

Kelley (2003) showed reductions in the use of hypnotic anesthetics both volatile and intravenous (propofol, isoflurane, desflurane and sevoflurane) ranging from 15-39%, as compared to standard clinical practice, with a reduction in drug cost. On the other hand, in this study, we were able to confirm a reduction of only sevoflurane but not intravenous anesthetics.

Although, Yli-Hankala *et al*. (1999) and Liu (2004) were in accordance with us and demonstrated that BIS monitoring decreased anesthetic consumption and recovery time, yet they stated that detailed cost analysis showed that monitoring increased direct costs of anaesthesia treatment in these patients, mainly due to the price of special EEG electrodes used for relatively short gynecological procedures.

Thomas and Harvey (2002) designed a study comparing BIS values derived from the original expensive BIS sensor with BIS values derived from commercially available cheap ECG electrodes. They examined the agreement of BIS values obtained in both cases. They stated that these ECG electrodes can replace more expensive BIS sensors. This calls for investigation as it would be of great benefit for the cost/efficacy profile of BIS monitor.

On the other hand, we were not in accordance with other studies that were not able to show differences in the patients' recovery profiles after BIS guided general anesthesia (Ahmad *et al*., 2003; Agarwal *et al*., 2004; Bruhn *et al*., 2005; Dahaba, 2005; Zohar *et al*., 2006). Also, another prospective nonrandomized multicenter study showed no significant difference using BIS (Sebel *et al*., 2004).

There might be a variety of reasons for this inconsistency, as the recovery process appears to be dependent on factors such as age, gender, ASA physical status and duration of anesthesia (Mayer *et al*., 2007). Buchanan *et al*. (2006) found that gender is an independent factor influencing recovery from general anesthesia. Despite similar amounts of anesthetic, drug administration, women recover faster and are eligible for discharge from the recovery room sooner than men. The minimum alveolar concentration (MAC) of a volatile anesthetic may be gender-dependent.

On the other hand, Zohar *et al*. (2006) performed their study on geriatric patients, undergoing outpatient short surgical procedures. Also, Ahmad *et al*. (2003) performed their study on laparoscopic gynecological patients. These patients were carefully chosen in the middle age group, undergoing moderate abdominal surgical procedures. And for the former reasons, we sought a balanced male-female ratio to avoid bias in our study. Table 2 shows that the ratio between male to female, age, ASA physical status as well as duration of surgery were comparable in both groups, hence did not influence present results.

Moreover, anesthetists vary in the way and timing of reducing anesthetic drug administration towards the end of surgery. Some discontinue administration before or during wound dressing, while others wait until wound dressing is complete. Variation in the timing of the starting point of the recovery process could have had an effect on the results. the judgment of the time to start recovery was immediately after last surgical stitch was taken. We discontinued the anesthetic at that point in both groups. But, in group BIS-b we tapered the concentration of anesthetic, according to standard clinical practice, 10 min before last stitch: while in group BIS-g we tailored the anesthetic to maintain BIS values between 55 and 70 to facilitate recovery (Myles *et al*., 2004). Anesthetists were blinded to the BIS values in the BIS-b group, so as to avoid bias.

The reduced costs of faster orientation and shorter time to arrive at and to discharge from PACU and subsequent savings of operating theater time, in the BIS-guided group compared with BIS-blinded group, have not been considered in this calculations and require further analysis.

Aspect medical recommends maintaining BIS between 40 and 60, which ensures adequate hypnotic effect while improving recovery process (Lefoll-Masson *et al*., 2007). Values <40 are consistent with deep anesthesia, values between 40 and 60 are the target range and values >60 are consistent with light anesthesia (Sinha and Koshy, 2007). An upper limit of 60 has been validated by studies in which maintaining BIS below 60 decreased the incidence of intraoperative awareness (Punjasawadwong *et al*., 2007). The advisability of a lower limit of 40 has been disputed, because it has been reported that cumulative deep hypnotic time with a BIS value lower than 45 may be an independent predictor of mortality in the first year after major non-cardiac surgery (Monk *et al*., 2005). Accordingly, our target range was set at BIS values between 50 and 60 in the BIS-g group. Hypnotic drug titration to BIS index of 55-70 was allowed during wound closure in BIS-g group to facilitate recovery, according to Myles *et al*. (2004).

BIS-measurements are susceptible to sources of error. In a recent article (Dahaba, 2005), electromyography activity and electric device interference, air-warming blankets close to a patient's forehead, or planned hypothermia, increased BIS-value without affecting the signal quality indicator. This issue was incorporated in this study protocol and no BIS values were recorded during electro-cautery.

Baseline BIS values are not reduced by nitrous oxide at inspired concentrations of up to 50% (Sinha and Koshy, 2007). In the present study we delivered 50% nitrous oxide in oxygen in both groups. Opioid contribution to the clinical depth of hypnosis was comparable in both groups, as there was no difference in opioid consumption between groups as shown in Table 3.

Ultimately, with the aid of BIS-monitoring, the reduced sevoflurane consumption demonstrated in this study, will reduce anesthetic cost by 32% and together with a shorter orientation time and faster arrival at and shorter stay in PACU, might justify the cost of the BIS-monitor, as well as avoid irrelevant excessive anesthetic administration. These facts, with other benefits of decreased side effects that accompany decreased consumption of inhalational anesthetic, would force hospitals and anesthesia providers throughout the world to come to realize that utilization of BIS monitoring can lead to substantial safety, quality, efficiency and ultimately financial benefits for their patients and the healthcare system.

CONCLUSION AND RECOMMENDATION

In addition to the monitoring of awareness during anesthesia, the data given by the BIS monitor allows for better tailoring of anesthetic management. The potential benefit of implementing BIS monitoring is significant. Drug savings combined with improved recovery will allow patients to go home faster with fewer residual drug effects. This leads to higher patient satisfaction with their overall surgical experience.

REFERENCES

Agarwal, A., R. Pandey, S. Dhiraaj, K.S. Prabhat and M. Raza *et al*., 2004. The effect of epidural bupivacaine on induction and maintenance doses of propofol (evaluated by bispectral index) and maintenance doses of fentanyl and vecuronium. Anesth. Analg., 99: 1684-1688.

Ahmad, S., M. Yilmaz, R.J. Marcus, S. Glisson and A. Kinsella, 2003. Impact of bispectral index monitoring on fast tracking of gynecologic patients undergoing laparoscopic surgery. Anesthesiology, 98: 849-852.

Aldrete, J.A. and D. Kroulik, 1970. A postanesthetic recovery score. Anesth. Analg., 49: 924-934.

Bannister, C.F., K.K. Brosius, J.C. Sigl, J.M. Barbara and S.S. Peter, 2001. The effect of bispectral index monitoring on anesthetic use and recovery in children anesthetized with sevoflurane in nitrous oxide. Anesth. Analg., 92: 877-881.

Billard, V. and P. Mavoungou, 2007. Depth of anesthesia monitoring in anesthetic literature, illustrated by bispectral index history. CA American Society of Anesthesiologists-Annual Meeting Abstracts. October 13-17, 2007 San Francisco.

Bruhn, J., S. Kreuer, P. Bischoff, P. Kessler and G.N. Schmidt *et al*., 2005. Bispectral index and A-line AAI index as guidance for desflurane-remifentanil anaesthesia compared with a standard practice group: A multicentre study. Br. J. Anaesth., 94: 63-69.

Buchanan, F.F., P.S. Myles, K. Leslie, A. Forbes and F. Cicuttini, 2006. Gender and recovery after general anesthesia combined with neuromuscular blocking drugs. Anesth. Analg., 102: 291-297.

Burrow, B., B. McKenzie and C. Case, 2001. Do anaesthetized patients recover better after bispectral index monitoring Anaesth. Intensive Care, 29: 239-245.

Dahaba, A.A., 2005. Different conditions that could result in bispectral index indicating and incorrect hypnotic state. Anesth. Analg., 101: 765-773.

Domino, K.B., K.L. Posner, R.A. Caplan and F.W. Cheney, 1999. Awareness during anesthesia: A closed claim analysis. Anesthesiology, 90: 1053-1061.

Gan, T.J., P.S. Glass, A. Windsor, F. Payne and C. Rosow *et al*., 1997. Bispectral index monitoring allows faster emergence and improved recovery from propofol, alfentanil and nitrous oxide anesthesia. Anesthesiology, 87: 808-815.

Guignard, B., C. Coste, C. Menigaux and M. Chauvin, 2001. Reduced isoflurane consumption with bispectral index monitoring. Acta Anaesthesiol. Scand., 45: 308-814.

Katoh, T., A. Suzuki and K. Ikeda, 1998. Electroencephalographic derivatives as a tool for predicting the depth of sedation and anesthesia induced by sevoflurane. Anesthesiology, 88: 642-650.

Kearse, L.A. Jr., C. Rosow, A. Zaslavsky, P. Connors, M. Dershwitz and W. Denman, 1998. Bispectral analysis of the electroencephalogram predicts conscious processing of information during propofol sedation and hypnosis. Anesthesiology, 88: 25-34.

Kelley, S.C., 2003. Clinical application for BIS monitoring. In: Monitoring Level of Consciousness During Anesthesia and Sedation: A Clinician's Guide to the Bispectral Index. Newton Aspect Medical Systems, 2003.

Lefoll-Masson, C., C. Fermanian, I. Aimé, N. Verroust and G. Taylor *et al*., 2004. The comparability of bispectral index and state entropy index during maintenance of sufentanil-sevoflurane-nitrous oxide: Anesthesia. Anesth. Analg., 105: 1319-1325.

Leslie, K., P.S. Myles, A. Forbes, M.T.V. Chan, T.G. Short and S.K. Swallow, 2005. Recovery from bispectral index-guided anesthesia in a large randomized controlled trial of patients at high risk of awareness. Anaesth. Inten. Care, 33: 443-451.

Liu, S.S., 2004. Effects of bispectral Index monitoring on ambulatory anesthesia: A meta-analysis of randomized controlled trials and a cost analysis. Anesthesiology, 101: 311-315.

Mayer, J., J. Boldt, S. Alexander, B. Hiller and W. Stefan, 2007. Suttner, bispectral index-guided general anesthesia in combination with thoracic epidural analgesia reduces recovery time in fast-track colon surgery. Anesth. Analg., 104: 1145-1149.

Monk, T.G., V. Saini, B.C. Weldon and J.C. Sigl, 2005. Anesthetic management and one-year mortality after noncardiac surgery. Anesth. Analg., 100: 4-10.

Myles, P.S., K. Leslie, J. McNeil, A. Forbes and M.T.V. Chan, 2004. Bispectral index monitoring to prevent awareness during anaesthesia: The B-aware randomized controlled trial. Lancet, 363: 1757-1763.

Punjasawadwong, Y., N. Boonjeungmonkol and A. Phongchiewboon, 2007. Bispectral index for improving anaesthetic delivery and postoperative recovery. Anesth. Analg., 106: 1326.

Sascha, K., J. Bruhn, C. Stracke, L. Aniset and M. Silomon *et al*., 2005. Narcotrend or bispectral index monitoring during desflurane-remifentanil anesthesia: A comparison with a standard practice. Anesth. Analg., 101: 427-434.

Sebel, P.S., T.A. Bowdle, M.M. Ghoneim, I.J. Rampil and R.E. Padilla *et al*., 2004. The incidence of awareness during anaesthesia: A multicenter United States study. Anesth Analg., 99: 833-839.

Sinha, P.K. and T. Koshy, 2007. Depth of anaesthesia and monitoring devices. Ind. J. Anaesth., 51: 365-381.

Song, D., G.P. Joshi and P.F. White, 1997. Titration of volatile anesthetics using bispectral index facilitates recovery after ambulatory anesthesia. Anesthesiology, 87: 842-848.

Thomas, M.H. and P. Harvey, 2002. Electrocardiographic electrodes provide the same results as expensive special sensors in the routine monitoring of anesthetic depth. Anesth Analg., 94: 369-371.

Yli-Hankala, A., A. Vakkuri, P. Annila and K. Korttila, 1999. EEG bispectral index monitoring in sevoflurane or propofol anaesthesia: Analysis of direct costs and immediate recovery. Acta Anaesthesiol Scand, 43: 545-549.

Zohar, E., I. Luban, P.F. White, E. Ramati, S. Shabat and B. Fredman, 2006. Bispectral index monitoring does not improve early recovery of geriatric outpatients undergoing brief surgical procedures. Can. J. Anesth., 53: 20-25.