Original Article

Comparison of recovery times by using bispectral index monitoring versus end-tidal agent concentration monitoring in patients undergoing inhalational general anaesthesia

Address for correspondence:
Dr. Shalini Chaudhuri, Flat No. 504, Block A, MPMMCC Staff Quarters, Sundar Bagiya, Sunderpur, BHU Campus, Varanasi- 221 005, Uttar Pradesh, India.
E-mail: shalinichaudhuri@gmail.com

Submitted: 03-Aug-2021
Revised: 18-Apr-2022
Accepted: 29-Apr-2022
Published: 17-May-2022

Access this article online
Website: www.ijaweb.org
DOI: 10.4103/ija.ija_716_21
Quick response code

Shalini Chaudhuri, Sandipan Banerjee, Uddalak Chattopadhyay, Syed S. Hussain
Department of Anaesthesiology, Critical Care and Pain, Homi Bhabha Cancer Hospital/Mahamana Pandit Madan Mohan Malviya Cancer Centre, Varanasi, Uttar Pradesh, India

ABSTRACT

Background and Aims: End-tidal anaesthetic gas concentration (ETAG) and bispectral index (BIS) are both used to monitor depth of anaesthesia. Maintaining an accurate depth of anaesthesia helps in early post-operative recovery. This study compared the recovery times from sevoflurane–nitrous oxide anaesthesia using ETAG monitoring with BIS monitoring. **Methods**: Four hundred and two patients undergoing elective surgeries under sevoflurane- nitrous oxide anaesthesia were enroled in this double blinded parallel group prospective randomised trial and allocated into two groups. The depth of anaesthesia was monitored using BIS in BIS group (n = 202) and end-tidal sevoflurane concentration (EtSevo) in ETAG group (n = 200). The time to extubation and recovery were compared between the groups. Parametric, non-parametric and categorical variables were compared using Student's '*t*' test, Wilcoxon's rank sum test and Chi-square test, respectively. **Results**: Time to extubation (min) [BIS group – 10, 5; ETAG group – 10, 5 (median, inter-quartile range, IQR), P = 0.32] and time to recovery (min) [BIS group – 14, 6; ETAG group – 13.5, 7 (median, IQR), P = 0.34] did not differ significantly between the two groups. The EtSevo concentration (vol%) was significantly higher in the BIS group at 5 min [BIS group – 1.2, 0.4; ETAG group – 1.0, 0.4 (median, IQR), P < 0.001], 30 min [BIS group – 1.1, 0.4; ETAG group – 1.0, 0.3 (median, IQR), P = 0.002] and 120 min [BIS group – 1.11 ± 0.28; ETAG group – 0.96 ± 0.27 (mean ± standard deviation), P = 0.014] after induction of anaesthesia. **Conclusions**: BIS and ETAG monitoring are associated with comparable recovery profiles. ETAG monitoring is associated with significantly less sevoflurane consumption.

Key words: Anaesthesia recovery period, consciousness monitors, sevoflurane

INTRODUCTION

Maintaining an optimal depth of anaesthesia during surgery is essential to prevent awareness, and to ensure a rapid, smooth recovery.[1] Clinical parameters for assessing anaesthetic depth (heart rate, blood pressure, increased secretions or movements) are subjective, affected by factors like pain, hypovolaemia, bladder distension, and are thus not reliable.[2] A widely used anaesthetic depth monitor is the bispectral index (BIS) (Aspect Medical Systems), which processes a single frontal electroencephalographic signal to calculate a dimensionless number ranging from 100 to 0, indicating the awake state and absence of brain activity, respectively. Maintaining BIS values between 40 and 60 prevents awareness.[3,4] Numerous studies have proven the efficacy of BIS monitoring in reducing the incidence of awareness as compared to the standard

How to cite this article: Chaudhuri S, Banerjee S, Chattopadhyay U, Hussain SS. Comparison of recovery times by using bispectral index monitoring versus end-tidal agent concentration monitoring in patients undergoing inhalational general anaesthesia. Indian J Anaesth 2022;66:S161-8.

practice of monitoring clinical parameters.[2] Studies have also shown the usefulness of BIS in reducing recovery times and sevoflurane consumption, over standard practice.[5,6] Early and enhanced recovery after surgery is encouraged nowadays with depth of anaesthesia monitoring being a part of it.[7] End-tidal anaesthetic gas concentration (ETAG) also reflects the anaesthetic depth. Maintaining the ETAG between 0.7 and 1.3 minimum alveolar concentration (MAC) decreases the likelihood of awareness.[3]

This study was conducted to compare the efficacy of BIS monitoring with end-tidal sevoflurane concentration (EtSevo) monitoring in reducing post-operative recovery times in adult patients undergoing gynaecological, general surgical, rhinootolaryngological and orthopaedic surgeries under sevoflurane and nitrous oxide anaesthesia. The null hypothesis of this study was that there is no difference in the recovery times from anaesthesia using BIS or EtSevo monitoring.

METHODS

The study was conducted in a central government medical college from October 2017 to July 2018 after obtaining Institutional Ethics Committee approval [No. 412 (DEAN-JOKA)/IEC/2014-15/Vol 1] and retrospectively registered with Clinical Trials Registry, India (CTRI/2018/03/012457). This double blinded parallel group prospective randomised trial was conducted in 402 American Society of Anesthesiologists (ASA) physical status I and II patients aged 18–60 years of both genders, undergoing elective surgical procedures requiring general anaesthesia. Patients with the history of long-term use of anticonvulsants, opiates, benzodiazepines, cocaine, alcohol, patients with pre-existing renal, hepatic and cardiac diseases, anticipated difficult intubation; patients with dementia and stroke with residual neurologic deficits were excluded. The study followed all the principles of the declaration of Helsinki.

Consenting patients fulfilling the inclusion criteria, scheduled to undergo elective surgery were randomised into two groups (BIS group and ETAG group) using a computer-generated random number sequence of integers. The group assignment was known only to the principal investigator and the anaesthesia provider involved in maintaining general anaesthesia of the patient, but not to the independent observer noting the times of reversal after discontinuing anaesthetic agents.

In the BIS group, sevoflurane was administered to maintain a BIS value of 40–60 intraoperatively. In the ETAG group, EtSevo was maintained between 0.7 and 1.3 times the age adjusted MAC for sevoflurane in 65% nitrous oxide as per summary of product characteristics leaflet.

In the operating theatre, electrocardiography, pulse oximetry and non-invasive blood pressure were attached. BIS™ Quatro sensor was applied on the left side of the forehead of each patient. The BIS sensor was not connected to the monitor in the ETAG group. In the BIS group, the sensor was disconnected from the monitor after switching-off the sevoflurane vaporiser by the anaesthesiologist involved in the maintenance phase. The anaesthesiologist noting the recovery times could see a BIS strip attached to the patient's forehead in both groups. SpaceLabs 92518 multigas module with SpaceLabs Ultraview monitor was used for EtSevo monitoring and was auto-calibrated at the start of each surgery. In the BIS group, both EtSevo and BIS values were monitored. In the ETAG group, only EtSevo was monitored.

Dexamethasone 8 mg and fentanyl 2 μg/kg were given intravenously(IV)aspremedication.Afterpre-oxygenation with an oxygen flow of 6L/min, patients were induced using propofol 2 mg/kg IV. Airway was secured using i-gel or endotracheal tube. Atracurium 0.5 mg/kg IV was used for endotracheal intubation. Anaesthesia was maintained with oxygen 1 L/min (35%), nitrous oxide 2 L/min (65%) and sevoflurane, maintaining end-tidal carbon di-oxide concentration ($ETCO_2$) between 32 and 36 mmHg. Neuromuscular blockade was maintained by intermittent boluses of atracurium, limiting hourly dose to 0.4 mg/kg/h. Multimodal analgesia including tramadol (100 mg IV infusion), diclofenac (75 mg IV infusion) and paracetamol (1000 mg IV infusion) was given intraoperatively to all patients.

In the BIS group, if blood pressure and/or heart rate increased to >25% above the pre-anaesthetic values and BIS was within the targeted range, fentanyl (1 μg/kg) IV was to be given. In the ETAG group, fentanyl (1 μg/kg) IV was to be administered if, despite increasing the EtSevo concentration upto 1.3 MAC, the haemodynamic variables were increased by >25% of the pre-anaesthetic values. Hypotension was corrected with the help of fluid boluses and vasopressors. In the BIS group, an audible alarm was set to indicate when the BIS values exceeded 60 or fell below 40. In the ETAG group, an audible alarm was

set to indicate when the EtSevo fell below 0.7 times or exceeded 1.3 times the MAC of sevoflurane in 65% nitrous oxide. Temperature was monitored throughout the perioperative period. Ondansetron 4 mg IV was administered. Sevoflurane was discontinued at the beginning of skin closure or when the laparoscope was removed. Nitrous oxide was discontinued after the surgery was completed and oxygen flow rate increased to 6 L/min. Neuromuscular block was antagonised with neostigmine 0.05 mg/kg and glycopyrrolate 0.01 mg/kg IV. Patients were reversed, awakened, extubated and assessed post-operatively by an anaesthesiologist unaware about the patients' group assignment.

Data were collected using observer entered record forms. Data recorded were: demographic data (age, gender, weight, type of surgery), duration of sevoflurane administration (from induction of anaesthesia to discontinuation of sevoflurane), duration of anaesthesia (from induction of anaesthesia to discontinuation of nitrous oxide), time to extubation (from discontinuation of sevoflurane to extubation/removal of i-gel), time to recovery (from discontinuation of sevoflurane to achievement of Aldrete score ≥9). Intraoperative parameters including heart rate, systolic blood pressure, peripheral oxygen saturation (SpO_2), $EtCO_2$, temperature, BIS score and EtSevo were recorded at baseline (T_0), after induction (T_i), 5 min (T_5), 30 min (T_{30}), 60 min (T_{60}) and 120 min (T_{120}) after induction. The total MAC delivered at these time points was also calculated from the EtSevo using Mapleson's formula. The primary outcome parameter was recovery time. The secondary outcome parameters were extubation time and EtSevo at various points of time as a surrogate for sevoflurane consumption. Intraoperative awareness was assessed in all patients using the modified Brice questionnaire 60 min and 24 h after recovery by an interviewer blinded to the study.

To detect a 30% difference in recovery time (approximately 4 min difference, considering a mean recovery time of 13 min from sevoflurane-based anaesthesia) between both the groups, 201 patients would be required in each group to reject the null hypothesis with a power of 0.85 and a Type I error of 0.05. The sample size and power calculations were done using 'G*Power' Statistical Power Analyses software version 3.1.9.2, April 2016, Faul, F., Erdfelder, E., Buchner, A., and Lang, A.-G, © 2010-2019 Heinrich-Heine-Universität Düsseldorf. Continuous variables were tested for normality of distribution using the Shapiro–Wilk normality test. Non-parametric and parametric variables were compared with the Wilcoxon rank sum test and Student's '*t*' test, respectively. Categorical data were analysed using the Pearson Chi-square test. *P* value <0.05 was considered statistically significant. Data analysis was performed using the R Commander statistical package version 2.3.2 on base R version 3.2.3.

RESULTS

Among the 409 patients enroled in the study, 7 were excluded due to deviation from the study protocol and 402 patients completed the study [Figure 1].

All non-parametric variables were expressed as median and inter-quartile range (IQR). Parametric variables were expressed as mean ± standard deviation (SD).

Both groups were comparable with respect to demographic and intraoperative parameters [Tables 1 and 2]. The anaesthesia and sevoflurane durations were significantly higher in the BIS group (P = 0.032 and 0.027, respectively). The extubation and recovery times did not differ significantly between the groups. Significantly higher EtSevo was delivered in the BIS group at T_5, T_{30}, T_{120} [Table 2 and Figure 2]. The total MAC delivered was significantly higher in the BIS group at T_5 and T_{30} [Table 2]. None of the study patients reported any intraoperative awareness when interviewed 60 min and 24 h after recovery. Additional fentanyl boluses were not required in any of the patients.

Since the difference in anaesthesia duration may impact the extubation and recovery times, further

Table 1: Demographic distribution of study populations

Parameter	BIS Group (*n*=202)	ETAG Group (*n*=200)	P value
Age (years)			
Median	38.5	40	0.988
Interquartile range	18	21	
Gender, number of patients (%)			
Female	151 (74.8%)	146 (73%)	0.689
Male	51 (25.2%)	54 (27%)	
Weight (kg)			
Median	57.5	56	0.240
Interquartile range	16	15	
Category of surgery			
Rhinootolaryngology	5	8	0.752
Gynaecology	60	57	
General Surgery	110	104	
Orthopaedics	27	31	

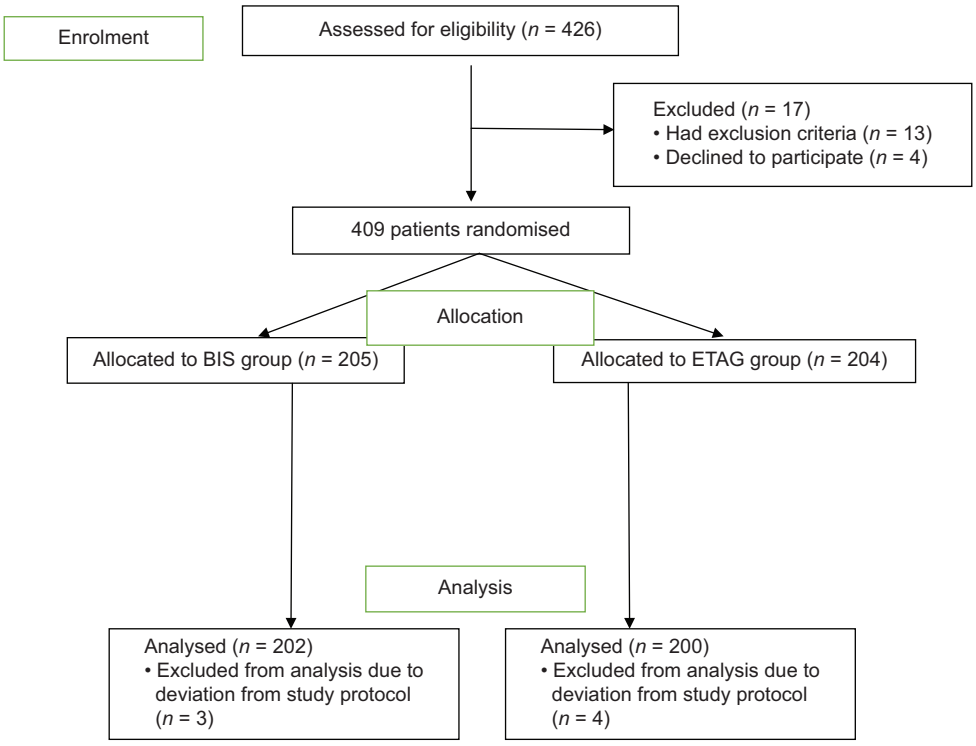

Figure 1: Study flow following consolidated standards of reporting trials (CONSORT) guidelines

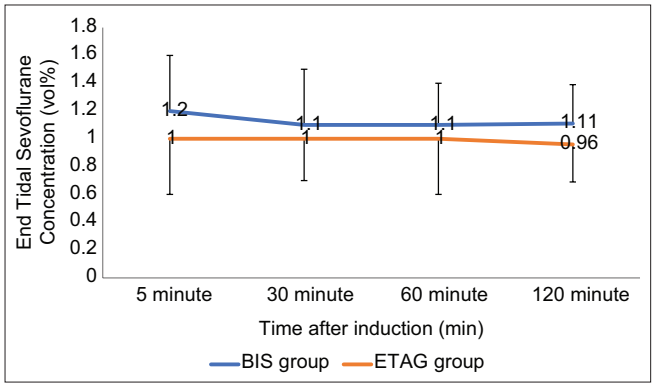

Figure 2: Comparison of EtSevo between BIS and ETAG groups at various points of time after induction of anaesthesia. Mean/median values plotted against time. SD/IQR depicted as error bars

subgroup analysis based on anaesthesia duration was done. The study population was subdivided into five subgroups according to anaesthesia duration (<30 min, >30 min ≤60 min, >60 min ≤120 min, >120 min ≤ 180 min, >180 min). The outcome variables were compared between the BIS and the ETAG groups in each subgroup.

There was no significant difference in the anaesthesia and sevoflurane durations between the BIS and the ETAG groups within each subgroup. Extubation and recovery times did not differ significantly within each subgroup between the BIS and the ETAG groups [Table 3 and Figure 3].

The EtSevo at T_5 was significantly higher in the BIS group compared to the ETAG group in patients with anaesthesia duration >30 min but ≤60 min ($P = 0.001$). The MAC total at T_5 was also significantly higher in the BIS group in this subgroup of patients ($P = 0.009$). In patients with anaesthesia duration >60 min but ≤120 min, a significant difference between the groups was found in the EtSevo at T_5 ($P = 0.018$) and T_{30} ($P = 0.028$) with greater values in the BIS group. The MAC total values were however comparable between the groups. Patients with anaesthesia duration >120 min but ≤180 min had significantly higher EtSevo in the BIS group at T_5 ($P = 0.005$) and T_{120} ($P = 0.005$). The MAC total values at T_5 and T_{120} were also significantly higher in the BIS group [Table 3].

In the subgroup of patients with anaesthesia duration >180 min, all the outcome parameters were comparable between both the groups [Table 3].

DISCUSSION

In the present study, the extubation times for both groups were comparable: 10 min, 5 min (median, IQR) for the BIS group and 10 min, 5 min (median, IQR) for the ETAG group ($P = 0.32$). The recovery times were

Table 2: Comparison of intraoperative variables and outcome variables among study groups

	BIS Group (*n*=202)	ETAG Group (*n*=200)	*P*
Heart rate (bpm):			
At baseline (T_0)	91.64±15.21*	89.22±17.20*	0.135
After induction (T_i)	87, 24.5#	87, 26.0#	0.743
5 min after induction (T_5)	85, 24.75#	83, 28.25#	0.416
30 min after induction (T_{30})	74, 22#	74, 26#	0.494
60 min after induction (T_{60})	64, 20#	63.75, 22.5#	0.806
120 min after induction (T_{120})	74.0±10.67*	77.93±15.65*	0.193
Systolic BP (mmHg):			
At baseline (T_0)	135, 21.75#	132,25#	0.517
After induction (T_i)	111, 26.5#	113,29#	0.425
5 min after induction (T_5)	111, 24.75#	114, 22.25#	0.901
30 min after induction (T_{30})	120,27#	120, 26#	0.867
60 min after induction (T_{60})	120.5, 26#	120, 22.25#	0.706
120 min after induction (T_{120})	118, 23#	118, 21.25#	0.390
Temperature (°C):			
At baseline (T_0)	34.5, 1.5#	34.8, 1.55#	0.054
After induction (T_i)	34.65, 1.4#	34.8, 1.3#	0.067
5 min after induction (T_5)	34.8, 1.175#	34.9, 1.225#	0.101
30 min after induction (T_{30})	35.0, 1.0#	35.1, 1.2#	0.442
60 min after induction (T_{60})	35.14±0.83*	35.20±0.91*	0.546
120 min after induction (T_{120})	35.00±0.82*	35.16±0.84*	0.415
$EtCO_2$ (mmHg):			
5 min after induction (T_5)	34, 4#	35, 4#	0.073
30 min after induction (T_{30})	35, 5#	35, 5#	0.351
60 min after induction (T_{60})	35, 4.75#	35, 4#	0.926
120 min after induction (T_{120})	34, 5#	33.5, 5#	0.601
SpO_2 (%):			
At baseline (T_0)	100, 0#	100, 0#	0.091
After induction (T_i)	100, 0#	100, 0#	0.994
5 min after induction (T_5)	100, 0#	100, 0#	0.401
30 min after induction (T_{30})	100, 0#	100, 0#	0.173
60 min after induction (T_{60})	100,0#	100, 0#	0.006
120 min after induction (T_{120})	100,0#	100, 0#	0.345
Sevoflurane Duration (min)	82, 48.75#	73, 53.25#	0.027
Anaesthesia Duration (min)	87.0, 48.75#	77.5, 55.75#	0.032
Extubation time (min)	10, 5#	10, 5#	0.320
Recovery time (min)	14, 6#	13.5, 7#	0.340
EtSevo (%):			
5 min after induction (T_5)	1.2,0.4#	1.0, 0.4#	<0.001
30 min after induction (T_{30})	1.1,0.4#	1.0, 0.3#	0.002
60 min after induction (T_{60})	1.1, 0.3#	1.0,0.4#	0.075
120 min after induction (T_{120})	1.11±0.28*	0.96±0.27*	0.014
MAC total:			
5 min after induction (T_5)	1.19, 0.21#	1.13, 0.21#	<0.001
30 min after induction (T_{30})	1.19±0.14*	1.16±0.16*	0.035
60 min after induction (T_{60})	1.16,0.17#	1.15, 0.22#	0.432
120 min after induction (T_{120})	1.18±0.15*	1.13±0.15*	0.174

Parametric variables marked with *, expressed as mean±Standard deviation.
Non-parametric variables marked with #, expressed as median, IQR.
$EtCO_2$: End-tidal carbon dioxide; MAC: Minimum alveolar concentration; SpO_2: Peripheral oxygen saturation; n: Number; bpm: Beats per minute; IQR: Interquartile range; BP: Blood pressure

also comparable – 14 min, 6 min (median, IQR) for the BIS group, and 13.5 min, 7 min (median, IQR) for the ETAG group ($P = 0.34$). However, these results might have been influenced by the significant difference between the groups in the anaesthesia and sevoflurane durations. To overcome this, both the groups were subdivided into five subgroups based on anaesthesia duration. In all the five subgroups, despite comparable anaesthesia durations, the extubation and recovery times did not significantly differ between the BIS and the ETAG groups. An increase of similar magnitude in extubation and recovery times in both BIS and ETAG groups with increase in anaesthesia duration was seen.

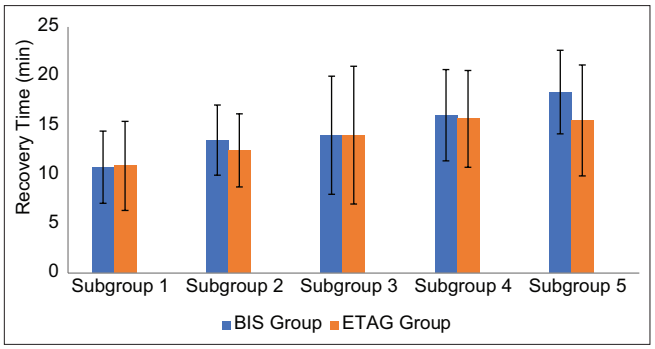

Figure 3: Comparison of recovery times between BIS and ETAG groups in the five subgroups. Mean/median values depicted by bars. SD/IQR depicted as error bars

Studies comparing the effect of BIS guided protocols with standard practice protocols (monitoring clinical signs) on recovery profiles of patients have shown early recovery in the BIS group.[2,5,6] Some studies have also found BIS and standard practice protocols to be comparable.[8-11]

Few studies comparing BIS monitoring with ETAG monitoring provide conflicting results. R. Sudhakaran *et al*.[12] compared the recovery profiles of patients receiving desflurane, nitrous oxide anaesthesia for lumbar spine surgeries using BIS monitoring, end-tidal agent concentration monitoring or standard practice. They found that emergence time and extubation time were significantly less in the BIS and end-tidal agent concentration groups compared to the standard practice group. However, end-tidal agent concentration guided anaesthesia was comparable to BIS guided anaesthesia for early recovery. In contrast, in a comparison of ETAG with BIS guided protocol in 60 patients receiving sevoflurane–nitrous oxide anaesthesia, Shukla *et al*.[13] found that extubation times and mean sevoflurane concentration set on vaporiser were significantly less in BIS group compared to ETAG group. This study included only surgical procedures lasting <120 min. A study comparing BIS monitoring with ETAG guided protocol in patients receiving halothane-based

Table 3: Comparison of outcome variables in subgroups

Subgroup 1 – Anaesthesia duration <30 min	**BIS Group (*n*=12)**	**ETAG Group (*n*=16)**	***P***
Anaesthesia duration (min)	18.42±7.17*	22.06±6.16*	0.172
Sevoflurane duration (min)	16.92±7.48*	20.13±5.50*	0.225
Extubation time (min)	9,5#	8,5.25#	0.400
Recovery time (min)	10.75±3.67*	10.88±4.53*	0.936
EtSevo (%):			
5 min after induction (T_5)	1.16±0.32*	1.18±0.29*	0.856
MAC total:			
5 min after induction (T_5)	1.2±0.2*	1.16±0.14*	0.537
Subgroup 2 – Anaesthesia duration >30 min ≤60 min	**BIS Group (*n*=32)**	**ETAG Group (*n*=51)**	***P***
Anaesthesia duration (min)	50, 14.75#	49, 12.50#	0.840
Sevoflurane duration (min)	44.75±7.97*	44.77±7.98*	0.994
Extubation time (min)	9, 3#	9, 4#	0.562
Recovery time (min)	13.50±3.56*	12.45±3.71*	0.203
EtSevo (%):			
5 min after induction (T_5)	1.25, 0.425#	1.0, 0.4#	0.001
30 min after induction (T_{30})	1.1, 0.5#	1.0, 0.3#	0.141
MAC total:			
5 min after induction (T_5)	1.2, 0.22#	1.1, 0.17#	0.009
30 min after induction (T_{30})	1.15±0.2*	1.11±0.13*	0.316
Subgroup 3- Anaesthesia duration >60 min ≤120 min	**BIS Group (*n*=113)**	**ETAG Group (*n*=95)**	***P***
Anaesthesia duration (min)	87, 29#	88, 25.5#	0.257
Sevoflurane duration (min)	82, 30#	81, 27#	0.224
Extubation time (min)	10, 5#	11, 5.5#	0.528
Recovery time (min)	14, 6#	14, 73	0.716
EtSevo (%):			
5 min after induction (T_5)	1.1, 0.3#	1.1, 0.4#	0.018
30 min after induction (T_{30})	1.1, 0.3#	1.0, 0.3#	0.028
60 min after induction (T_{60})	1.1, 0.2#	1.0, 0.4#	0.117
MAC total:			
5 min after induction (T_5)	1.21, 0.18#	1.14, 0.20#	0.067
30 min after induction (T_{30})	1.2±0.13*	1.18±0.16*	0.239
60 min after induction (T_{60})	1.16,0.16#	1.15,0.22#	0.443
Subgroup 4 – Anaesthesia duration >120 min ≤180 min	**BIS Group (*n*=36)**	**ETAG Group (*n*=29)**	***P***
Anaesthesia duration (min)	142.5, 25#	140, 21#	0.771
Sevoflurane duration (min)	137.5, 24.75#	134, 24#	0.697
Extubation time (min)	12, 5.25#	12, 5#	0.671
Recovery time (min)	16.03±4.64*	15.66±4.92*	0.757
EtSevo (%):			
5 min after induction (T_5)	1.16±0.33*	0.95±0.28*	0.005
30 min after induction (T_{30})	1.07±0.29*	0.99±0.22*	0.196
60 min after induction (T_{60})	1.05,0.325#	1.0,0.3#	0.312
120 min after induction (T_{120})	1.14±0.31*	0.93±0.25*	0.005
MAC total:			
5 min after induction (T_5)	1.22±0.17*	1.13±0.17*	0.038
30 min after induction (T_{30})	1.17±0.14*	1.15±0.15*	0.498
60 min after induction (T_{60})	1.16, 0.27#	1.13, 0.21#	0.663
120 min after induction (T_{120})	1.20±0.14*	1.12±0.16*	0.028
Subgroup 5 – Anaesthesia duration >180 min	**BIS Group (*n*=8)**	**ETAG Group (*n*=10)**	***P***
Anaesthesia duration (min)	203, 34.25#	205, 28.75#	0.563
Sevoflurane duration (min)	196.5,31.25#	195, 32.25#	0.563
Extubation time (min)	14.5±4.60*	11.9±5.02*	0.270
Recovery time (min)	18.375±4.24*	15.5±5.64*	0.235
EtSevo (%):			
5 min after induction (T_5)	1.16±0.23*	1.03±0.31*	0.307
30 min after induction (T_{30})	1.09±0.28*	1.18±0.32*	0.522
60 min after induction (T_{60})	1.00±0.24*	1.12±0.27*	0.333
120 min after induction (T_{120})	1.04±0.29*	1.07±0.21*	0.818

Contd...

Table 3: Contd...

Subgroup 5 – Anaesthesia duration >180 min	BIS Group (*n*=8)	ETAG Group (*n*=10)	*P*
MAC total:			
5 min after induction (T_5)	1.22±0.14*	1.18±0.17*	0.553
30 min after induction (T_{30})	1.18±0.12*	1.25±0.19*	0.333
60 min after induction (T_{60})	1.14±0.09*	1.22±0.16*	0.180
120 min after induction (T_{120})	1.15±0.09*	1.19±0.08*	0.336

Parametric variables marked with * and expressed as mean±SD. Non-parametric variables marked with # and expressed as median, IQR: Interquartile range; MAC: Minimum alveolar concentration; n Number

anaesthesia by Jain *et al.*[14] found that mean time to tracheal extubation was significantly longer in BIS group (9.63 ± 3.02 min) as compared to ETAG group (5.29 ± 1.51 min). Only patients undergoing open cholecystectomy and abdominal hysterectomy were studied. Unlike previous studies, our study had a diverse surgical population (general surgery, gynaecology, orthopaedics and rhinootolaryngology) and included longer surgical durations.

None of the 402 participants of our study reported any recall when interviewed using the Brice questionnaire 60 min and 24 h after recovery. Thus, ETAG monitoring was found to be equally effective in preventing awareness as BIS monitoring in our study.

Though BIS monitoring has been shown to reduce the incidence of awareness as compared to the standard practice of maintaining anaesthesia depth using clinical signs, previous studies have found it to be comparable with ETAG monitoring in preventing awareness.[3,6]

An important finding of our study was that the EtSevo was significantly higher in the BIS group compared to the ETAG group at 5, 30 and 120 min after induction. This difference in EtSevo persisted during the subgroup analysis, with higher values in the BIS group in the subgroups with anaesthesia duration 30–60 min (at T_5), 60–120 min (at T_5 and T_{30}), 120–180 min (at T_5 and T_{120}). This may reflect an increased sevoflurane consumption in BIS group compared to the ETAG group. In a meta-analysis of 36 trials, Punjasawadwong *et al.*[6] noted that BIS-guided anaesthesia reduced the requirement of volatile anaesthetics (desflurane, sevoflurane, isoflurane) by 0.65 MAC (95% confidence interval (CI) −1.01 to −0.28) in 985 participants compared to standard practice. Our study indicates that compared to EtSevo monitoring, BIS monitoring may increase sevoflurane consumption without reducing incidence of awareness or hastening recovery. This can be attributed to the fact that though BIS monitoring is good at predicting the alert state and helps prevent awareness, the BIS monitoring algorithm does not accurately predict an asleep state and may show values >60 in those already asleep, erroneously increasing the anaesthetic consumption.[2,15] This is corroborated by the findings of Schneider *et al.* and Sleigh *et al.* Schneider *et al.*[16] reported a sensitivity of 90.6% and a specificity of 26.3% for the detection of consciousness (proportion of those awake who were identified as awake) by BIS monitoring. Sleigh *et al.*[17] reported a sensitivity of 61% and a specificity of 89% for the detection of unconsciousness (proportion of those asleep who were identified as asleep).

However, the limitation of our study was that EtSevo concentrations at specific time points during surgery were used as a marker of sevoflurane consumption. A more accurate method of measuring sevoflurane consumption, like weighing of the vaporiser before and after anaesthesia should be used in future studies to reach any definitive conclusion. Another limitation of our study was that only 18 patients with anaesthesia duration >180 min were included. More patients need to be studied for these findings to be extrapolated to long duration surgeries.

CONCLUSION

The study concludes that BIS monitoring and ETAG monitoring are associated with comparable recovery times in patients receiving general anaesthesia with nitrous oxide and sevoflurane. However, ETAG monitoring is associated with significantly less sevoflurane consumption.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Somchai A. Monitoring for depth of anaesthesia: A review. J Biomed Graph Comput 2012;2:119-27.
2. Medical Advisory Secretariat. Bispectral index monitor: An evidence-based analysis. Ont Health Technol Assess Ser 2004;4:1-70.
3. Avidan MS, Zhang L, Burnside BA, Finkel KJ, Searleman AC, Selvidge JA, *et al*. Anaesthesia awareness and the bispectral index. N Engl J Med 2008;358:1097-108.
4. Avidan MS, Jacobsohn E, Glick D, Burnside BA, Zhang L, Villafranca A, *et al*. Prevention of intraoperative awareness in a high-risk surgical population. N Engl J Med 2011;365:591-600.
5. Ibraheim O, Alshaer A, Mazen K, El-Dawlaty A, Turkistani A, Alkathery K, *et al*. Effect of bispectral index (BIS) monitoring on postoperative recovery and sevoflurane consumption among morbidly obese patients undergoing laparoscopic gastric banding. Middle East J Anaesthesiol 2008;19:819-30.
6. Punjasawadwong Y, Phongchiewboon A, Boonjeungmonkol N. Bispectral index for improving anaesthetic delivery and postoperative recovery. Cochrane Database Syst Rev 2014; 6:CD003843.
7. Mehdiratta L, Mishra SK, Vinayagam S, Nair A. Enhanced recovery after surgery (ERAS)…. still a distant speck on the horizon! Indian J Anaesth 2021;65:93-6.
8. Nelskyla KA, Yli-Hankala AM, Puro PH, Korttila KT. Sevoflurane titration using bispectral index decreases postoperative vomiting in phase II recovery after ambulatory surgery. Anaesth Analg 2001;93:1165-9.
9. Ahmad S, Yilmaz M, Marcus RJ, Glisson S, Kinsella A. Impact of bispectral index monitoring on fast tracking of gynaecologic patients undergoing laparoscopic surgery. Anaesthesiology 2003;98:849-52.
10. Puri GD, Murthy SS. Bispectral index monitoring in patients undergoing cardiac surgery under cardiopulmonary bypass. Eur J Anaesthesiol 2003;20:451-6.
11. Basar H, Ozcan S, Buyukkocak U, Akpinar S, Apan A. Effect of bispectral index monitoring on sevoflurane consumption. Eur J Anaesthesiol 2003;20:396-400.
12. Sudhakaran R, Makkar JK, Jain D, Wig J, Chabra R. Comparison of bispectral index and end-tidal anaesthetic concentration monitoring on recovery profile of desflurane in patients undergoing lumbar spine surgery. Indian J Anaesth 2018;62:516-23.
13. Shukla U, Yadav U, Yadav JB, Agrawal S. Comparison of end-tidal anaesthetic gas concentration versus bispectral index- guided protocol as directing tool on time to tracheal extubation for sevoflurane- based general anaesthesia. Anaesth Essays Res 2020;14:600-4.
14. Jain N, Mathur PR, Khan S, Khare A, Mathur V, Sethi S. Effect of bispectral index versus end-tidal anaesthetic gas concentration-guided protocol on time to tracheal extubation for halothane- based general anaesthesia. Anaesth Essays Res 2016;10:591-6.
15. Dias R, Dave N, Agrawal B, Baghele A. Correlation between bispectral index, end tidal anaesthetic gas concentration and difference in inspired-end-tidal oxygen concentration as measures of anaesthetic depth in paediatric patients posted for short surgical procedures. Indian J Anaesth 2019;63:277-83.
16. Schneider G, Gelb AW, Schmeller B, Tschakert R, Kochs E. Detection of awareness in surgical patients with EEG-based indices—bispectral index and patient state index. Br J Anaesth 2003;91:329-35.
17. Sleigh JW, Steyn-Ross DA, Steyn-Ross ML, Williams ML, Smith P. Comparison of changes in electroencephalographic measures during induction of general anaesthesia: Influence of the gamma frequency band and electromyogram signal. Br J Anaesth 2001;86:50-8.