Chhanwal *et al.*
Ain-Shams Journal of Anesthesiology (2022) 14:74
https://doi.org/10.1186/s42077-022-00268-5

Ain-Shams Journal of Anesthesiology

ORIGINAL ARTICLE Open Access

Bispectral index: the current tool for monitoring unintended awareness and depth of anesthesia

Heena Chhanwal[1], Divya Kheskani[1*], Parita Gandhi[1], Meet Bhadresh Shah[1], Devendra Makwana[1] and Vasu Rathod[2]

Abstract

Background: Awareness under general anesthesia is an unpleasant phenomenon that usually goes unnoticed and neglected. Numerous incidences of intraoperative awareness are not reported. Reasons for awareness might be the inadequate depth of anesthesia, less effective drugs, lack of proper anesthesia monitoring equipment, and untrained medical staff.

The purpose of this study is to evaluate intraoperative awareness during general anesthesia and titrate the amount of anesthetic agents according to BIS values among patients and monitor hemodynamic parameters throughout the surgery.

Results: The intraoperative awareness reported was 2% in the BIS group and 8% in the non-BIS group. The total propofol consumption in the BIS group was significantly less as compared to the non-BIS group (*P* value<0.0001).

Conclusions: The incidence of definite awareness with postoperative recall and propofol consumption was reduced in the BIS group as compared to the non-BIS group.

Keywords: Anesthesia, Consciousness monitors, Intraoperative awareness, Propofol

Key messages

Bispectral index monitoring aids to prevent intraoperative awareness and recall under anesthesia with a reduced dosage of anesthetic drugs.

Background

Balanced anesthesia is the balance between the amount of anesthetic drugs administered and the state of arousal of the patient (Rani & Harsoor, 2012; Bhargava et al., 2004).

The depth of anesthesia refers to the degree of CNS depression and decrease in responsiveness to stimulation.

Inappropriate dosage of administered drugs results in delayed recovery with postoperative complications (Sebel et al., 2004).

Inadequate anesthesia leads to awareness that is difficult to recognize and frequent serious problems with psychological consequences for the patient and medicolegal implications for anesthesiologist (Liu et al., 1991).

Therefore, the BIS monitoring system is intended to monitor intraoperative awareness and consumption of propofol.

Methods

This randomized, prospective study was conducted between February 202`and August 2021, after obtaining the institutional ethical committee approval no. (GCSMC/EC/Projects/APPROVED/2020/136, dated on October 02, 2020) and registering the study with the Clinical Trials

*Correspondence: divya.kheskani@gmail.com

[1] Department of Anaesthesiology, GCS Medical College Hospital and Research Centre, Address 25 Balgayatri Society Part 1, Opp. Gokul Row House, Shyamal, Satellite, Ahmedabad, Gujarat 380015, India
Full list of author information is available at the end of the article

Springer Open

© The Author(s) 2022. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

Registry of India (CTRI/2021/07/035116). For sample size determination, the purposive (convenient) sampling size determination technique was applied. After written informed consent, this study included 100 patients of the American Society of Anesthesiologists grade I/II, aged 20–60 years, weighing 40–75 kg, posted for elective operative procedures of a duration of 30 min to 3 h. The patients with the American Society of Anesthesiologists (ASA) 3 and 4, consent refusal, psychiatric illness, language barrier, pregnancy or known allergy to propofol or its emulsion, patients on regular sedatives or narcotic medications, and emergency surgeries were excluded from the study.

To account for the potential dropout and losses to follow-up of a few cases, we recruited a higher number of patients in our study as per the consort statement 2010 (Fig. 1). They were randomized by a computer-generated randomization method in two groups.

Each group consists of 50 patients:

Group BIS: BIS monitoring with propofol titrated to achieve BIS 40 to 60

Group non-BIS: without BIS monitoring, propofol dosage according to lean body weight (2mg/kg) IV

A detailed pre-anesthetic check-up was done, and written and informed consent was taken. The patients were kept Nil by mouth 8 h prior to surgery. On the day of surgery, in the preoperative room, all patients were monitored to record the baseline parameters with an electrocardiograph, non-invasive blood pressure, end-tidal carbon dioxide ($ETCO_2$), and pulse oximetry. The patients were preloaded with 500 ml of IV Ringer lactate after securing an 18-G peripheral intravenous (IV) line. Each patient was shown a color picture on paper to aid an easy postoperative recall.

On shifting to operation theater multi-paramonitoring, electrocardiograph (ECG), non-invasive blood pressure, $ETCO_2$, and pulse oximeter were recorded.

In the group BIS, the BIS monitor with Quadro sensor was applied to the patient's forehead. This sensor enabled the continuous recording of electroencephalogram (EEG) from induction of anesthesia up to awake

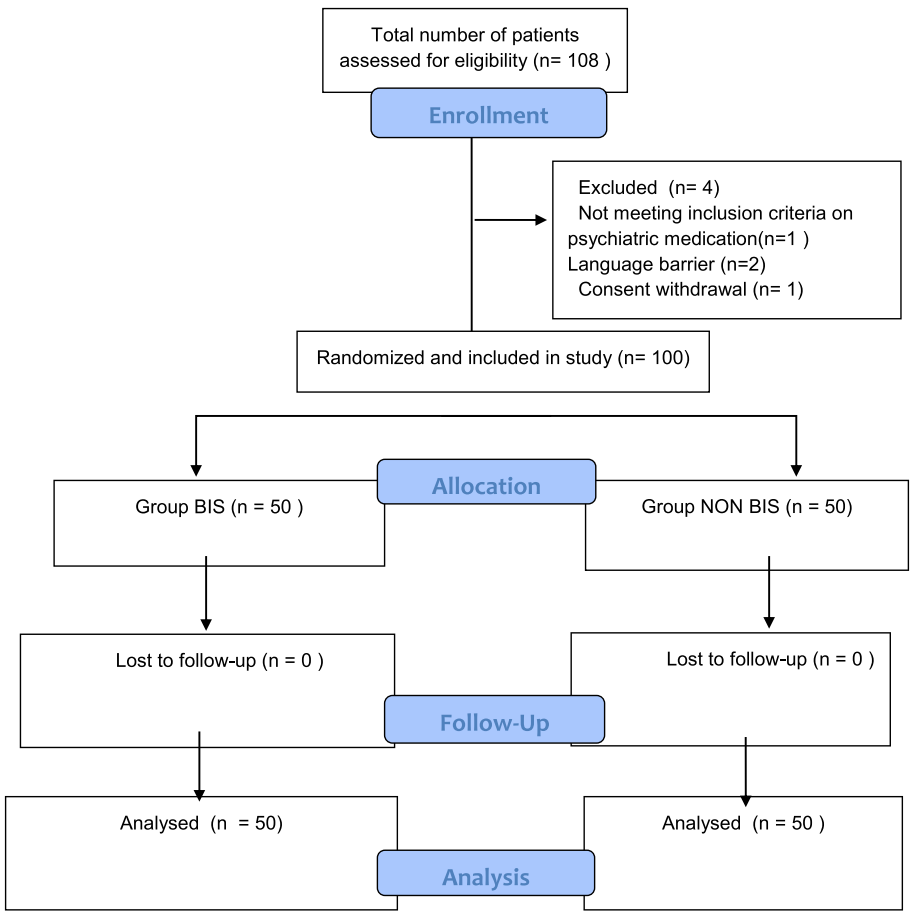

Fig. 1 Consort statement 2010

state at the conclusion of surgery. Patients were pre-oxygenated with 100% oxygen for 3 min.

Premedication was done with injection glycopyrrolate of 0.004mg/kg IV, injection ondansetron of 0.1mg/kg IV, injection midazolam of 1mg IV, and injection fentanyl of 2mcg/kg IV given slowly.

Induction proceeded with IV propofol according to group distribution. The trachea was intubated with an appropriate-sized adult cuffed endotracheal tube after muscle paralysis achieved by IV succinylcholine of 2mg/kg.

The placement of the endotracheal tube was confirmed with clinical auscultation and $ETCO_2$, and the anesthesia was maintained with 50% O_2 + 50% N_2O + sevoflurane (2–3%) + loading dose of atracurium of 0.5mg/kg IV followed by incremental doses of 0.1mg/kg IV along with subsequent propofol infusion (dosage as per group).

> Group BIS: propofol infusion to maintain BIS of 40 to 60 throughout the surgery
> Group non-BIS: standard propofol infusion dosage of 4–6 μg/kg/h IV

Intraoperatively, the maintenance and deficit fluid were administered with an IV ringer lactate solution. Hemodynamic monitoring was recorded such as pulse, mean arterial pressure (MAP), SPO_2 at regular intervals—baseline, at induction, 5 min, 10 min, 15 min, and then every 30 min until the end of surgery. Parallel to group BIS, the BIS data was recorded and correlated in accordance with its graphical wave representation.

Prior to the closure stage of surgery, propofol infusion was gradually tapered in both groups, and in the last 15 min, BIS was targeted between 60 and 70: reversed with injection glycopyrolate (0.008mg/kg) IV + injection neostigmine (0.05 mg/kg) IV and extubation done on regaining of consciousness, reflexes, and response to verbal command.

In both groups, total propofol consumption (loading and maintenance) was studied and calculated. Picture recall was tested, and the patients were assessed by following verbal commands and eye-opening upon arrival in post-anesthesia care unit.

The patients of both groups were asked with a modified form of the BRICE Questionnaire immediately after extubation, after 2 h in postoperative recovery, and before the patient was transferred to the ward.

The modified form of the BRICE questionnaire included the following questions:

Sr.No	Questions	Ans. Yes/No
1.	Did you remember anything before you became unconscious?	
2.	Did you remember anything in between the surgery?	
3.	Did you remember anything after the completion of your surgery?	
4.	Did you recall any scary or unusual event that happened during the operation?	
5.	Did you experience any imaginary things during your operation?	

All patients were asked the above questions, interpreted according to the coding system, and described in the percentage system. The data was entered into a structured proforma and was analyzed.

We used SPSS Trial version 26 for all statistical analyses. Categorical variables were expressed as the percentage while continuous variables were expressed as the mean and standard deviation. The independent sample *t* test was used to compare the continuous variables while chi-squared test was used for comparing categorical variables. A p value of <0.05 was considered significant.

Results

A total of 100 patients posted for surgery under general anesthesia were included with an equal number of patients distributed randomly by a computerized method in both groups.

Demographic data such as age, height, weight, sex, ASA, and duration of surgery were noted. There was no significant difference in any demographic variables between the two groups (p value >0.05).

The propofol consumption was studied in both groups of patients. The total propofol consumption was remarkably reduced in group BIS 8.25± 1.7mg/kg/h and group non-BIS—11.15±2.5mg/kg/h and on the application of ANOVA test, and the p value<0.0001 is found to be highly significant.

Hemodynamic variables were recorded in both groups, and graphs were plotted the same. The heart rate and mean arterial pressure remained more stable in group BIS as compared to the non-BIS group (Figs. 2 and 3).

The percentage of awareness in the postoperative period in the BIS group was 2% and in the non-BIS group was 8% (Fig. 4).

Discussion

This prospective, randomized comparative study was conducted using the bispectral index, a dimensionless number from 0 (isoelectric) to 100 (awake) where 80 reflects

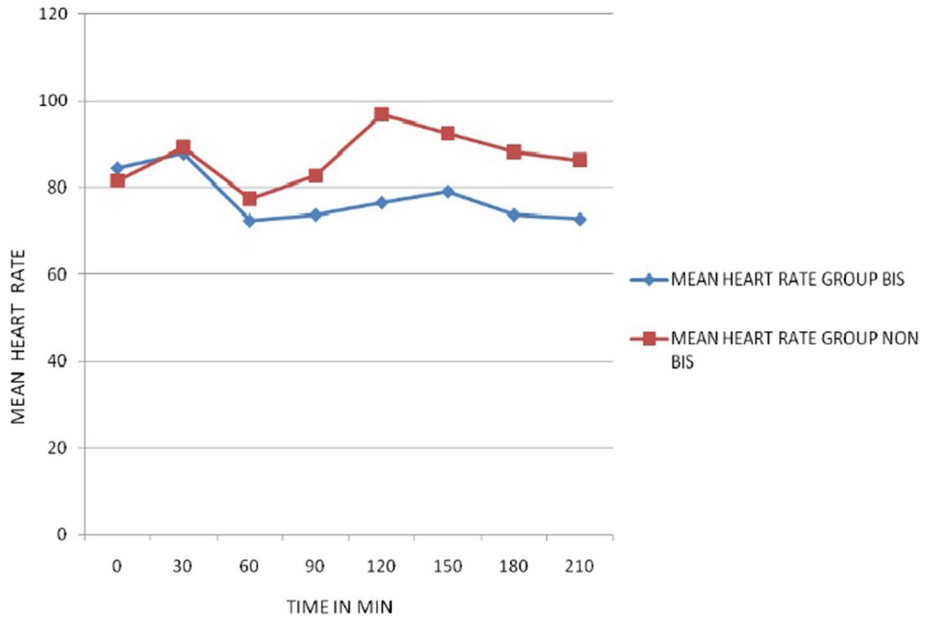

Fig. 2 Heart rate in both groups

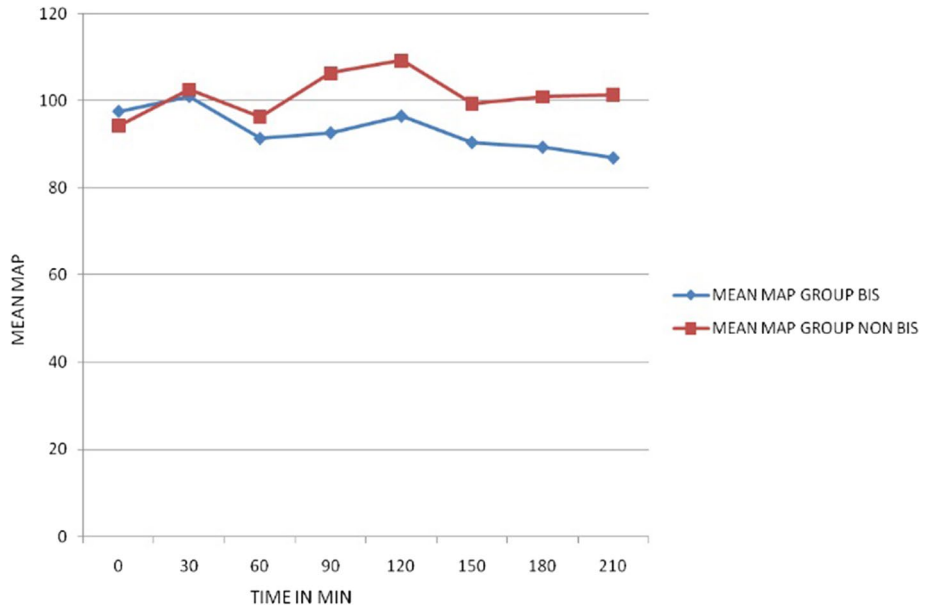

Fig. 3 Mean arterial pressure (MAP) in both groups

some sedation and 40 to 60 adequate depth of anesthesia with reasonable rapid recovery (Arya et al., 2013).

Awareness under anesthesia is an unintended intraoperative distressing complication during general anesthesia and can occur due to various reasons. This awareness has the potential for long-term psychological consequences; hence, every effort of utilizing modern technology has been put into clinical practice with a titrated dosage of drugs to prevent it (Samuelsson et al., 2007).

BIS monitoring system is the depth of anesthesia-monitoring device that was introduced in 1992. It works on the principle of providing continuous single variable

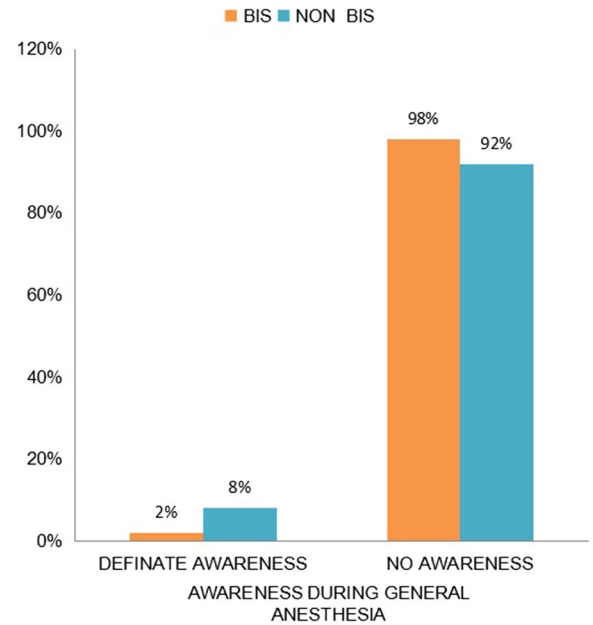

Fig. 4 Awareness during general anesthesia

Table 1 Demographic variables

Demographic variables	Group BIS	Group non-BIS	*P* value
Age (years)	39±11.25	38±11.63	0.66
Height (CM)	161±12.63	159±11.55	0.4106
Weight (kg)	61.5±11.47	62±9.30	0.8113
Gender (M/F)	30/20	27/23	--
ASA 1:2	32/18	29/21	--
Duration of surgery (MIN)	180±20	175±19	0.203

Data expressed as mean ± SD

data on display by integrating processed several EEG discrepancies at various stages of anesthesia by applying QUADRO SENSOR on the patient's forehead (Parikh, 2012).

Nowadays, BIS has been used in routine clinical practices to achieve adequate depth of anesthesia, and thus, its preference is increasing to obtain remarkable recovery by using a required titrated dosage of drugs.

This leads to reduced propofol consumption, prompt smooth recovery with an adequate depth of anesthesia, and smooth outcome for patients.

In our study, in both groups BIS and non-BIS, there was no significant difference with respect to demographic variables such as age, height, weight, gender, ASA physical status, and duration of surgery (Table 1).

In the group of BIS patients where propofol was titrated as per the BIS target, the induction dose of propofol was 1.75 ± 0.15 mg/kg and the maintenance dose was 5.50 ± 1.5 mg/kg/h. While the propofol

Table 2 Propofol consumption

Dose	Group BIS	Group non-BIS	*P* value
Induction (mg/kg)	1.75±.15	2.15±0.15	<0.0001
Maintainance (mg/kg/h)	5.50±1.5	9.0±1.8	<0.0001
Total	8.25±1.7	11.15±2.5	<0.0001

Data expressed as mean ± SD

dosage in the non-BIS group was according to the standard propofol dose of 2.15 ± 0.15 mg/kg and the maintenance infusion dosage was 9.0 ± 1.8mg/kg/h. The p value is <0.0001 for both loading dose and maintenance dose. This reflected a highly significant difference among them.

Thus, the total propofol consumption in the BIS group was reduced to 8.25 ± 1.7 as compared to the non-BIS group value where the total propofol required was 11.15 ± 2.5mg/kg with a p value <0.0001, a highly statistically significant (Table 2).

Parikh and Mehta's study entitled "Utility of BIS index for titration of propofol dosage and recovery from anesthesia" revealed observations similar to ours where they observed a total propofol consumption in the BIS group of 7.28 ± 1.38 versus 10.86 ± 2.03 mg/kg in the non-BIS group which is reduced with an early recovery in the group of BIS patients (Parikh, 2012).

Their observations had similar results to the study of Masula et al. research entitled "BIS monitoring is useful to reduce the total amount of propofol and to obtain immediate recovery after propofol anesthesia" who studied 46 pts and concluded that propofol required was decreased significantly in the BIS group of 709 ± 210 mg compared to the control group of 914 ± 326 mg with a p< 0.05 (Masuda et al., 2002).

Other eminent researchers ELerkMarnRk and Myus also had similar observations and henceforth strengthen our results (Ellerkmann et al., 2006; Myles et al., 2004)

Thus, it is stated that clinical utility trials showed that the BIS has the potential to be used as an index to measure the pharmacodynamic effect of propofol and facilitate its titration of dosage which allows improved recovery from anesthesia.

In our study, we monitored hemodynamic parameters; the mean heart rate (HR) and mean arterial pressure (MAP) at various time intervals were observed and variations were seen. The patients of both groups remained hemodynamically stable throughout.

However, the HR and MAP of patients in the BIS group showed fewer fluctuations as compared to the non-BIS groups (Figs 2 and 3).

The HR and BP increased immediately after intubation in both groups, and this increase was more evident in the non-BIS group. The reason for fewer fluctuations in hemodynamic variables in BIS could be due to the titrated dosage of drugs given according to BIS values during the perioperative period.

These results suggest that BIS monitoring aids to stabilize hemodynamic parameters during induction of anesthesia with titrated propofol dosage as compared to a routine dosage regimen.

Biswal in his study "Evaluation of the effect of BIS monitoring in patients undergoing Renal Transplant" included 30 adults and concluded that the hemodynamic parameter variability was lesser in the BIS group compared to the control group. These results were in accordance with our study results (Biswal et al., 2017).

In our study, we found that 98% of patients in the BIS group and 92% of patients in the non-BIS group showed no awareness while 2% of patients in the BIS group and 8% of patients in the non-BIS group reported awareness postoperatively when interviewed by a modified form of BRICE questionnaire at various time intervals (Fig. 4).

Ambulkar in her study among the Indian population revealed the incidence of awareness to be <0.33% and mentioned that the reason for such decreased incidence of awareness would be that the patients received inhalation-based balanced anesthesia and respiratory gas monitoring with ETAC (end-tidal anesthetic agent concentration) measurement that led to dose accuracy for adequate depth of anesthesia (Ambulkar et al., 2016).

Norton et al. in their research on "Intra-operative awareness detected using BRICE interview in European Journal Of anaesthesia" included 118 patients and interviewed them with a BRICE questionnaire post-anesthesia; a total of 8 patients answers proved awareness and dreams during general anesthesia. This would account near to 9% on approximation, remarkably similar to ours (Norton et al., 2013).

Avidan et al. conducted a randomized control trial and implemented the modified BRICE questionnaire in 967 BIS-monitored patients, and 6 patients among them reported awareness (Avidan et al., 2008).

On the other hand, Myles et al. in 2004 included 1225 patients in the BIS group and only 2 patients had a recall of events (Myles & Cairo, 2004).

Conclusions

In a nutshell, BIS monitoring-guided anesthesia prevents intraoperative awareness and judiciously aids in the titration of induction and maintenance of propofol dosage, facilitating early emergence with hemodynamic stability.

Abbreviations

BIS: Bispectral index; $ETCO_2$: End-tidal carbon dioxide; ECG: Electrocardiograph; EEG: Electroencephalogram.

Acknowledgements

Dr. Viral Dave, Professor, Department of Community Medicine, for preparing the database and doing the statistical analysis.

Authors' contributions

HC: conceptual and design, along with an intellectual content and manuscript review. DK: literature research, clinical evaluation, and manuscript writing. PK: data collection, analysis, and manuscript editing. MS: data acquisition. DM: data acquisition and analysis. VR: statistical analysis and table preparation. The authors read and approved the final manuscript.

Funding

Not applicable

Availability of data and materials

Duely provided and made available by the institute

Declarations

Ethics approval and consent to participate

Presentation at a meeting: Institutional Ethics Committee: Organisation GCS Medical College, Hospital and Research Centre, Ahmedabad Place GCS Medical College, Hospital and Research Centre, Ahmedabad. Date 10/02/2020. GCSMC/EC/Projects/APPROVED/2020/136. CTRI registration No. CTRI/2021/07/035116. Written informed consent was obtained.

Consent for publication

Written and informed consent from participants was taken.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Anaesthesiology, GCS Medical College Hospital and Research Centre, Address 25 Balgayatri Society Part 1, Opp. Gokul Row House, Shyamal, Satellite, Ahmedabad, Gujarat 380015, India. [2]Department of Community Medicine, GCS Medical College Hospital and Research Centre, Ahmedabad, Gujarat, India.

Received: 24 December 2021 Accepted: 23 September 2022
Published online: 15 October 2022

References

Ambulkar RP, Agarwal V, Ranganathan P, Divatia JV (2016) Awareness during general anesthesia: an Indian viewpoint. J Anaesthesiol Clin Pharmacol 32(4):453–457. https://doi.org/10.4103/0970-9185.173363 PMID: 28096574; PMCID: PMC5187608

Arya S, Asthana V, Sharma JP (2013) Clinical vs. bispectral index-guided propofol induction of anesthesia: A comparative study. Saudi J Anaesth 7(1):75–79. https://doi.org/10.4103/1658-354X.109819 PMID: 23717237; PMCID: PMC3657931

Avidan MS, Zhang L, Burnside BA et al (2008) Anesthesia awareness and the bispectral. Anesthesia Awareness Bispectral 358:1097–1108

Bhargava AK, Setlur R, Sreevastava D (2004) Correlation of bispectral index and Guedel's stages of ether anesthesia. Anesth Analg. 98(1):132–134. https://doi.org/10.1213/01.ANE.0000090740.32274.72 PMID: 14693605

Biswal D, Mohanty BB, Sahoo T, Muduli SR (2017) Evaluation of the effect of BIS monitoring in patients undergoing renal transplant. Ann. Int. Med. Den. Res. 3:AN32–AN36

Ellerkmann RK, Kreuer S, Wilhelm W, Röpcke H, Hoeft A, Bruhn J (2006) Reduction in anaesthetic drug consumption is correlated with mean titrated intra-operative bispectral Index values. Acta Anaesthesiol Scand. 50(10):1244–1249. https://doi.org/10.1111/j.1399-6576.2006.01146.x PMID: 17067324

Liu WH, Thorp TA, Graham SG, Aitkenhead AR (1991) Incidence of awareness with recall during general anaesthesia. Anaesthesia. 46(6):435–437. https://doi.org/10.1111/j.1365-2044.1991.tb11677.x PMID: 2048657
Masuda T, Yamada H, Takada K, Sagata Y, Yamaguchi M, Tomiyama Y et al (2002) Bispectral index monitoring is useful to reduce total amount of propofol and to obtain immediate recovery after propofol anesthesia. Masui 51:394–399
Myles PS, Cairo S (2004) Artifact in the bispectral index in a patient with severe ischemic brain injury. Anesth Analg 98(3):706–707. https://doi.org/10.1213/01.ane.0000099360.49186.6b PMID: 14980924
Myles PS, Leslie K, McNeil J, Forbes A, Chan MT (2004) Bispectral index monitoring to prevent awareness during anaesthesia: the B-Aware randomised controlled trial. Lancet. 363(9423):1757–1763. https://doi.org/10.1016/S0140-6736(04)16300-9 PMID: 15172773
Norton M, Antunes MJ, Cruz S, Sousa G, Abelha F et al (2013) Intraoperative awareness detected using Brice interview, 17AP3-5. Eur J Anaesthesiol 30:240
Parikh H (2012) Mehta M The utility of bispectral index for titration of propofol dosages and recovery from anaesthesia. Natl J Med Res. 2:484–487
Rani DD, Harsoor S (2012) Depth of general anaesthesia monitors. Indian J Anaesth. 56(5):437–441. https://doi.org/10.4103/0019-5049.103956 PMID: 23293381; PMCID: PMC3530997
Samuelsson P, Brudin L, Sandin RH (2007) Late psychological symptoms after awareness among consecutively included surgical patients. Anesthesiology. 106(1):26–32. https://doi.org/10.1097/00000542-200701000-00009 PMID: 17197842
Sebel PS, Bowdle TA, Ghoneim MM, Rampil IJ, Padilla RE, Gan TJ, Domino KB (2004) The incidence of awareness during anesthesia: a multicenter United States study. Anesth Analg. 99(3):833–839. https://doi.org/10.1213/01.ANE.0000130261.90896.6C PMID: 15333419

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Submit your manuscript to a SpringerOpen journal and benefit from:

- ► Convenient online submission
- ► Rigorous peer review
- ► Open access: articles freely available online
- ► High visibility within the field
- ► Retaining the copyright to your article

Submit your next manuscript at ► springeropen.com