Original article

Evaluation of minimum alveolar concentration of sevoflurane and bispectral index for maintenance of central eye position during short ophthalmic procedures under general anaesthesia: an observational study.

Renu Sinha[1], Ankur Sharma[2], Ghansham Biyani[3], Riddhi Kundu[4], Kanil Ranjith Kumar[5], Chandralekha[6], Anjan Trikha[7], Rajesh Sinha[8]

[1]Prof. Dept. of Anaesthesiology, Pain Medicine & Critical Care, A.I.I.M.S, New Delhi.
[2]Add. Prof. Dept. of Anaesthesiology & Critical Care, A.I.I.M.S, Jodhpur
[3]Add. Prof. Dept. of Anaesthesiology, Pain Medicine & Critical Care, A.I.I.M.S, Mangalagiri
[4]Senior Consultant, Critical Care Medicine, Ruby Hall Clinic, Pune
[5]Add. Prof. Dept. of Anaesthesiology, Pain Medicine & Critical Care, A.I.I.M.S, Delhi.
[6]Ex-Professor, Dept of Anaesthesiology, Pain Medicine & Critical Care, A.I.I.M.S. New Delhi.
[7]Prof. Dept of Anesthesiology and Perioperative Medicine Penn State College of Medicine, Penn State Health Milton S. Hershey Medical Center, Hershey, PA 17033
[8]Prof. Dept. of Ophthalmology, Dr R. P. Centre, A.I.I.M.S. New Delhi.

Abstract

Background: Central eye position during ophthalmic procedures under general anaesthesia depends on the depth of anaesthesia. This study aimed to determine the optimal depth of sevoflurane anaesthesia required to maintain a centralized eye position during short ophthalmic procedures in children.

Methods: Study included one hundred children aged between 1-8 years who underwent short ophthalmic procedures under general anaesthesia. After induction of general anesthesia with 100% oxygen with sevoflurane, bispectral index (BIS) sensors were applied to the child's forehead. Intravenous cannulation and insertion of classic laryngeal mask airway was attempted after achieving adequate depth of anaesthesia. Sevoflurane dial concentrations were modified according to the eye movement by the experienced anesthesiologist. Parameters like eye position, BIS, MAC, inspired and expired sevoflurane concentration (FiSevo, EtSevo) were recorded.

Address for correspondence:
Dr Ankur Sharma,
Additional Professor,
Department of Anaesthesiology & Critical Care,
A.I.I.M.S, Jodhpur,
INDIA
Email: ankuranaesthesia@gmail.com

Article History
Received: 31st Oct 2023
Revision: 3rd Nov 2023
Accepted: 8th Jan 2024
Published: 24th Jan 2024

How to cite this article: Renu Sinha, Ankur Sharma, Ghansham Biyani, Riddhi Kundu, Kanil Ranjith Kumar, Chandralekha, Anjan Trikha, Rajesh Sinha. Evaluation of minimum alveolar concentration of sevoflurane and bispectral index for maintenance of central eye position during short ophthalmic procedure under general anaesthesia: an observational study. Indian J Ophthal Anaesth 2024;4(1):5-14

Results: Total 100 children's datas were analysed. Central eye position was maintained at mean± SD BIS and MAC of 41.67±0.40 [95%CI (40.88-42.47)] and 1.68±0.01 [95%CI (1.65-1.70)] respectively. Up rolled eye position was seen at mean (SD) BIS 44.1±0.67 [95%CI (42.78-45.43)] and MAC of 1.87±0.03 [95%CI (1.80-1.93)]. Down rolled eye position was observed at mean±SD BIS 38.4±1.3 [95% CI (35.92-40.89)] and MAC of 1.9±0.04 [95%CI (1.83-1.97)]. EtSevo corresponding to a centrally located, up rolled and down rolled eyeball were 3.45±0.02 [95% CI= 3.34-3.49], 3.82±0.06 [95% CI= 3.69-3.94] and 3.87±0.08 [95% CI=3.72-4.02] respectively.

Conclusion: BIS values between 40-43 may maintain central eye position during short ophthalmic procedures under general anaesthesia in children. Sevoflurane MAC, EtSevo and FiSevo are not good predictor to judge up rolled and down rolled eye position.

Keywords: BIS, MAC, eye position, children, sevoflurane

Introduction

Ophthalmic examinations in children are routinely performed under general anaesthesia. Maintenance of central eye position during ophthalmic examination is a prerequisite for optimal visualization of the ocular area and precise measurement of ocular parameters.[1] Any deviation of the eyeball from the central position during the procedure also increases the risk of inadvertent ocular injury.

Muscle relaxant administration can decrease the chances of eyeball deviation during ophthalmic procedure. However, it will increase the duration of anaesthesia and recovery time. Spontaneous ventilation during short ocular procedures under general anaesthesia shortens recovery time and enhances the quality of postoperative recovery.

The position of the eye during induction and maintenance phase of anaesthesia is related to the depth of anaesthesia. Depth of anaesthesia can be measured objectively with the bispectral index (BIS), which relies on bispectral analysis of electroencephalography and ranges from 100 (fully awake) to 0 (isoelectric EEG).[1] Studies have found an inverse correlation between end-tidal sevoflurane concentration (Et_{Sev}) and BIS values after adequate time for equilibration.[2–5] To the best of our knowledge, there has been no study which objectively measured the optimal anaesthetic depth [with minimum alveolar concentration (MAC) and BIS] required for maintaining centralized and motionless eye position during sevoflurane anaesthesia without the use of muscle relaxants.

Therefore, we planned this study to determine the optimal depth of sevoflurane anaesthesia required to maintain a centralized eye position during ophthalmic examination in children. The primary outcome of the study was to evaluate the anaesthetic depth with sevoflurane MAC and BIS requirement to maintain central eye position during short ophthalmic procedures in children under general anaesthesia.

The secondary outcome of the study was to evaluate the correlation between MAC of sevoflurane and BIS to maintain central eye position during short ophthalmic procedures.

Methods

This prospective observational study was conducted in the operation theatre of a tertiary care hospital. After receiving institutional ethical committee approval (Ref No.: IEC/NP-318/2013 RP-09), informed written consent was obtained from the parents of the children to participate in the study. One hundred children, aged 1-8 years, with American Society of Anaesthesiologists (ASA) physical status I & II posted for short ophthalmic procedures under general anaesthesia were included in the study. All the children underwent pre-anaesthetic check-up for evaluation of any systemic illness, recent upper respiratory tract infection. Any significant family history was noted. Patients with significant eye deviation, need for eye intervention, known cardiovascular, neurological, pulmonary or genetic disorder, anticipated difficult airway, known allergy to proparacaine and parent refusal were excluded from the study.

In our institute, ophthalmic examinations and short procedures are routinely performed under general anaesthesia with maintenance of spontaneous ventilation due to high turnover rate. Standard fasting guidelines were followed and no pharmacological premedication was administered to any of the participants.

A single anaesthesiologist, who had more than ten years of experience provided anaesthesia for ophthalmic examinations and short procedures. This anaesthesiologist was blinded to BIS values and inspired sevoflurane concentration (Fi_{Sev}) to maintain central eye position and clinically observed for any signs of awakening. BIS monitor was kept in a position so that attending anaesthesiologist was not able to look on the monitor screen. Vaporiser dial was covered with gloves and Fi_{Sev}/Et_{Sev}, MAC values on the multipara monitor were also kept away from the attending anaesthesiologist. The rest of the study parameters [any body movement, eye position, Fi_{Sev}/Et_{Sev}, MAC, BIS, respiratory rate, tidal volume, end-tidal carbon dioxide (etCO2)] were noted by a second anaesthesiologist who was not involved in any intervention during the procedure.

After application of standard monitoring [ECG leads, pulse oximeter and non-invasive blood pressure (NIBP)], anaesthesia was induced with 100% O_2 at a fresh gas flow rate (FGF) of 4 litres min^{-1} with sevoflurane at 8% dial setting via facemask through closed circle breathing system. Starting time (T_0) was measured from the time of face mask application on the child's face. Once the child was calm with the loss of eyelash reflex BIS leads were applied on the forehead. The dial concentration of sevoflurane was then reduced to a 5%, attempting to maintain spontaneous ventilation. Breath-by-breath Fi_{Sev}/Et_{Sev}, MAC, and $etCO_2$ values were measured with a multi-gas analyzer (Datex-ohmeda-S/5™ critical care monitor).

BIS (IntelliVue patient monitor) were monitored with the 4 sensor paediatric sensor (Aspect Medical System International, Mansfield, MA, USA).

On achieving adequate depth of anaesthesia (regular respiration, adequate tidal volume, jaw relaxation), an intravenous line was secured. At the time of intravenous cannula insertion, any body movement, eye position, Fi_{Sev}/Et_{Sev}, MAC, BIS and a number of attempts were noted (T_{IV}). Proparacaine 0.5% was instilled in the eye and an eye speculum was placed. After reassessing adequate depth of anaesthesia (regular respiration, adequate tidal volume, no response to jaw thrust), an appropriate size classic laryngeal mask airway (LMA) was inserted, and any body movement, eye position, Fi_{Sev}/Et_{Sev}, MAC and BIS values were noted (T_{LMA}). If LMA was not placed properly at the first attempt, then it was removed and reinserted after achieving adequate depth of anaesthesia, and the number of attempts for LMA insertion was noted. FGF was reduced to 2 litres min^{-1}; anaesthesia was subsequently maintained with O_2, air (FiO_2-0.5) and sevoflurane. In case of any eye or body movement during the examination, the depth of the anaesthesia was increased by increasing the inspired sevoflurane concentration. If movements persisted, rescue propofol (0.5 mg kg^{-1}) was administered intravenously. Any deviation of the eyeball from its central position (up rolling or down rolling) was managed by titrating the Fi_{Sev} and MAC. Ventilation was assisted in case of hypoventilation [hypercapnia ($EtCO_2$ >45 mm Hg) or tidal volume <4ml/kg].

The etCO2, MAC, FiSev, EtSev, BIS and clinical monitoring of respiratory rate, depth and tidal volume were noted at 1-minute intervals from the time of LMA insertion till the end of the procedure. At the end of the procedure, eye speculum was removed, sevoflurane was switched off and 100% O2 was administered. LMA was removed once the child was fully awake.

Statistical Analysis

The sample size was calculated using StatsToDo (http:// www.statstodo.com), an open-source calculator. In the absence of any previous literature studying the MAC and BIS values required to maintain a central eye position, we did a pilot study of 10 cases. We found that (mean ± SD) MAC and BIS required to maintain a centralised eye position in those 10 cases were 1.72 ± 0.41 and 35.9 ± 7.4 respectively. Assuming a precision of 5% relative to the mean and a confidence interval of 95%, we found that a sample size of 89 is required to detect the optimal MAC, 65 to study BIS and 82 to study the correlation between MAC and BIS to maintain centralized eye position. So, we recruited 100 patients for the present study with an added safety margin of 10%.

Statistical analyses were performed using STATA14 software. Statistically appropriate tests were applied analyzing the data. The results are expressed as the mean + SD or percentage. Correlation of different eye position was analysed by one way ANOVA followed by post hoc comparison by Bonferrani test. Karl pearson correlation coefficient was used for analysis.

Results

Initially, 115 children were enrolled in this study. Out of these, 11 did not meet inclusion criteria, two declined to participate, and BIS reading was not recorded in two children due to malfunctioning the BIS monitor. Finally, one hundred children were included in this research (Figure 1).

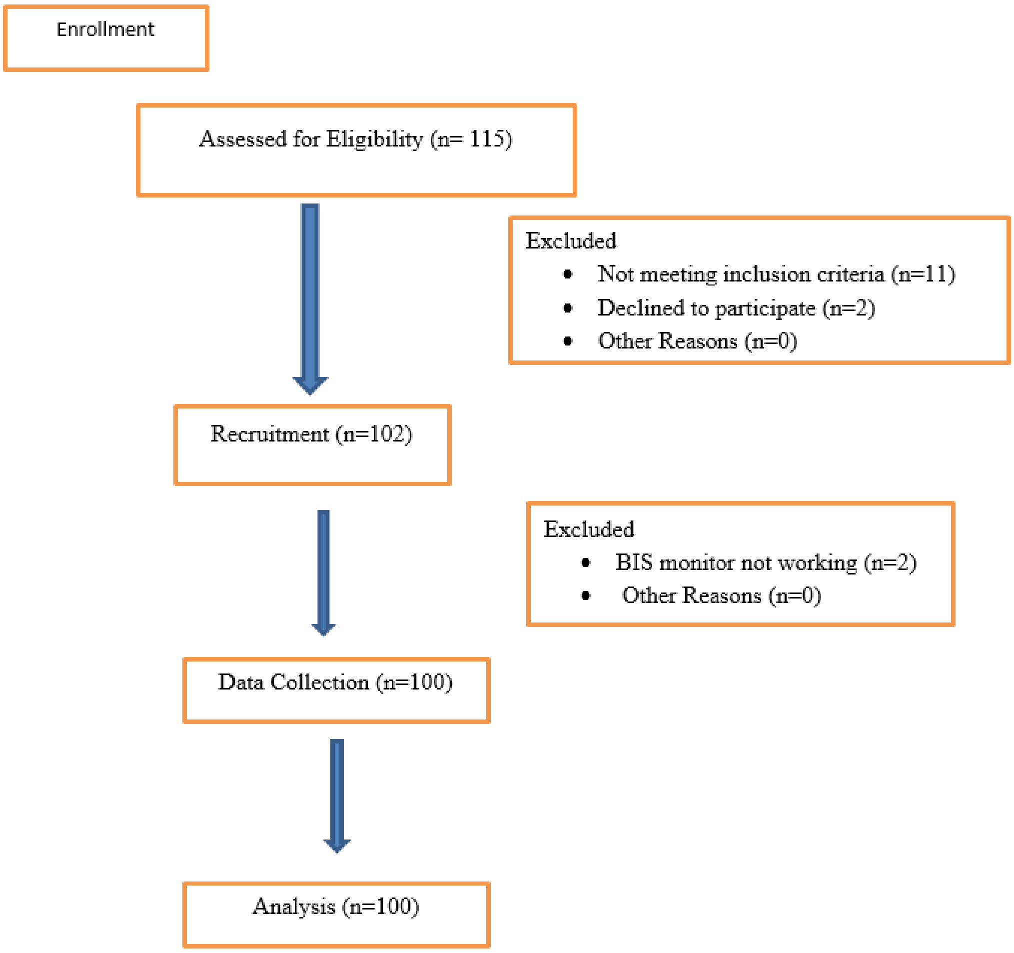

Figure 1: Flow of patients through the study

The demographic parameters of the children included in the study are shown in Table 1.

Table 1: Demographic parameters of the study population

Variables	Mean+SD
Age (yrs)	3.78+2.3
Sex (M/F)	60/37
Weight (kgs)	12.75+4.11
Duration of procedure (minutes)	10.41+3.72

The mean ± SD duration of the ophthalmic examination was 10.41 ± 3.72 minutes.

The mean ± SD of BIS and MAC values corresponding to a centrally located eyeball were 41.67 ± 0.40 [95% CI (40.88-42.47)] and 1.68 ± 0.01 [95% CI (1.65-1.70)] respectively. In patients with up rolling of the eyeball during examination, BIS and MAC values were 44.10 ± 0.67 [95% CI (42.78-45.43)] and 1.87 ± 0.03 [95% CI (1.80-1.93)]. Down rolling of the eyeball was observed at mean BIS of 38.41 ± 1.25 [95% CI (35.92-40.89)] and MAC values of 1.9 ±0.04 [95% CI (1.83-1.97)] (Table 2).

Table 2: Sevoflurane concentration, Bispectral Index and Eye position

	Eye position					
	Central		Up rolled		Down Rolled	
	Mean±SD	95% CI	Mean±SD	95% CI	Mean±SD	95% CI
BIS	41.67± 0.40	40.88-42.47	44.10±0.67	42.78-45.43	38.41±1.25	35.92-40.89
MAC	1.68± 0.01	1.65-1.70	1.87± 0.03	1.80-1.93	1.9± 0.04	1.83-1.97
FiSev	3.89± 0.03	3.83-3.95	4.35± 0.08	4.19-4.52	4.47±0.10	4.26-4.67
EtSev	3.45 ± 0.02	3.34-3.49	3.82± 0.06	3.69-3.94	3.87±0.08	3.72-4.02

Bispectral Index (BIS), minimum alveolar concentration (MAC), inspired sevoflurane concentration (FiSev), end-tidal sevoflurane concentration (EtSev)

End Tidal sevoflurane concentration [EtSevo] corresponding to a centrally located, uprolled and down rolled eyeball were 3.45 ± 0.02 [95% CI= 3.34-3.49], 3.82 ± 0.06 [95% CI= 3.69-3.94] and 3.87 ±0.08 [95% CI=3.72-4.02] respectively. Inspired Sevoflurane concentration [FiSevo] corresponding to a centrally located, uprolled and down rolled eyeball were 3.89 ± 0.03 [95% CI= 3.83-3.95], 4.35 ± 0.08 [95% CI= 4.19-4.52] and 4.47 ± 0.10 [95% CI=4.26-4.67] respectively (table 2).

Correlation of BIS and MAC at central, up rolled and down rolled eye position was -0.109, -0.217, 0.097 respectively (table 3).

Ten children had movement at the time of intravenous cannulation, and six children had movement during LMA insertion. In one child, movement was seen both at intravenous cannulation and LMA insertion. There were no body movements during the ophthalmic examination in any children. However, two children required propofol bolus due to ocular deviation interfering with the ophthalmic procedure despite changing the sevoflurane concentration. Five children required assisted pressure support ventilation due to inadequate tidal volumes and hypercapnia. One patient had ocular deviation towards the right side instead of an up or down roll. No other significant complications occurred in any of the children.

Table 3: Correlation of BIS, sevoflurane MAC and Eye Position

Eye position	BIS	MAC	Correlation
Central	41.67	1.68	-0.1092
Uprolled	44.10	1.87	-0.2171
Downrolled	38.41	1.9	0.0975

Bispectral Index (BIS), minimum alveolar concentration (MAC)

Discussion

Maintenance of centralized eye position without muscle relaxation during ophthalmic examination is a significant challenge for the anesthesiologist. Deviation of the eye increases the surgeon's difficulty by reducing the space required for instrumentation. This also increases the chances of inadvertent ocular injury and can lead to improper ocular measurements. While eccentric eye positions are well described under lighter planes of anaesthesia, an indiscriminate increase in the anaesthetic depth may lead to a down-rolled eye instead of solving the puzzle. The literature is silent regarding the optimal depth of anaesthesia to keep the eye centralized while avoiding the possibilities of awakening on one hand and hazards of over sedation on the other.

Our study included children between 1-8 years of age. Children under one year of age were excluded from our study as myelination is incomplete in this age group, resulting in poor predictability of EEG in measuring the depth of anaesthesia4. We also avoided premedication or any other anaesthetic agent that could have contributed to lowering the sevoflurane requirement and BIS values.

An independent anaesthesiologist titrated sevoflurane concentration attempting to maintain a centralized eye position and avoiding patient movement during the procedure. Sevoflurane is one of the most attractive agents for pediatric daycare procedures under anaesthesia due to its sweet smell, smooth induction characteristics, low blood-gas partition coefficient resulting in rapid induction and recovery, and comprehensive cardio-respiratory safety profile. Hence, it was administered during induction and maintenance of anaesthesia.

We chose an initial target EtSev concentration of 3.2% based on a previous study by Tsuruta et al, authors have reported that 95% of children aged 1-8 years had BIS values less than 50 with an EtSev concentration of 3.14%6. Unidirectional change in EtSev concentration is justified by the fact that any lowering of EtSev from its starting concentration of 3.2% could have resulted in awareness during the procedure, which is undesirable.

An anesthesiologist often faces difficulty in maintaining a centrally located eyeball during eye examination and procedures. Our study has a few interesting observations.

Moreover, up rolling of the eye were seen at lighter planes of anaesthesia led with higher mean BIS values of 44.10. The eye has been classically described to deviate eccentrically in extreme upward gaze under conditions of anaesthesia without the use of neuromuscular blockers.[6,7] This is in agreement with our study, in which lighter planes of anaesthesia led to an uprolled eyeball that shifted downwards with a deepening of anaesthetic depth. Therefore, it can be expected that children in our study had adequate depths of anaesthesia to prevent awareness throughout the procedure.

In the present study, centralized eye position was observed at mean MAC of 1.68. Eye was at uprolled and downrolled position at mean MAC of 1.87 and 1.9 respectively. Similarly, mean Et_{Sevo} for central, uprolled, downrolled eye position was 3.45, 3.82 and 3.87 respectively. These observations suggest that with MAC and Et_{Sevo} values, prediction of uproll & downrolled eye position is difficult, however centralized eye position was seen at lower MAC and Et_{Sevo} values.

The use of muscle relaxants can provide an immobile surgical field and with ease of procedure. However, daycare ophthalmic examinations under anaesthesia are short-duration procedures lasting 10-15 minutes with a high turnover rate in our institute. Unwarranted use of muscle relaxants can delay patient recovery and increase the chances of residual weakness. Anaesthesia without the use of muscle relaxants is therefore preferred for such procedures.

Based on the BIS findings of the present study, an up rolled eyeball indicates a lighter plane of anaesthesia and may benefit from an increase in anaesthetic depth by increasing the FiSev concentration. On the other hand, a down-rolled eyeball indicates deeper level of anaesthesia and will benefit from slight decrease in depth of anaesthesia by decreasing FiSev concentration. Alternatively, if alteration of anaesthetic depth by change in FiSev failed to centralize the eyeball; rescue propofol bolus can be administered as was done in two children in our study. However, supplementation of propofol to deepen the anaesthetic depth may lead to apnea, delay in postoperative recovery which may increase anaesthesia duration and turnover time for short procedures. Other agents like dexmedetomidine, opioids, and regional blocks have also been described in the literature as adjuncts to keep the eye centralized.8 Opioids and dexmedetomidine also increased anaesthesia duration due to the prolonged sedation. Regional blocks are not the choice for small procedures which have minimal pain.

Our study showed a poor correlation between EtSev concentrations and BIS values at predetermined time points. However, in short-duration procedures with high gas flow rates and rapid fluctuations in FiSev/EtSev concentration as in our study; BIS may be more reliable indicator of anaesthetic depth than EtSev concentrations9. The effect of cerebral anaesthetic partial pressure of inhalational agent on EEG measured objectively by BIS may be a better guide to adequate sedation than EtSev concentration measured peripherally that is more prone to fluctuations unless allowed adequate times for equilibration.

The present study has a few limitations. Firstly, EtSev concentration and BIS were parameters to gauge anaesthetic depth. However, neither of these methods can predict, with certainty, the occurrence of accidental awareness under general anaesthesia (AAGA)10-12. Secondly, the initial target EtSev concentration was set at 3.2% and titrated incrementally. This can lead to missing cases, which could have a centrally located eyeball at a lower EtSev concentration. However, concerns about AAGA led us to adopt this approach.

Conclusion

In conclusion, maintaining a centralized eyeball during short ophthalmic procedures can be difficult. An optimal anaesthetic depth guided by BIS values between 40-43 may help to attain the goal. MAC of sevoflurane, ETSevo and FiSevo are poor predictors for eye position during maintenance of anaesthesia. We did not find correlation between MAC of sevoflurane and BIS to maintain central eye position during short ophthalmic procedures.

References

1. James I. Anesthesia for paediatric eye surgery. Contin Educ Anaesth Crit Care Pain 2008;8:5-10.
2. Rosow C, Manberg PJ: Bispectral index monitoring. Anesthesiol Clin North Am 1998;2:89-107.
3. Denman WT, Swanson EL, Rosow D et al. Pediatric evaluation of the bispectral index (BIS) monitor and correlation of BIS with end-tidal sevoflurane concentration in infants and children. Anesth Analg 2000; 90: 872–7.
4. Brosius KK, Bannister CF. Effect of oral midazolam premedication on the awakening concentration of sevoflurane, recovery times and bispectral index in children. Paediatr Anaesth 2001;11: 585–90.
5. Davidson AJ, McCann ME, Devavaram P et al. The differences in the bispectral index between infants and children during emergence from anesthesia after circumcision surgery. Anesth Analg 2001;93:326–30.
6. Tsuruta S, Satsumae T, Mizutani T, Inomata S, Shimizu T, Takahashi S, Tanaka M. Minimum alveolar concentrations of sevoflurane for maintaining bispectral index below 50 in children. Paediatr Anaesth. 2011;21:1124-7.
7. Mindel JS, Eisenkraft JB, Raab EL, Teutsch G. Succinyldicholine and the basic ocular deviation. Am J Ophthalmol 1983;95:315-26.
8. Rossiter JD, Wood M, Lockwood A, Lewis K. Operating conditions for ocular surgery under general anesthesia: An eccentric problem. Eye (Lond) 2006;20:55-8.
9. Ibrahim AE, Taraday JK, Kharasch ED. Bispectral index monitoring during sedation with sevoflurane, midazolam, and propofol. Anesthesiology 2001;95:1151–9.

10. Avidan MS, Jacobsohn E, Glick D, Burnside BA, Zhang L, Villafranca A, Karl L, Kamal S, Torres B, O'Connor M, Evers AS, Gradwohl S, Lin N, Palanca BJ, Mashour GA; BAG-RECALL Research Group. Prevention of intraoperative awareness in a high-risk surgical population. N Engl J Med. 2011;18;365(7):591-600.

11. Chhabra A, Subramaniam R, Srivastava A, Prabhakar H, Kalaivani M, Paranjape S. Spectral entropy monitoring for adults and children undergoing general anesthesia. Cochrane Database Syst Rev. 2016;14;(3):CD010135.

12. Shanks AM, Avidan MS, Kheterpal S, Tremper KK, Vandervest JC, Cavanaugh JM, Mashour GA. Alerting thresholds for the prevention of intraoperative awareness with explicit recall: a secondary analysis of the Michigan Awareness Control Study. Eur J Anesthesiol. 2015;32(5):346–53.