ELSEVIER

Ambulatory Surgery 9 (2002) 207–211

Ambulatory Surgery

www.elsevier.com/locate/ambsur

Sevoflurane requirements during ambulatory surgery: a clinical study of bispectral index and auditory evoked potential guided anaesthesia

Hamid Assare [a], Russell E. Anderson [c], Jan Jakobsson [b,*]

[a] *Departments of Orthopaedics, Sabbatsberg Hospital, S-113 24 Stockholm, Sweden*
[b] *Departments of Anaesthesja, Sabbatsberg Hospital, S-113 24 Stockholm, Sweden*
[c] *Department of Cardiothoracic Anaesthetics and Intensive Care, Karolinska Hospital, Stockholm, Sweden*

Received 17 November 2001; accepted 5 January 2002

Abstract

The bispectral index (BIS) is processed passively from the EEG, while the auditory evoked potential (AEP) response actively tests brain activity. In the present study 60 patients undergoing elective day surgery (knee arthroscopy) were randomised to titrate sevoflurane (with O_2:N_2O, 1:2) either clinically or in combination with either a target BIS-index of 60 ± 5 (20 patients) or AEP-index of 30 ± 5 (20 patients). Induction was with propofol and fentanyl (0.1 mg). The BIS- or AEP-index did not improve either sevoflurane consumption or emergence times. In minor ambulatory anaesthesia, without muscle relaxants, neither BIS nor AEP-index guidance reduces anaesthetic consumption or emergence times. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Auditory evoked potential-index; Bispectral-index; Fentanyl; Sevoflurane; Ambulatory surgery

1. Introduction

Ambulatory anaesthesia is increasing world-wide. While a number of factors promote this rapid growth, cost-effectiveness is without doubt one of the major driving forces. The economic consequences of anaesthesia are given increasing consideration [1]. Direct drug costs are but one factor in an equation that includes residence times in both the operating theatre and post-operative care unit.

With the continual introduction of both new drugs and anaesthetic equipment, impartial comparisons must be made with established techniques to allow clinicians to make informed choices including cost. Two new monitors of the depth of anaesthesia have recently been introduced. They use the electroencephalogram (EEG) in slightly different ways to determine the anaesthetic state. Bispectral analysis (BIS) is a passive monitor, interpreting the EEG based on an algorithm which provides a simple index to guide the clinician. The auditory evoked response (AEP) differs in that it uses an auditory stimulus to actively test the level of activity of the brain when it reacts to a signal-correlated EEG response. AEP has been suggested as one method for determining the effects of anaesthetics sensitive to the noxious effects of surgery and therefore possibly a useful technique for the determination of an adequate depth of anaesthesia during surgery [2,3].

The aim of the present study was to compare the anaesthetic consumption and emergence times for minor ambulatory surgery when sevoflurane anaesthesia is guided by BIS- or AEP-index as compared with routine clinical titration.

2. Methods

Sixty ASA I–II patients (described in Table 1) scheduled for elective knee arthroscopy were studied after approval from the hospital's ethics committee and informed consent. Premedication with cyclozine 50 mg was given orally 30 min prior to anaesthesia. Routine

* Corresponding author. Tel.: +46-8-5177-7013; fax: +46-8-323-482.
E-mail address: jan.jacobsson@mm-medical.se (J. Jakobsson).

PII: S0966-6532(02)00004-5

monitoring included ECG, pulsoximetry, heart rate and non-invasive systemic blood pressure.

Patients were randomised into three groups of 20 patients each. In group I ($n = 20$) sevoflurane was titrated according to routine clinical signs. In group II ($n = 20$) sevoflurane was titrated to maintain a target BIS of 60 during surgery. In group III ($n = 20$) sevoflurane was titrated to maintain a target AEP-index of 30 during surgery. Sevoflurane was combined with oxygen in nitrous oxide and given at 1 and 2 l/min, respectively, for a total fresh gas flow of 3 l/min.

In the AEP group, two AEP electrodes were placed on the forehead and one behind the ear and earphones provided an intermittent click (9 Hz, 65 dB sound pressure level) for AEP monitoring (A-Line AEP Monitor, Danmeter A/S; Odense, Denmark). Processing time for the AEP-index is 30 s for the first signal and a total update delay of 6 s. Latency and amplitude of the mid-latency AEP are weighted equally.

In the BIS group, four EEG electrodes were placed on the patient's forehead according to the manufacturer's instructions for BIS monitoring (Aspect 2000, Aspect Medical Systems; BIS algorithm 3.4, Natick, MA) and the BIS index was measured continuously.

2.1. Induction study protocol

Patients were preoxygenated ($FiO_2 = 0.7$) via a facemask for 3 min prior to induction. All patients received the same induction with fentanyl (0.1 mg) and propofol given according to clinical need. Muscle relaxants were not used and a laryngeal mask airway was placed in all patients and connected to a circle absorber system (Q-2 system, Anmedic AB, Valentuna, Sweden). All patients received 5 ml lidocaine in the skin prior to incision and 5 ml intra-articular lidocaine (5 mg/ml) with adrenaline at the start of surgery and 10 ml lidocaine with 50 μg fentanyl at the end of surgery.

At the end of surgery all anaesthetics were discontinued and a fresh oxygen flow of 6 l/min was given until the removal of the laryngeal mask. Emergence, calculated as the time to removal of the laryngeal mask and to when the patient could properly state his name and date of birth, were both defined from the cessation of sevoflurane.

2.2. Anaesthetic consumption determination

The sevoflurane vaporiser was filled and weighed (scale type) prior to induction. When anaesthesia was complete, the vaporiser was disconnected and reweighed. Inhaled anaesthetic consumption per minute was calculated for each patient.

2.3. Postoperative care

All patients received paracetamol 2 g and lornoxicam 8 mg orally as postoperative analgesia. Criteria for discharge were standard hospital routines: ability to drink, ambulate, void and have a VAS pain score less than 3.

2.4. Statistics

Data is presented as means and standard deviation unless otherwise stated. Differences between groups, for weights before and after anaesthesia were studied using ANOVA. $P < 0.05$ was considered statistically significant. We considered a 30% reduction in sevoflurane consumption to be clinically relevant. The number of

Table 1
Patients' characteristics and pre- and post-operative observations for the three groups studied (mean ± S.D.)

	BIS guidance ($n = 20$)	AEP guidance ($n = 20$)	Control ($n = 20$)
Age (years)	45 ± 14	45 ± 12	44 ± 11
Weight (kg)	77 ± 19	85 ± 15	82 ± 12
Duration of anaesthesia (min)	15 ± 5.0	15 ± 5.5	17 ± 4.8
Duration of surgery (min)	14 ± 4.8	14 ± 4.8	14 ± 4.8
Diagnostic	3	2	3
Meniscus resection	7	8	11
Shaving of synovia	11	10	6
Time until removal of larynx mask (min)	2.5 ± 0.8	2.7 ± 1.3	2.2 ± 0.7
Time until state date of birth and name (min)	3.2 ± 0.9	3.1 ± 1.3	2.6 ± 0.7*
VAS 30'	2.0 ± 2.5	1.8 ± 2.8	1.4 ± 1.6
Rescue analgesics	2	0	0
PONV	1	0	0
Time to ready for discharge (min)	56 ± 36	44 ± 18	43 ± 14
Fentanyl (μg/kg)	1.4 ± 0.3	1.2 ± 0.3	1.3 ± 0.2
Sevoflurane consumption (g/min)	0.21 ± 0.09	0.22 ± 0.16	0.19 ± 0.04

PONV, postoperative nausea and vomiting.
* $P < 0.05$.

patients in the brain guidance and clinical adjusted groups was based on a power analysis showing a 33% difference with a power of 90% and a 5% chance of an α-error.

3. Results

Patient's characteristics and peroperative observations are shown in Table 1. Patient groups did not differ in age or either duration or indication for surgery. Anaesthesia and surgery were uneventful in all patients and no major events were noticed in any patient. Postoperative interview revealed no awareness in any group.

None of the groups differed for either sevoflurane consumption, time to removal of laryngeal mask or time to discharge (Table 1). The time to stating date of birth was shorter for controls than the two study groups ($P < 0.05$).

4. Discussion

This is a negative study showing no major benefits from brain monitoring guidance with either BIS- or AEP-index during short ambulatory anaesthesia for knee arthroscopy.

There is a need for monitoring techniques that can objectively quantify anaesthetic depth. Such a monitor should optimally determine the depth of hypnosis independently of which drug is used and whether it is used alone or in combination with other drugs. Just as adequate anaesthesia is the balance between surgical stimulation and the combined effects of hypnosis and analgesia, so must an anaesthesia monitor be able to detect or respond to the arousal effects of noxious stimulation associated with surgery. The ideal depth of anaesthesia monitor should provide a real time description of the net effect of these factors.

Presently available BIS monitors approach these criteria. While the BIS-index does correlate with increasing sedating effects of hypnotics, it is far less discriminating for the effects of opioids, nitrous oxide or ketamine or when combinations of drugs are used [4–7]. The A-line model is a novel monitor based on the auditory evoked response. The AEP-index has not been studied previously from the perspective of optimising anaesthetic delivery. The auditory evoked response has been shown to correlate with anaesthetic effects and has been suggested to be one possible tool for determining adequate depth of anaesthesia [8].

Guidance from the BIS-index has been found to decrease anaesthetic consumption and facilitate the recovery in some studies [9–13]. Due to the high cost associated with the BIS electrodes, the cost-effectiveness from its use has been disputed [11]. Song et al. found that BIS monitoring reduced anaesthetic consumption as well as increased speed of emergence in patients who received muscle relaxants during tubal ligation [9]. Gan et al. studied patients having propofol anaesthesia and found BIS-guidance to be associated both with decreased propofol consumption and faster overall recovery [10]. In a study by Yli-Hankala et al., BIS shortened emergence times in patients anaesthetised with propofol but not in those anaesthetised with sevoflurane. The use of BIS-monitoring lowered anaesthetic consumption for both anaesthetics [11]. Bannister et al. also found differences in the effects of using BIS-monitoring when comparing patients undergoing tonsillectomies (with muscle relaxants) with those undergoing hernia repairs (without muscle relaxants). Sevoflurane consumption was decreased in both groups using BIS, but while the average emergence time was shortened in the tonsillectomy group, no differences were found in the children undergoing inguinal hernia repair with sevoflurane and supplemental caudal block [12]. Heck et al. studied hemodynamic and other autonomic responses during intubation and found that BIS guidance lowered the incidence of autonomic response [13]. Autonomic responses intraoperatively were only very minor in the present study and did not interfere with surgery in any patient.

The present study's negative finding with no major difference regarding drug consumption, emergence time and time to discharge, is to some extent in contrast to previously published results with BIS. Comparing the result of the present study with previous studies where anaesthetic administration has also been guided by brain monitoring should, however, take into account differences in the study population and protocol. Making comparisons of results from studies involving different surgical procedures and anaesthetic protocols is always difficult. It should be kept in mind that patients in the present study received a minor dose of fentanyl at induction, local anaesthesia before the initial incision and did not receive any muscle relaxants. Even the group relying only on clinical signs had a considerable number of variables available for determination of anaesthetic depth. In addition to routine clinical signs, as defined by Evens to include heart rate, blood pressure, tearing, and sweating [14], the patients in this study were mostly breathing spontaneously and thus could give motor signs. While end-tidal anaesthetic gas concentrations were monitored online, no fixed MAC level was sought but rather the vaporiser was adjusted according to patient needs and the sevoflurane consumption throughout the procedure was the primary study end-point.

Time to discharge was the same in all three groups. The time to discharge is dependent on a number of factors and one may argue about the extent to which intraoperative hypnotic monitoring has a causal relation to such a finding [15,16]. It is well known that pain and emesis are the two most important factors during the recovery process. All our patients had low postoperative pain scores and no patient needed rescue therapy for postoperative nausea or vomiting. Therefore, the influence from pain and emesis should have been minor and one may consider that the anaesthetic delivery regime would have had some impact.

To determine the full economic consequences of this new technology, even the cost for the special electrodes (approximately 5 Euro) and the monitoring equipment must be considered. Neither AEP- nor BIS-index guidance seems to be cost-effective in light, general anaesthesia without muscle relaxants as in this study: a finding similar to that in the BIS study by Yli-Hankala [10]. The benefits of brain monitors such as AEP or BIS may be greater during deeper anaesthesia with muscle relaxants and controlled ventilation when fewer clinical signs are available and a wider margin of safety is needed to avoid awareness as suggested by Johansen et al. [17]. It may be that the benefits of such guidance are more pronounced for intravenous anaesthesia than for inhalation anaesthesia with end-tidal gas monitoring.

Several factors may explain the shorter emergence time (ability to state name and date of birth) in the control group. A recent study demonstrated the most prominent decrease in sevoflurane consumption when first-year trainees were guided by the BIS-index [18]. Before comparing these results with the present study, it must be remembered that in the cited reference, anaesthesia cases were combined including short and long cases and those with and without muscle relaxants. Their finding is important. Brain monitors can be of value as pedagogical methods and may also influence the results of the present study in which anaesthesia was in the hands of a single anaesthesiologist with two decades of clinical experience. The control group had not only slightly faster emergence but also a tendency—which did not reach significance-of the lowest sevoflurane consumption. As there was no awareness in any group, one explanation would be that the inexperienced anaesthesiologist will feel confident to use less anaesthetic with the aide of brain monitors, while the experienced anaesthesiologist has less to gain from these monitors, at least for the type of cases studied here.

The choice of index target values can also affect the results of this and other studies. The target AEP-index of 30 was set in accordance with the manufacturer's recommendations. The BIS of 60 was taken from previous studies on day surgery patients [19]. Further studies with these devices may alter the chosen target values, particular in non-relaxed patients. As awareness is less critical in the absence of muscle relaxants, these target values may differ considerably for different anaesthetic protocols.

In summary, the new depth of anaesthesia monitors presently available, BIS and AEP, are interesting new modalities for the objective determination of depth of anaesthesia. Their effect during light general anaesthesia needs further studies in order to determine their relevant roles in clinical practice.

References

[1] Fisher DM, Macario A. Economics of anaesthesia care. A call to arms! (Editorial views). Anesthesiology 1997;86:1018–9.

[2] Heneghan CP, Thornton C, Navaratnarajah M, Jones JG. Effect of isoflurane on the auditory evoked response in man. Br J Anaesth 1987;59:277–82.

[3] Thornton C, Konieczko K, Jones JG, Jordan C, Dore CJ, Heneghan CP. Effect of surgical stimulation on the auditory evoked response. Br J Anaesth 1988;60:372–8.

[4] Barr G, Jakobsson JG, Öwall A, Anderson RE. Nitrous oxide does not alter bispectral index: a study with nitrous oxide as sole agent and as adjunct to intravenous anaesthesia. Br J Anaesth 1999;82:827–30.

[5] Barr G, Anderson R, Öwall A, Jakobsson J. Effects on the bispectral index during medium-high dose fentanyl induction with or without propofol supplement. Acta Anaesth Scand 2000;44:807–11.

[6] Sakai T, Singh H, Mi WD, Kudo T, Matsuki A. The effect of ketamine on clinical endpoints of hypnosis and BEG variables during propofol infusion. Acta Anaesth Scand 1999;43:212–6.

[7] Mi WD, Sakai T, Singh H, Kudo T, Kudo M, Matsuki A. Hypnotic endpoints vs. the bispectral index, 95% spectral edge frequency and median frequency during propofol infusion with and without fentanyl. Br J Anaesth 1999;16:47–52.

[8] Doi M, Gajraj RJ, Mantzaridis H, Kenny GN. Prediction of movement at laryngeal mask airway insertion: comparison of auditory evoked potential index, bispectral index, spectral edge frequency and median frequency. Br J Anaesth 1999;82:203–7.

[9] Song D, Joshi GP, White PF. Titration of volatile anesthesia using bispectral index facilitates recovery after ambulatory anesthesia. Anesthesiology 1997;87:842–8.

[10] Gan TJ, Glass PS, Windsor A, Payne F, Rosow C, Sebel P, Manberg P. Bispectral index monitoring allows faster emergence and improved recovery from propofol, alfentanil, and nitrous oxide anesthesia. BIS utility study group. Anesthesiology 1997;87:808–15.

[11] Yli-Hankala A, Vakkuri A, Annila P, Korttila K. EEG bispectral index monitoring in sevoflurane or propofol anaesthesia: analysis of direct costs and immediate recovery. Acta Anaesthesiol Scand 1999;43:545–9.

[12] Bannister CF, Brosius KK, Sigl JC, Meyer BJ, Sebel PS. The effect of bispectral index monitoring on anesthetic use and recovery in children anesthetized with sevolfurane in nitrous oxide. Anesth Analg 2001;92:805–7.

[13] Heck M, Kumle B, Boldt J, Lang J, Lehmann A, Saggau W. Electroencephalogram bispectral index predicts hemodynamic and arousal reactions during induction of anesthesia in patients undergoing cardiac surgery. J Cardio Vasc Anesth 2000;14:693–7.

[14] Evans JM, Bithell JF, Vlachonikolis IG. Relationship between lower oesophageal contractility, clinical signs and halothane concentration during general anaesthesia and surgery in man. Br J Anaesth 1987;59:1346–55.

[15] Marshall S, Chung F. Discharge criteria and complications after

ambulatory surgery. Anesth Analg 1999;88:508–17.
[16] Pavlin DJ, Rapp SE, Polissar NL, Malmgren JA, Koerschgen M, Keyes H. Factors affecting discharge time in adult outpatients. Anaesth Analg 1999;87:816–26.
[17] Johansen JW, Sebel PS, Sigl JC. Clinical impact of hypnotic-titration guidelines based on EEG bispectral index (BIS) monitoring during routine anesthetic care. J Clin Anesth 2000;12:433–43.
[18] Pavlin DJ, Hong JY, Freund PR, Koerschgen ME, Bower JO, Bowdle TA. The effect of bispectral index monitoring on end-tidal gas concentration and recovery duration after outpatient anesthesia. Anesth Analg 2001;93:613–9.
[19] Nelskyla KA, Yli-Hankala AM, Puro PH, Korttila KT. Sevoflurane titration using bispectral index decreases postoperative vomiting in phase II recovery after ambulatory surgery. Anesth Analg 2001;93:1165–9.