Anesthesiology 2003; 99:813–8

Effect of Auditory Evoked Potential Index Monitoring on Anesthetic Drug Requirements and Recovery Profile after Laparoscopic Surgery

A Clinical Utility Study

Alejandro Recart, M.D., Paul F. White, Ph.D., M.D.,† Agnes Wang, M.S.,‡ Irina Gasanova, Ph.D., M.D.,* Stephanie Byerly, M.D.,§ Stephanie B. Jones, M.D.§*

Background: **The auditory evoked potential (AEP) monitor provides an electroencephalogram-derived index (AAI) that has been reported to correlate with the central nervous system depressant effects of anesthetic drugs. This clinical utility study was designed to test the hypothesis that AAI-guided administration of the maintenance anesthetics and analgesics would improve their titration and thereby provide a faster recovery from general anesthesia.**

Methods: **Seventy consenting patients undergoing elective general surgery procedures were randomly assigned to either a control (standard clinical practice) or AEP-monitored group. Although the AEP monitor was connected to all patients, the information from the monitor was only made available to the anesthesiologists assigned to patients in the AEP-monitored group. In the AEP-monitored group, the inspired desflurane concentration was titrated to maintain an AAI value of 15–20. In the control group, the inspired desflurane concentration was varied based on standard clinical signs. The AAI values and hemodynamic variables, as well as end-tidal desflurane concentrations, were recorded at 3- to 5-min intervals. The recovery times to achieve a White fast-track score greater than 12 and an Aldrete score of 10, as well as the actual duration of the PACU stay, were evaluated at 5- to 10-min intervals. Patient satisfaction with recovery from anesthesia was assessed using a 100-point verbal rating scale at 24 h after surgery.**

Results: **The average intraoperative AAI value in the AEP-monitored group was significantly higher than in the control group (16 ± 5 *vs.* 11 ± 8, $P < 0.05$). Use of the AEP monitor reduced the desflurane requirement by 26% compared to the control group ($P < 0.01$). In addition, the AEP-monitored group received less intraoperative fentanyl (270 ± 120 *vs.* 390 ± 203 μg, $P < 0.05$) and more rapidly achieved fast-track eligibility (29 ± 19 *vs.* 56 ± 41 min, $P < 0.05$). The time required to achieve an Aldrete score of 10 (60 ± 31 *vs.* 98 ± 55 min) and the duration of stay in the recovery room (78 ± 32 *vs.* 106 ± 54 min) were also significantly reduced in the AEP-monitored (*vs.* control) group ($P < 0.05$).**

Conclusion: **Use of AEP monitoring as an adjunct to standard clinical monitors improved titration of anesthetic drugs, thereby facilitating the early recovery process after laparoscopic surgery.**

* Clinical Research Fellow, † Professor and Holder of the Margaret Milam McDermott Distinguished Chair in Anesthesiology, ‡ Medical Student, § Associate Clinical Professor.

Received from the Department of Anesthesiology and Pain Management, University of Texas Southwestern Medical Center, Dallas, Texas. Submitted for publication January 28, 2003. Accepted for publication May 1, 2003. An educational grant to conduct this study was provided by Alaris Medical Systems, San Diego, California. Endowment funds were received from the Margaret Milam McDermott Distinguished Chair of Anesthesiology.

Address reprint requests to Dr. White: Department of Anesthesiology and Pain Management, University of Texas Southwestern Medical Center, 5323 Harry Hines Boulevard, Dallas, Texas 75390-9068. Address electronic mail to: paul.white@utsouthwestern.edu. Individual article reprints may be purchased through the Journal Web site, www.anesthesiology.org.

INTEREST in finding a reliable cerebral function monitor to assess a patient's level of consciousness during anesthesia has increased as practitioners attempt to optimize the recovery process and improve perioperative efficiency by using anesthetic techniques associated with a more rapid emergence. Use of standard clinical signs does not provide the clinician with the ability to precisely assess the level of hypnosis during general anesthesia.[1,2]

Previous studies with the electroencephalographic-derived Bispectral Index (BIS) and physical state index (PSI) have suggested that these cerebral monitors can improve the titration of both intravenous[3,4] and volatile[5] anesthetics. Preliminary studies have suggested that the middle-latency auditory evoked potentials (MLAEPs) may also be a reliable indicator of the sedative and hypnotic effect of anesthetic drugs.[6,7] The auditory evoked potential (AEP) monitor detects the cortical response to a standardized auditory stimulus, and the derived index (AAI) appears to be decreased by general anesthetics in a dose-dependent manner.[8,9] It has been suggested that the AAI value may possess an advantage over the BIS and PSI values because the MLAEP measures the central nervous system responsiveness to a specific auditory stimulus rather than measuring the resting state of the brain.[10] The MLAEP signal is processed using an autoregressive analyzer with an exogenous input model to generate the AAI index over a numerical range from 1 to 100. The AAI value reflects the shape of MLAEP waveforms and is calculated from the amplitude difference between successive segments of the waveform at 3-s intervals.[11–13]

This clinical utility study was designed to test the hypothesis that the availability of the AAI value during the intraoperative period would alter the use of the volatile anesthetic (desflurane), opioid analgesic (fentanyl), and sympatholytic (labetalol) drugs compared to standard clinical monitoring practices. Secondary objectives were to evaluate the impact of AEP monitoring on the speed and quality of recovery, as well as patient satisfaction with recovery.

Materials and Methods

After obtaining institutional review board approval at the University of Texas Southwestern Medical Center

(Dallas, Texas), written informed consent was obtained from 70 patients undergoing elective laparoscopic general surgery procedures. These patients were randomly assigned to one of two study groups: (1) control (standard clinical practices; n = 35) or (2) AEP monitored (n = 35). Exclusion criteria included a history of central nervous system disease (*e.g.*, hearing disorders, seizures), chronic use of psychoactive medication, and any clinically significant cardiovascular, renal, hepatic, or endocrinologic disorders.

In the preoperative holding area, two AEP electrodes were placed on the forehead and one behind the left ear over the mastoid bone, and acceptable contact impedance was confirmed when the electrodes were connected to the AEP monitor (A-line; Danmeter, Denmark). All patients received 2 mg intravenous midazolam for premedication in the holding area. Although the AEP monitor was connected to all patients in the operating room, the intraoperative AAI values were only made available to anesthesiologists providing care to the patients in the AEP-monitored group. The AAI values, as well as heart rate and systolic, diastolic, and mean blood pressure values were recorded at specific time intervals after entering the operating room and at 3- to 5-min intervals throughout the intraoperative period. The baseline values were based on the average of three consecutive readings before induction of anesthesia.

Anesthesia was induced with 1.5–2.0 mg/kg intravenous propofol and 0.75–1.5 μg/kg intravenous fentanyl, and tracheal intubation was facilitated with 0.6 mg/kg intravenous rocuronium. Anesthesia was initially maintained with desflurane, 4% inspired concentration, in combination with air (0.5 l/min) and oxygen (0.5 l/min). The inspired desflurane concentration was varied in increments of 1–2%, and intermittent bolus doses of 50 μg intravenous fentanyl and/or 5 mg intravenous labetalol were given to maintain hemodynamic variables within 15% of the baseline values. All patients received 0.625–1.25 mg intravenous droperidol for antiemetic prophylaxis. At the end of the surgical procedure, residual neuromuscular block was antagonized with 50–80 μg/mg intravenous edrophonium and 0.6 mg intravenous atropine. Desflurane was discontinued, and fresh oxygen was administered at a flow rate of 5 l/min until tracheal extubation. The desflurane anesthetic requirement was calculated based on the average end-tidal concentrations recorded at 3- to 5-min intervals throughout the maintenance period.

In the AEP-monitored group, the inspired desflurane concentration was titrated in 1–2% increments to maintain an AAI value between 15 and 20. The targeted range for the AAI was based on earlier studies[7,10] suggesting that values of 15–20 are associated with hypnotic effect-site anesthetic concentrations. In the presence of an AAI value less than 20, 5 mg intravenous labetalol was administered to treat increases in blood pressure exceeding 15% of the baseline value, and 50 μg intravenous fentanyl was used to treat increases in heart rate exceeding 15% of the baseline value. If the AAI was less than 15, the inspired desflurane was decreased by 1–2%. If the acute autonomic response occurred in the presence of an AAI value of 20 or greater, the inspired desflurane concentration was increased in 1–2% increments. In the control group, the inspired desflurane concentration was increased or decreased in 1–2% increments depending on whether the patient displayed clinical signs of inadequate or excessive anesthesia, respectively. Acute hyperdynamic responses (*e.g.*, increases in mean arterial pressure and/or heart rate exceeding 15% of the baseline values) without other clinical signs of inadequate anesthesia were treated with either 50 μg intravenous fentanyl or 5 mg intravenous labetalol, analogous to the AEP-monitored group.

Recovery times to awakening (*i.e.*, opening eyes in response to a verbal command), extubation, and orientation were continuously assessed (at approximately 1-min intervals after discontinuation of desflurane) by a blinded observer. Time to extubation was calculated as the time from cessation of desflurane until the endotracheal tube was removed. Time to orientation was the time from cessation of desflurane until the patient could state his/her name, date of birth, and location (city, state) when questioned by the blinded observer. Time to achieve a White fast-track score[14] greater than 12 and a modified Aldrete score[15] of 10 were continuously assessed (at 5- to 10-min intervals) by the same blinded observer. However, the duration of the stay in the PACU was calculated based on the actual clock times from admission until discharge from the PACU. The patients were discharged to the postsurgical ward when they met the standard PACU discharge criteria as assessed by a recovery room nurse, who was also unaware of the intraoperative monitoring.

Finally, the occurrence of postoperative side effects (*e.g.*, pain, nausea, vomiting), the times to first "rescue" analgesic and/or antiemetic medication, and the total dosage of opioid analgesics required were recorded at the time of discharge from the PACU. Patients were also asked to evaluate their pain and nausea in the PACU using an 11-point verbal rating scale (0 = none; 10 = highest). At 24 h after surgery, patient satisfaction with anesthesia and quality of recovery were assessed using a 100-point verbal rating scale (1 = poor; 100 = excellent), and patients were also queried about recall of intraoperative events, postoperative pain, and the occurrence of postoperative nausea and vomiting (PONV).

Statistical Analysis

An *a priori* power analysis estimated that a minimum of 30 patients would be required in each group to detect a 25% or greater difference in volatile anesthetic requirement with a power of 0.8 ($\alpha = 0.05$).[16] Continuous data

Table 1. Patient Demographic Characteristics, Anesthesia, and Surgery Times, and Intraoperative Fluid Consumption in the Two Study Groups

	Control	AEP Monitored
No.	34	34
Age, yr	44 ± 13	44 ± 15
Weight, kg	102 ± 43	100 ± 41
Height, m	1.65 ± 1.3	1.66 ± 0.9
Sex (M/F), No.	8/26	9/25
ASA physical status, No.	2 (1–3)	2 (1–3)
Types of laparoscopic surgery, No.		
Cholecystectomy	14	13
Gastric banding/bypassing	8	8
Nephrectomy/nephrolithotomy	8	5
Miscellaneous procedures	4	8
Anesthesia time, min	134 ± 46	134 ± 56
Surgery time, min	108 ± 45	103 ± 41
Total intravenous fluids, l	2.5 ± 1.4	2.3 ± 1.4

Values are mean ± SD, median (range), and number. No significant differences between groups.

AEP = auditory evoked potential; ASA = American Association of Anesthesiologists.

were analyzed and compared using repeated-measures analysis of variance followed by multiple Wilcoxon matched-pairs tests, with the Bonferroni correction or Student *t* test for multiple comparisons, as well as one-way analysis of variance where appropriate. Categorical data were analyzed using the chi-square test with Fisher exact test where appropriate. Power and probability level were analyzed using NCSS software (Number Cruncher Statistical Systems for Windows, Kaysville, UT). Data are presented as mean values (± SD), median values (interquartile ranges), numbers, and percentages, with *P* values less than 0.05 considered statistically significant.

Results

A total of 70 patients were enrolled in the study; however, two were eliminated because of protocol violations. Of the remaining 68 patients, 34 were randomized to the control group and 34 were randomized to the AEP-monitored group. The two study groups were comparable with respect to their demographic characteristics, baseline AAI and hemodynamics values, and durations of surgery and anesthesia (tables 1 and 2). During surgery, the average hemodynamic variables were also similar in both study groups (table 2). However, the averaged AAI value during the maintenance period was significantly lower (11 ± 8 *vs.* 16 ± 5, respectively, $P < 0.05$) in the control (*vs.* AEP-monitored) group (table 2).

During the surgical procedure, the mean end-tidal concentration of desflurane was significantly lower in the AEP-monitored (*vs.* control) group (3.7 ± 0.6 *vs.* 5.0 ± 1.0% $P < 0.01$). Despite the AEP-monitored (*vs.* control) group's receiving less intraoperative fentanyl (270 ± 120 *vs.* 390 ± 203 μg, $P < 0.05$; table 3), the total dosage of fentanyl administered in the PACU was nonsignificantly decreased (119 ± 60 *vs.* 171 ± 100 μg, respectively). The number of patients receiving labetalol was significantly higher in the AEP-monitored (*vs.* control) group (20 *vs.* 8, $P < 0.05$). However, the average dose of labetalol administered during the maintenance period was similar for treated patients in both groups (12 ± 5 and 8 ± 2 mg in the AEP-monitored and control groups, respectively).

The emergence (*e.g.*, awakening), orientation, and extubation times were not significantly reduced in the AEP-monitored (*vs.* control) group (table 3). However, patients in the AEP-monitored (*vs.* control) group more rapidly achieved fast-track eligibility (29 ± 19 *vs.* 56 ±

Table 2. Preoperative Baseline and Average Intraoperative Auditory Evoked Potential Index (AAI) Values and Hemodynamic Variables in the Two Study Groups

	Control (n = 34)	AEP Monitored (n = 34)
Baseline AAI	70 ± 15	72 ± 16
Baseline hemodynamics		
Systolic BP, mmHg	132 ± 23	135 ± 17
Diastolic BP, mmHg	74 ± 16	74 ± 12
Mean BP, mmHg	93 ± 18	97 ± 16
Heart rate, beats/min	80 ± 11	76 ± 12
Average intraoperative AAI	11 ± 8	16 ± 5*
Average intraoperative hemodynamic values		
Systolic BP, mmHg	119 ± 4	122 ± 4
Diastolic BP, mmHg	65 ± 3	68 ± 2
Mean BP, mmHg	87 ± 3	89 ± 3
Heart rate, beats/min	72 ± 2	70 ± 2

Values are mean ± SD and units.

* $P < 0.05$ *vs.* control group.

AEP = auditory evoked potential; BP = blood pressure.

Table 3. Intraoperative Anesthetic Drug Consumption, Early Recovery Times, White Fast-Track and Aldrete Discharge Scores, and Duration of PACU Stay in the Two Study Groups

	Control (n = 34)	AEP Monitored (n = 34)
Propofol, mg	175 ± 33	174 ± 53
Initial fentanyl, μg	139 ± 37	133 ± 57
Desflurane, ET%	5.0 ± 1.0	3.7 ± 0.6*
Average fentanyl dose, μg	390 ± 203	270 ± 120†
Labetalol used, No. (%)	8 (24)	20 (59)†
Average labetalol dose, mg	8 ± 2	12 ± 5
Rocuronium, mg	78 ± 36	79 ± 21
Recovery times, min		
To eye opening	6 ± 3	5 ± 3
To obey command	8 ± 4	6 ± 4
To extubation	10 ± 6	7 ± 5
White fast-track score > 12, min	56 ± 41	29 ± 19†
Aldrete discharge score of 10, min	98 ± 55	60 ± 31†
PACU stay, min	106 ± 54	78 ± 32†

Values are mean and SD, numbers, and percentages.

* $P < 0.01$ *vs.* control group. † $P < 0.05$ *vs.* control group.

AEP = auditory evoked potential; ET = end-tidal; PACU = postanesthesia care unit.

Table 4. Pain and Nausea Scores, Analgesic Consumption in the PACU, and Patient Satisfaction and Quality of Recovery Assessments at 24 h after Surgery in the Two Study Groups*

	Control (n = 34)	AEP Monitored (n = 34)
At PACU discharge assessment		
Maximum pain score (0–10), No.	7 (4–10)	8 (5–10)
Maximum nausea score (0–10), No.	0 (0–8)	0 (0–6)
Time to rescue analgesic, min	43 ± 40	49 ± 53
Time to rescue antiemetic, min	71 ± 23	95 ± 85
Rescue antiemetic medication, No. (%)	6 (18)	7 (20)
Fentanyl requirement, No. (μg)	17 (171 ± 100)	14 (119 ± 60)
Morphine requirement, No. (mg)	19 (10 ± 6)	15 (8 ± 6)
At 24-h follow-up assessment		
Maximum pain score (0–10), No.	6 (5–9)	5 (4–8)
Nausea and/or vomiting, No. (%)	11 (32)	5 (15)*
PCA morphine requirement, No. (mg)	6 (10 ± 5)	8 (8 ± 6)
Patient satisfaction (1–100), No.	93 ± 18	97 ± 5
Quality of recovery (1–100), No.	68 ± 30	72 ± 18

Values are mean and SD, median (with interquartile range), numbers, and percentages.

* $P < 0.05$ *vs.* control group.

AEP = auditory evoked potential; PCA = patient-controlled analgesia.

41 min; 20 [15–45] *vs.* 42 [20–80] min) and an Aldrete score of 10 (60 ± 31 *vs.* 98 ± 55 min; 55 [37–75] *vs.* 88 [59–147] min) after surgery ($P < 0.05$). More important, the duration of recovery room stay was significantly reduced in the AEP-monitored (*vs.* control) group (78 ± 32 *vs.* 106 ± 54 min, $P < 0.05$; table 3).

There were no differences between the two groups with respect to pain scores and opioid analgesic consumption in either the PACU or on the postsurgical ward (table 4). At the 24-h follow-up evaluation, none of the patients reported recall of any intraoperative events. However, the incidence of PONV was significantly reduced in the AEP-monitored group (15 *vs.* 32 in the control group, $P < 0.05$). Finally, patient satisfaction with anesthesia (93 ± 18 *vs.* 97 ± 5; 100 [90–100] *vs.* 100 [90–100]) and quality of recovery (68 ± 30 *vs.* 72 ± 18; 80 [60–95] *vs.* 80 [60–100]) did not differ between the control and AEP-monitored groups, respectively (table 4).

Discussion

The AEP monitor provides the anesthesiologist with information regarding the effect of anesthetic drugs on the MLAEP during sedation and general anesthesia.[7,10] Several clinical studies have suggested that the AAI can discriminate between the conscious and unconscious states, with higher awake AAI values compared with AAI values during general anesthetic states.[7,8,17–19] Kurita *et al.*[20] reported that the AAI could predict the depth of sedation and movement in response to skin incision during sevoflurane anesthesia. Although Struys *et al.*[7] also found that the AAI could track the level of sedation and loss of consciousness with propofol, they found it had a poor predictive power with respect to movement in response to noxious stimuli. Other investigators have also reported that the MLAEP-derived index is not a very sensitive indicator of the effects of opioid analgesics.[21,22]

Analogous to the previously published studies with the electroencephalogram-based BIS® monitor (Aspect Medical Systems, Natick, MA) [3,5] and PSI[4] monitor (Baxter Healthcare, Chicago, IL), this study demonstrated that the AEP monitor could improve the titration of maintenance anesthetic drugs by minimizing the time the AAI value was below 15. As expected, patients in the control group had significantly lower AAI values during surgery than the AEP-monitored group because they received higher average concentrations of the volatile anesthetic. The availability of the AAI value not only influenced the anesthesiologist's use of the volatile anesthetic (desflurane), but also the opioid analgesic (fentanyl) and sympatholytic drug (labetalol) during the maintenance period. As a result of the apparent anesthetic-sparing effect, patients in the AEP-monitored group were able to more rapidly achieve surrogate recovery endpoints (*e.g.*, fast-track eligibility) and to satisfy PACU discharge criteria (Aldrete score of 10). Even though none of the patients in this preliminary study with the AEP monitor were actually fast-tracked, the actual duration of the PACU stay was reduced by approximately 30 min. Earlier studies[3–5,23] with the BIS® and PSI monitors have demonstrated that use of cerebral monitoring can lead to a faster emergence from anesthesia as a result of the anesthetic-sparing effect. However, these studies all failed to find a significant difference in the duration of the PACU stay or the time to discharge home. The negative findings in these earlier studies may have been related in part to the impact of institutional recovery protocols on the duration of the PACU stay.

Preliminary studies describing the impact of AEP monitoring on recovery times after anesthesia have yielded

contradictory findings. The recent study by Maattanen *et al.*[16] reported decreased desflurane consumption and faster emergence times after spine surgery with AEP monitoring when they maintained an AAI value of 20 ± 5. However, they failed to demonstrate a benefit with respect to clinically meaningful recovery times. This may have been related to the fact that the duration of PACU stay can be influenced by institutional protocols that are unrelated to anesthesia. Interestingly, Assareh *et al.*[24] used the AAI index to titrate sevoflurane during brief ambulatory surgery procedures and reported a decreased time to discharge even though the intraoperative anesthetic requirement was allegedly unchanged. The current study has demonstrated that the anesthetic- and analgesic-sparing effects of AEP monitoring can lead to a clinically meaningful reduction in the duration of PACU stay and the incidence of PONV.

In their recent editorial, Kalkman and Drummond[25] suggested that use of cerebral monitors to reduce anesthetic drug use and expedite PACU discharge may result in increased autonomic stress responses and adverse outcomes (*e.g.*, myocardial ischemia, intraoperative awareness, purposeful movements during surgery). In our study, the intraoperative hemodynamic variables were similar in both study groups despite the AEP-monitored group's receiving 26% less desflurane and 31% less fentanyl (compared to the control group). Not surprisingly, labetalol was more frequently administered to control acute hemodynamic responses during surgery in the AEP-monitored group (59% *vs.* 30%, $P < 0.05$). The anesthesiologists were apparently more comfortable using the sympatholytic drug because of the availability of AAI information suggesting that the patient was unconscious. In this study, there was no evidence to suggest that the use of AEP monitoring contributed to adverse outcomes. However, the study was not adequately powered to assess rare adverse events (*e.g.*, awareness under anesthesia).

Previous studies have demonstrated that patient outcome is similar whether general anesthetic, opioid analgesic, or sympatholytic drugs were used to control acute stress responses during general anesthesia.[26,27] At a recent national meeting, Weldon *et al.*[28] reported a correlation between the duration of time during anesthesia that the BIS value was less than 45 and the incidence of adverse clinical outcomes in an elderly surgical population. Therefore, avoiding excessively deep levels of anesthesia by using sympatholytic drugs such as labetalol may actually have benefits beyond the early recovery period (*e.g.*, reduced PONV). It would seem that the availability of information regarding the patient's hypnotic state may lead to an increased use of drugs lacking in central nervous system depressant effects to control acute autonomic responses during general anesthesia. As a result, more purposeful movements may occur during surgery in nonparalyzed patients. It should be noted that the presence of increased electromyographic activity during surgery can also interfere with the interpretation of the AAI.

Practitioners are increasingly being required to provide economic data that justifies the use of new monitoring devices. Cerebral monitoring with an AEP device could potentially affect the cost of patient care by reducing anesthetic and analgesic drug use during surgery, as well as decreasing the need for medication to treat postoperative side effects (*e.g.*, pain, PONV). In addition, if patients emerged more rapidly from anesthesia, it might be possible to reduce turnover times in the operating room and allow additional cases to be performed.[29] More important, by increasing the proportion of patients who could be fast tracked (*i.e.*, bypass the PACU), use of a cerebral monitor could reduce PACU and day-surgery personnel costs, as well as the need for overtime nursing staff.[30] A carefully performed cost–benefit analysis will be required to determine the future role of AEP monitoring in clinical practice.

The major shortcoming of this clinical utility study involving the AEP monitor relates to the fact that it was not adequately powered to examine important secondary outcomes that are needed to justify the use of the device in routine clinical practice. Of importance, the AEP-monitored group received less desflurane and fentanyl and more labetalol than the control group during the maintenance period despite the fact that the same basic anesthetic technique was used by anesthesiologists in both study groups. If anesthesiologists caring for patients in the control group learned from their previous experience with the AEP monitor, it would have biased the results *against* finding differences between the two study groups. Unfortunately, the anesthesiologists directly involved in the intraoperative patient care did not take advantage of the fact that patients in the AEP-monitored group more rapidly achieved fast-track eligibility after surgery by allowing appropriate patients to bypass the PACU.

Although we did not compare the AEP monitor to other available cerebral monitors (*e.g.*, BIS®, PSI), these data should not be interpreted to imply that the AEP device is superior to the other electroencephalogram-based monitoring devices. Finally, we failed to perform an in-depth assessment of conscious perception (*i.e.*, awareness) during anesthesia (*e.g.*, implicit and explicit memory). However, no patient reported awareness at either the time of discharge from the PACU or at the 24-h follow-up evaluation, and patient satisfaction with anesthesia was equally high in both study groups. It is important to realize that although all the patients in the current study were adequately anesthetized, use of the AEP monitor cannot guarantee that a rare outlier will not experience recall despite the presence of an AAI value less than 20.

In summary, this clinical utility study suggests that the

addition of AEP monitoring can reduce the maintenance desflurane and fentanyl requirements, leading to an earlier discharge from the PACU and reduced PONV after laparoscopic surgery compared to standard clinical monitoring practices alone. Further studies are needed to determine whether routine use of the AEP monitor is cost-effective in facilitating the perioperative recovery process.

References

1. Heier T, Steen PA: Assessment of anaesthesia depth. Acta Anaesthesiol Scand 1996; 40:1087–100
2. Drummond, JC: Monitoring depth of anesthesia. ANESTHESIOLOGY 2000; 93: 876–82
3. 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. ANESTHESIOLOGY 1997; 87:808–15
4. Drover DR, Lemmens HJ, Pierce ET, Plourde G, Loyd G, Ornstein E, Prichep LS, Chabot RJ, Gugino L: Patient state index: Titration of delivery and recovery from propofol, alfentanil, and nitrous oxide anesthesia. ANESTHESIOLOGY 2002; 97:82–9
5. Song D, Joshi GP, White PF: Titration of volatile anesthetics using bispectral index facilitates recovery after ambulatory anesthesia. ANESTHESIOLOGY 1997; 87: 842–8
6. Mantzaridis H, Kenny GN: Auditory evoked potential index: A quantitative measure of changes in auditory evoked potentials during general anaesthesia. Anaesthesia 1997; 52:1030–6
7. Struys MM, Jensen EW, Smith W, Smith NT, Rampil I, Dumortier FJ, Mestach C, Mortier EP: Performance of the ARX-derived auditory evoked potential index as an indicator of anesthetic depth. ANESTHESIOLOGY 2002; 96:803–16
8. Doi M, Gajraj RJ, Mantzaridis H, Kenny GN: Relationship between calculated blood concentration of propofol and electrophysiological variables during emergence from anaesthesia: Comparison of Bispectral Index, spectral edge frequency, median frequency and auditory evoked potential index. Br J Anaesth 1997; 78:180–4
9. Brunner MD, Umo-Etuk J, Sharpe RM, Thornton C: Effect of a bolus dose of midazolam on the auditory evoked response in humans. Br J Anaesth 1999; 82:633–4
10. Thornton C, Sharpe RM: Evoked responses in anaesthesia. Br J Anaesth 1998; 81:771–81
11. Jensen EW, Lindholm P, Henneberg SW: Autoregressive modeling with exogenous input of middle latency auditory evoked potentials to measure rapid changes in depth of anesthesia. Meth Inform Med 1996; 35:256–60
12. Jensen EW, Nygaard M, Henneberg S: On-line analysis of middle latency auditory evoked potentials (MLAEP) for monitoring depth of anaesthesia in laboratory rats. Med Eng Phys 1998; 20:722–8
13. Urhonen E, Jensen EW, Lund J: Changes in rapidly extracted auditory evoked potentials during tracheal intubation. Acta Anaesthesiol Scand 2000; 44:743–8
14. White PF, Song D: New criteria for fast-tracking after outpatient anesthesia: A comparison with the modified Aldrete's scoring system. Anesth Analg 1999; 88:1069–72
15. Aldrete JA: The post-anesthesia recovery score revisited. J Clin Anesth 1995; 7:89–91
16. Maattanen H, Anderson RE, Uusijarvi J, Jakobsson J: Auditory evoked potential monitoring with the AAITM-index during spinal surgery: Decreased desflurane consumption. Acta Anaesthesiol Scand 2002; 46:882–6
17. Gajraj RJ, Doi M, Mantzaridis H, Kenny GN: Comparison of bispectral EEG analysis and auditory evoked potentials for monitoring depth of anaesthesia during propofol anaesthesia. Br J Anaesth 1999; 82:672–8
18. Schraag S, Bothner U, Gajraj R, Kenny GN, Georgieff M: The performance of electroencephalogram bispectral index and auditory evoked potential index to predict loss of consciousness during propofol infusion. Anesth Analg 1999; 89:1311–5
19. Gajraj RJ, Doi M, Mantzaridis H, Kenny GN: Analysis of the EEG bispectrum, auditory evoked potentials and the EEG power spectrum during repeated transitions from consciousness to unconsciousness. Br J Anaesth 1998; 80:46–52
20. Kurita T, Doi M, Katoh T, Sano H, Sato S, Mantzaridis H, Kenny GN: Auditory evoked potential index predicts the depth of sedation and movement in response to skin incision during sevoflurane anesthesia. ANESTHESIOLOGY 2001; 95:364–70
21. Shinner G, Sharpe RM, Thornton C, Dore CJ, Brunner MD: Effect of bolus doses of alfentanil on the arousal response to intubation, as assessed by the auditory evoked response. Br J Anaesth 1999; 82:925–8
22. Schwender D, Rimkus T, Haessler R, Klasing S, Poppel E, Peter K: Effects of increasing doses of alfentanil, fentanyl and morphine on mid-latency auditory evoked potentials. Br J Anaesth 1993; 71:622–8
23. Wong J, Song D, Blanshard H, Grady D, Chung F: Titration of isoflurane using BIS index improves early recovery of elderly patients undergoing orthopedic surgeries. Can J Anaesth 2002; 49:13–8
24. Assareh H, Anderson RE, Uusijarvi J, Jakobsson J: Sevoflurane requirements during ambulatory surgery: A clinical study with and without AEP-index guidance. Acta Anaesthesiol Scand 2002; 46:495–9
25. Kalkman CJ, Drummond JC: Monitors of depth of anesthesia, quo vadis? (editorial). ANESTHESIOLOGY 2002; 96:784–7
26. Monk TG, Mueller M, White PF: Treatment of stress response during balanced anesthesia: Comparative effects of isoflurane, alfentanil, and trimethaphan. ANESTHESIOLOGY 1992; 76:39–45
27. Monk TG, Ding Y, White PF: Total intravenous anesthesia: Effects of opioid *versus* hypnotic supplementation on autonomic responses and recovery. Anesth Analg 1992; 75:798–804
28. Weldon BC, Mahla ME, Van der Aa MT, Monk TG: Advancing age and deeper intraoperative anesthetic levels are associated with higher first year death rates (abstract). ANESTHESIOLOGY 2002; 97:A1097
29. Watcha MF, White PF: Economics of anesthetic practice. ANESTHESIOLOGY 1997; 86:1170–96
30. Apfelbaum JL, Walawander CA, Grasela TH, Wise P, McLeskey C, Roizen MF, Wetchler BV, Korttila K: Eliminating intensive postoperative care in same-day surgery patients using short-acting anesthetics. ANESTHESIOLOGY 2002; 97:66–74