Awareness

Monitoring versus Remembering What Happened
Chantal Kerssens, Ph.D.,* Jan Klein, M.D., Ph.D.,† Benno Bonke, Ph.D.‡

Background: Awareness during anesthesia is foremost assessed with postoperative interviews, which may underestimate its incidence. On-line monitors such as the Bispectral Index® and patient response to verbal command are not necessarily commonly used. This study investigated response to command during deep sedation (Bispectral Index 60–70) and the ability of prevailing monitoring techniques to indicate awareness and predict recall.

Methods: The authors systematically assessed the response to command using the isolated forearm technique while monitoring electroencephalographic and hemodynamic variables. Fifty-six elective surgical patients were repeatedly given verbal instructions to squeeze the observer's hand during target-controlled infusion with propofol and alfentanil. After recovery, conscious recall was assessed with a short structured interview.

Results: Overall, 1,082 commands were given. No response was observed to 887 (82%) commands, an equivocal response was observed to 56 (5%) commands, and an unequivocal response was observed to 139 (13%) commands. Of the 37 patients (66%) with an unequivocal response to command (“awareness”), nine (25%) reported conscious recall after recovery. Their reports provided valuable insights as to how awareness may be adequately addressed. Hemodynamic variables poorly predicted awareness, whereas parameters derived from the encephalogram, especially the Bispectral Index, were highly significant predictors (P < 0.0001). Electroencephalographic parameters did not discriminate between patients with or without conscious recall, whereas heart rate and responsiveness to command did.

Conclusions: The incidence of awareness is underestimated when conscious recall is taken as evidence. Awareness can be monitored on-line with behavioral and modern neurophysiologic measures. Providing feedback during intra-anesthetic awareness helps patients to cope with a potentially stressful situation.

REGAINING consciousness during alleged general anesthesia (“awareness”) is a frightening experience that often causes patients to panic and feel helpless even when no pain is experienced.1 It is not necessarily the awakening itself that is most distressing to patients but rather the inability to move or communicate (i.e., awake paralysis) that gives rise to feelings that the worst is yet to come. Persistent adverse sequelae in those who remember being awake during surgery are not uncommon and include insomnia, recurrent nightmares, emotional distress, and posttraumatic stress disorder.1–3

In this article, we distinguish the literal meaning of awareness, referring to conscious subjective experiences, from the common definition used by anesthesia staff, referring to postoperative remembering what happened during surgery. Although the two phenomena are related, people are generally aware of more things than they remember. Conscious recall may thus underestimate instances of awareness. This notion is clearly illustrated by studies assessing response to verbal command during anesthesia. Patients who comply with the command to squeeze the investigator's hand, for instance, often fail to recall the event after recovery from anesthesia.4,5 In a similar vein, patients deliberately woken during surgery tend to completely forget what happened.6 We therefore propose to take awareness literally and to monitor the phenomenon during as opposed to after anesthesia.

Awareness monitoring is still complicated and controversial. A good monitor should be sensitive to conscious subjective experiences and take variation between individuals into account. The latter feature is important, because patients respond differently to anesthetics for a number of reasons, some of which we know (e.g., gender differences in pharmacodynamics and pharmacokinetics). Today's monitors based on electroencephalography, such as the Bispectral Index® (BIS®) or spectral edge frequency (SEF) and median frequency (MF), generally discriminate between conscious and unconscious states of mind as measured by patients' responsiveness to verbal or tactile stimuli,7 but individual variation is not yet fully accounted for and may be observed at comparable levels of sedation. The imperfect sensitivity to individual characteristics partly arises from using a database as a reference model, which renders the monitors probabilistic in nature. The auditory evoked potential, conversely, is a promising tool based on electroencephalographic responses in the individual brain, but this type of monitor has only rarely been used and studied during anesthesia. Its clinical utility therefore remains uncertain. Physiologic signs that are traditionally used to monitor awareness such as changes in hemodynamics, respiration, muscular, or autonomic activity generally fail to indicate cognitive change.8 It must be noted that these

* Instructor, Department of Anesthesiology, Emory University School of Medicine, Lecturer, Department of Psychology, Emory College of Emory University.
† Professor, Department of Anesthesiology; Associate Professor, Department of Medical Psychology and Psychotherapy, Erasmus MC.
‡ Received from the Departments of Anesthesiology and Medical Psychology and Psychotherapy, Netherlands Institute of Health Sciences, Erasmus MC-University Medical Center, Rotterdam, The Netherlands. Submitted for publication July 22, 2002. Accepted for publication April 16, 2003. Support was provided solely from institutional and/or departmental sources. Electroencephalographic equipment was borrowed from Aspect Medical Systems Inc. (Newton, MA) and Aspect Medical Systems Int. (Leiden, The Netherlands). This work was partly presented at the Fifth International Conference on Memory, Awareness and Consciousness (SMAC), June 1–3, 2001, New York, New York.

Address correspondence to Dr. Kerssens: Emory University School of Medicine, Grady Health System (Suite 6D016), 80 Jesse Hill Jr Drive, Atlanta, Georgia 30303. Address electronic mail to: chantal_kerssens@emoryhealthcare.org. Individual article reprints may be purchased through the Journal Web site, www.anesthesiology.org.
parameters were mainly studied in relation to conscious recall and not necessarily in relation to awareness.

As part of a randomized controlled study of memory function during deep sedation (Bispectral Index [BIS], 60–70) with propofol and alfentanil, we assessed response to verbal command while recording electroencephalographic and hemodynamic variables. On the basis of a large number of observations, this article reports on the merits of modern and traditional methods to monitor awareness during sedation as well as on the feelings of patients who consciously recalled awareness episodes. We also explored the possibility of predicting postoperative conscious recall from physiologic variables recorded during anesthesia.

Materials and Methods

After approval from the local human investigations committee, we consented and included 56 healthy (American Society of Anesthesiologists I–II) outpatients scheduled to undergo orthopedic (n = 45), general (n = 7), or plastic (n = 4) surgery under general anesthesia. Patients (25 women, 31 men) were aged (mean ± SD) 37 ± 10 yr (range, 19–58 yr), fluent in Dutch, and reported intact hearing and no history of drug abuse or current use of psychoactive medication. To avoid noxious stimulation and confounding effects thereof, anesthesia was induced 30 min before surgery. During this presurgical study period and while a hypnotic state was maintained at BIS 60 to 70, we assessed response to command while recording common parameters of hypnotic adequacy. After conclusion of the study period, the hypnotic state was deepened to BIS 45 (approximately) and surgery was started. After recovery, patients were interviewed about conscious recall.

Electroencephalography was measured using an A1000 monitor (Aspect Medical Systems Inc., Newton MA) and a two-referential montage. Four self-prepping electrodes (Zipprep; Aspect Medical Systems Inc.) were attached to the following sites: channels 1 and 2 to the left and right outer malar bone (At1 and At2), a referential electrode midway on the forehead (Fp2), and a ground electrode approximately 2 cm right from the reference electrode (Fp2). Electrode impedance remained less than 5 KΩ during electroencephalographic recordings. The following data were automatically and continuously recorded throughout the presurgical anesthetic period: BIS, SEF, and MF every 5 s, and heart rate (HR) and mean arterial pressure (MAP) every 5 min.

The anesthetic procedure was standardized and consisted of target-controlled infusion with propofol using an intravenous accurate control infusion pump (Alaris Medical Systems, San Diego, CA) with Diprifusor software (AstraZeneca, Macclesfield, Cheshire, United Kingdom) targeting plasma concentration propofol. Patients received no premedication, and anesthesia was induced with target-controlled infusion of 6 μg/ml propofol. After loss of the eyelash reflex, the lungs were ventilated with 100% oxygen. When BIS decreased to less than 80, an alfentanil (20 μg/kg) bolus was injected intravenously, followed by succinylcholine (1 mg/kg) when BIS decreased to less than 60. The trachea was intubated, and the lungs were mechanically ventilated with a mixture of air and oxygen (60:40%). When the train-of-four indicated return of muscular activity, a cuff was inflated to 250 mmHg around the forearm of the dominant hand. The isolated forearm technique (IFT) prevented the hand from being paralyzed when vecuronium (0.1 mg/kg) was subsequently administered. Propofol plasma concentration was targeted to BIS 60 to 70 for the remainder of the presurgical period.

At regular intervals, approximately once every 50 s, the observer (C.K.) determined awareness in terms of response to verbal command. A command started with the patient’s first name, followed by stroking the palm of the nonparalyzed hand. Patients were then asked to squeeze the observer’s hand once. When no squeeze occurred within approximately 10 s, responsiveness was scored absent (nonresponse). Patients who did squeeze once were subsequently instructed to squeeze twice. Failure to squeeze twice was considered an inadequate (equivocal) response, whereas squeezing twice evidenced an adequate (unequivocal) response, indicating awareness. In these instances, we asked patients to squeeze twice again if they felt comfortable or to stretch their fingers if not. In patients who indicated that they felt uncomfortable, target-controlled infusion was increased with 0.2 or 0.5 μg/ml propofol, depending on the going concentration (less than or greater than 3 μg/ml, respectively). If necessary, additional alfentanil (1 mg) was given. Before patients entered the operating room, propofol infusion was increased until BIS approximated 45 and the cuff, headphones, and electrodes were removed.

On the ward, just before hospital discharge, patients were interviewed about conscious recall with the following questions: (1) What is the last thing you remember before falling asleep? (2) What is the first thing you remember after waking up? (3) Do you remember anything in-between? (4) Did you dream?

Statistical Analysis

Because the incidence of awareness and conscious recall was unknown at the outset of the study, data were analyzed on a post hoc basis. Feelings were addressed by interviewing patients, who reported recall in more detail (e.g., what do you remember, how often were you given a command, how did you feel). Facts about awareness were addressed by associating the three types of response to command with recordings of electroencephalographic and hemodynamic variables. Automatic data logging allowed each response to be associated with a mean value for BIS, SEF, MF, HR, and MAP, which took

Anesthesiology. V 99, No 3, Sep 2003
the data preceding potential responses into account. We analyzed how well these parameters could monitor awareness and would thus discriminate between nonresponses and unequivocal responses to command. For this purpose, we used a random regression model for dichotomous data (a response is either present or absent) and the Generalized Estimating Equation method to estimate prediction performance of each parameter. Because data were obtained from repeated measurements (longitudinal data), observations were considered not to be independent, which standard regression analysis requires. The Generalized Estimating Equation method allows modeling of longitudinal data because it takes the correlated nature of such data into account. Using Statistical Analysis Systems (SAS 8.0; SAS Institute Inc., Cary, NC) software, BIS, SEF, MF, HR, and MAP were entered as covariates (predictor variables) of nonresponse versus unequivocal response to command. Finally, we analyzed differences between patients with and without conscious recall using ANOVA tests (SPSS 10.0; SPSS Inc., Chicago, IL). $P < 0.05$ was considered statistically significant. Data are presented as mean $\pm$ SD.

### Results

Patients were anesthetized for $39 \pm 11$ min in the presurgical study period, followed by $45 \pm 17$ min of general anesthesia for surgery. The IFT was implemented for $24 \pm 5$ min, during which time commands were given over a period of $19 \pm 2$ min. A total of 1,082 commands were given ($19 \pm 3$ per patient). No response was observed to 887 commands (82%), an equivocal response was observed to 56 commands (5%), and an unequivocal response was observed to 139 commands (15%). Fifteen patients (27%) did not respond to command at any time, whereas 37 patients (66%) responded unequivocally at some point during their anesthesia (range, 1–16 times).

Electroencephalographic and hemodynamic measurements during the three types of response to command are shown in table 1. For informative purposes, this table also shows the traditional electroencephalographic frequency bands (delta, theta, alpha, and beta) with their associated power. Because band powers are of limited utility for anesthesia-related applications and do not serve as on-line monitors of hypnotic adequacy, they were not considered for analysis of their predictive value to awareness. Nonetheless, our data show that changes in band power are associated with transitions from sleep (nonresponse) to awareness (unequivocal response) and thus underline the usefulness of electroencephalographic monitoring for anesthesia-related applications. Simultaneous inclusion of the remaining five parameters (BIS, SEF, MF, HR, and MAP) in the regression analysis yielded inconclusive results, because none of these parameters discriminated between unequivocal response and nonresponse. When each parameter was separately analyzed, however, all except HR predicted awareness. The latter observation combined with the former indicated that parameters shared predictive characteristics (“multicollinearity”), which makes sense given the mutual (central nervous system and autonomic nervous system) origin of variables.

A slightly different approach was therefore adopted to compare the predictive ability of parameters by consecutively analyzing all combinations of three parameters.

### Table 1. Electroencephalographic and Hemodynamic Variables during Three Types of Response to Command

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nonresponse ($n = 887$)</th>
<th>Equivocal ($n = 56$)</th>
<th>Unequivocal ($n = 139$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta power, %</td>
<td>25.0 ± 13.6 (24.1–25.9)</td>
<td>22.5 ± 14.7 (18.6–26.5)</td>
<td>13.3 ± 8.3 (11.9–14.7)</td>
</tr>
<tr>
<td>Theta power, %</td>
<td>10.4 ± 4.0 (10.2–10.7)</td>
<td>9.3 ± 3.1 (8.5–10.2)</td>
<td>7.1 ± 2.9 (6.6–7.6)</td>
</tr>
<tr>
<td>Alpha power, %</td>
<td>33.1 ± 9.4 (32.4–33.7)</td>
<td>31.1 ± 8.1 (28.9–33.3)</td>
<td>27.9 ± 9.2 (26.3–29.4)</td>
</tr>
<tr>
<td>Beta power, %</td>
<td>31.5 ± 13.5 (30.6–32.4)</td>
<td>37.0 ± 13.4 (33.4–40.6)</td>
<td>51.7 ± 13.9 (49.4–54.1)</td>
</tr>
<tr>
<td>Spectral edge frequency</td>
<td>20.3 ± 2.1 (20.2–20.5)</td>
<td>21.7 ± 1.9 (20.6–21.6)</td>
<td>22.7 ± 2.0 (22.4–23.0)</td>
</tr>
<tr>
<td>Median frequency</td>
<td>10.7 ± 2.7 (10.5–10.9)</td>
<td>10.7 ± 2.6 (10.0–11.4)</td>
<td>13.1 ± 2.5 (12.7–13.6)</td>
</tr>
<tr>
<td>Bispectral Index</td>
<td>63.2 ± 4.9 (62.9–63.5)</td>
<td>64.3 ± 4.3 (63.1–65.4)</td>
<td>67.3 ± 4.4 (66.5–68.0)</td>
</tr>
<tr>
<td>Heart rate</td>
<td>68.1 ± 11.6 (67.3–68.8)</td>
<td>68.0 ± 12.1 (64.7–71.3)</td>
<td>69.4 ± 13.6 (67.0–71.9)</td>
</tr>
<tr>
<td>Mean arterial pressure</td>
<td>84.3 ± 16.3 (83.2–85.4)</td>
<td>89.5 ± 14.8 (85.5–93.6)</td>
<td>88.8 ± 17.1 (85.7–91.9)</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD (95% confidence interval for mean). Power refers to the amplitude ($\mu V$) of waveforms in the electroencephalogram, which typically fall into one of four frequency bands: delta (0.5–3.5 Hz), theta (4.0–7.75 Hz), alpha (8.0–13.5 Hz), and beta (13.75–30 Hz) frequency. In general, high-frequency waveforms of low amplitude characterize an awake conscious brain.
The results (table 2) showed that HR never predicted awareness. MAP was a significant predictor \((P < 0.01)\) when HR was excluded from the analysis, but in these cases, electroencephalographic measures always yielded stronger predictors \((P < 0.0001)\). When HR and MAP were included with an electroencephalographic measure, neither predicted awareness in contrast to a highly significant electroencephalographic predictor. BIS, SEF, and MF all performed well \((P < 0.0001)\), although MF lost its predictive value when SEF was simultaneously included in the analysis. This suggests that SEF is a better predictor than MF. When BIS, SEF, and MF were simultaneously compared (analysis 10, table 2), only BIS predicted awareness reliably \((P < 0.05)\).

Conscious recall was assessed in all patients 2.8 \pm 0.5 \text{ h} after recovery from anesthesia. When asked whether they remembered anything in-between falling asleep and waking up, nine patients (16\%) responded affirmatively. Table 3 summarizes their memories. Foremost, all nine patients with conscious recall felt at ease after surgery. Looking back, five clearly expressed having felt fine during the awareness episode. One patient felt “closed in,” and two feared experiencing pain or the start of surgery. These patients reported that being told at the time what was happening and what they could expect had been a great relief. In dealing with the commands, three patients indicated that they had wanted to respond verbally but were unable to (without understanding why, the interviews suggested). Another patient reported having trouble understanding that he was being addressed and felt distressed over whether he complied with the commands. Similar distress over responding was expressed by two other patients and suggests that patients’ proprioception was distorted during sedation anesthesia. As our patients indicated, feedback from the outside world may fill the gap between the intention to move and the internal subjective perception of movement. Finally, it should be recognized that conscious recall of commands closely matched the number of times patients actually responded (table 3, Pearson correlation = 0.96).

Because only one quarter of patients responding to command reported conscious recall, we explored sources of variation in patients with recall \((n = 9)\) and those without \((n = 47)\). Preoperative data, reported elsewhere, revealed no differences between groups. Intra-anesthetic parameters during unequivocal responding to command are displayed in table 4. Patients with

---

### Table 2. P Values for Predictor Variables in Logistic Regression Analyses of Unequivocal versus Nonresponse to Command

<table>
<thead>
<tr>
<th>Predictor</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIS</td>
<td>&lt;0.0001</td>
<td>×</td>
<td>×</td>
<td>ns</td>
<td>&lt;0.0001</td>
<td>×</td>
<td>ns</td>
<td>×</td>
<td>&lt;0.0001</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>SEF</td>
<td>×</td>
<td>&lt;0.0001</td>
<td>×</td>
<td>&lt;0.0001</td>
<td>×</td>
<td>&lt;0.001</td>
<td>×</td>
<td>&lt;0.0001</td>
<td>&lt;0.001</td>
<td>×</td>
</tr>
<tr>
<td>MF</td>
<td>×</td>
<td>×</td>
<td>&lt;0.0001</td>
<td>×</td>
<td>&lt;0.0001</td>
<td>ns</td>
<td>×</td>
<td>ns</td>
<td>×</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>MAP</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>HR</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

This table indicates the usefulness of Bispectral Index (BIS), spectral edge frequency (SEF), median frequency (MF), mean arterial pressure (MAP), and heart rate (HR) for awareness monitoring and displays their ability to discriminate between unequivocal responses to command (awareness, \(n = 139\)) versus nonresponses to command (unconscious, \(n = 887\)). In 10 consecutive analyses, displayed in separate columns, all combinations of three parameters were explored. In each analysis, two parameters were left out (×). All analyses were performed on the same database.

ns = statistically nonsignificant \((P \geq 0.05)\).

---

### Table 3. Overview of Patients with Conscious Recall of Awareness during Anesthesia

<table>
<thead>
<tr>
<th>M/F</th>
<th>Age (yr)</th>
<th>No. of Unequivocal Responses</th>
<th>No. of Commands Recalled</th>
<th>Recollection</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>46</td>
<td>4</td>
<td>4</td>
<td>Squeeze hand. I felt all right, no panic. Wanted to talk.</td>
</tr>
<tr>
<td>M</td>
<td>43</td>
<td>16</td>
<td>10</td>
<td>Squeeze hand and how I felt, then I fell asleep. It felt all right.</td>
</tr>
<tr>
<td>F</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>My name and how I felt, a lot of questions. It felt all right.</td>
</tr>
<tr>
<td>F</td>
<td>33</td>
<td>2</td>
<td>3</td>
<td>My name, squeeze hand. I wanted to talk but couldn’t. I wasn’t afraid but felt closed in and a little awkward.</td>
</tr>
<tr>
<td>M</td>
<td>29</td>
<td>5</td>
<td>3</td>
<td>My name, squeeze hand. I had trouble to understand it was about me. Distress over responding, whether I succeeded.</td>
</tr>
<tr>
<td>F</td>
<td>41</td>
<td>3</td>
<td>3</td>
<td>Stretch fingers; remark [&quot;Look, she stretches her fingers.&quot;] I tried to respond but was not sure whether I succeeded. It felt all right.</td>
</tr>
<tr>
<td>M</td>
<td>23</td>
<td>7</td>
<td>4</td>
<td>Squeeze hand. No sense that I squeezed but understood that I succeeded. Not frightened but feared feeling pain. Glad to hear I was getting more anesthetic.</td>
</tr>
<tr>
<td>F</td>
<td>32</td>
<td>4</td>
<td>3</td>
<td>You called out but I couldn’t respond. Wanted to, but my arm didn’t go. Later sensed that it moved and then I fell asleep. Not afraid but worried that you would think I was asleep and surgery would start. Name, squeeze hand, a lot of questions. Felt all right, not afraid.</td>
</tr>
</tbody>
</table>

F = female; M = male.
Mean arterial pressure 87.0
Heart rate 72.9
Bispectral Index 67.6
Median frequency 13.1
Alpha power, % 27.4
Theta power, % 7.4
Unequivocal response, % 29.6

Discussion

Much effort has been directed in recent years toward developing a reliable monitor of anesthetic adequacy so as to prevent intraoperative awareness from happening. Because the brain is the target effect site of anesthetic agents, several measures have evolved around electroencephalographic activity. Whereas the SEF and MF are derived from power (amplitude) analysis of the electroencephalogram, the BIS® also incorporates synchronization of brain waves (phase coupling) into its calculation. Monitors such as these are based on the notion that amplitude and synchronization increase with deepening sleep and hypnotic state. The BIS®, SEF, and MF have been found to predict consciousness with much better accuracy than hemodynamic variables such as HR and blood pressure. Prediction probabilities are not yet per-
fused, most felt reassured by our proposed precautions to signal awareness, knowing it would not go unnoticed. Especially in situations in which anesthesia is expected to be light, awareness may be openly discussed.

Modern neurophysiologic techniques provide for other means to monitor awareness. Given that consciousness is a (higher) cortical function, it is not surprising that electroencephalographic indices predicted awareness better than autonomic signs. Given that the BIS® incorporates more characteristics of the electroencephalography into its calculation than spectral indices such as SEF and MF, it is also not surprising that the BIS® discriminated best between response to command and unresponsiveness. With a large number of observations, our findings corroborate what previous studies have suggested and strongly support the validity of the BIS® as well as SEF as awareness monitors during sedation and general anesthesia. Even though they are not 100% sensitive, a critique raised by skeptics of recent technologic advances, the BIS® and the SEF predict awareness more accurately than most often used traditional indices. The serious aftereffects of undesired intraoperative awareness do not warrant caution over the sensitivity of new monitoring techniques, even though reactions to awareness without concurrent recall are unknown.

With respect to prediction of postoperative recall, only HR and responsiveness to command discriminated between patients with and without conscious recall. Given that HR is a reportedly unreliable indicator of recall, the increased HR in patients with conscious recall observed in this study may perhaps be attributed to distress. As the interviews indicated, the systematic evaluation of response to command worried patients about whether or not they succeeded in responding. Rather than being indicative of postoperative conscious recall, increased HR may therefore have arisen as a result of our instructions. Furthermore, the minor difference in HR of patients with and without conscious recall casts doubt on its clinical value as a predictor of conscious recall, especially because anesthesiologists do not judge clinical signs uniformly.

Of the various electroencephalographic parameters, none discriminated between patients with and without conscious recall. This finding underlines the notion that the BIS and similar parameters were developed and are suitable to monitor awareness but not necessarily memory function. BIS and SEF were similar for patients with and without conscious recall, whereas the former group responded more often to command. This strongly suggests that some patients are more responsive to stimulation than others at equisedative levels of anesthesia and are thus prone to perception. Because responsiveness is related to conscious recall, it is worthwhile to direct future attention toward delineating the features of patients with awareness and recall so as to identify those at risk. Another way to prevent recall is to provide a level of anesthesia under which unequivocal response is absent. In this study, such a level was obtained at BIS less than 57, SEF less than 19 Hz, and MF less than 5 Hz.

We conclude that it is important to monitor awareness during surgery. Our data show that modern measures of hypnotic state such as the BIS® and SEF are useful tools in this respect. Conscious recall is not necessarily indicated by these parameters and is best predicted by patient responsiveness to verbal command during anesthesia. Awareness can be openly discussed with patients in advance provided that an effort is made to detect wakefulness during anesthesia. Acknowledging awareness as it occurs and providing comforting feedback may reduce neurotic symptoms in patients who experience awareness.

The authors are grateful to the patients and staff from the Ambulatory Surgical Unit (Erasmus Medical Center, Rotterdam, The Netherlands) for their cooperation; to Aspect Medical Systems (Newton, MA and Leiden, The Netherlands) for lending the electroencephalographic equipment; to Ian F. Russell, M.D. (Department of Anaesthesia, Hull Royal Infirmary, Kingston upon Hull, United Kingdom) for his advice regarding the IFT; to Dries van der Woerd, M.D. (Department of Thoracic Anaesthesia, Erasmus Medical Center, Rotterdam, The Netherlands), for his clinical assistance; and to Hugo J. Duijvenvoorden, Ph.D. (Department of Medical Psychology and Psychotherapy, Erasmus Medical Center, Rotterdam, The Netherlands), for his statistical advice.

References


Anesthesiology. V 99, No 3, Sep 2003