On being aware: Patient recall of intraoperative events

MICHAEL P. DOSCH, CRNA, MS
Detroit, Michigan

Intraoperative awareness in the patient undergoing general anesthesia, with or without later recall, is studied in this review of the literature.

General anesthetics, both inhaled and intravenous, produce differing amnestic effects with a high degree of variability in response among individual patients. Clinical signs of light anesthesia do not correlate with awareness. While no reliable monitors exist, evoked potential monitoring does show promise as a gauge of depth. The most important factor in preventing later recall is careful monitoring of operating room conversation, since it has been shown that an anesthetized patient can be aware of threatening or demeaning remarks made intraoperatively. These remarks, when accompanied by verbal amnesia, can produce harmful psychological effects.

Balanced and narcotic techniques are felt by many to carry a higher risk of inadequate amnesia. However, prospective studies show an incidence of approximately 1% awareness, regardless of the techniques utilized. Future study is needed to define more precisely the concentration of agents which will reliably prevent memory formation.

The literature concerning awareness of intraoperative events embraces a number of areas of concern for the nurse anesthetist.

Philosophically, the idea of a fully aware patient undergoing surgery is distasteful. Anesthetists expect that awareness will be extinguished by general anesthetics. Technically, literature on the subject is interesting because it presents widely varying results regarding the usefulness of various agents and techniques in preventing awareness. Historically, there are no reported cases of awareness associated with clinically adequate anesthesia prior to the widespread use of neuromuscular blocking agents in the 1940s. Legally, awareness under general anesthesia may be the result of negligence and has already given rise to law suits.

Scope of the problem

Awareness is defined as the ability of the patient to recall, with or without prompting, any event that occurs while he or she is presumed to be unconscious. Dreams may be taken as a train of thoughts or images which the patient believes to have occurred between the induction of anesthesia and his return to consciousness.

The reported incidence of awareness among anesthetized patients ranges from as little as 1% to as much as 40%. Dreams have been reported to occur anywhere from 2% to 57% of the time. Wakefulness, defined as amnestic awareness or the ability to follow commands without later recall,
has been reported to occur in as many as 44% of all patients. The inconsistencies in the data are related primarily to the sophistication of the methods used to detect awareness. Although patients rarely complain, they may very well provide recollections when asked properly.

History

Prior to the introduction of muscle relaxants in the 1940s, intraoperative awareness was not considered a problem. If a patient was adequately relaxed and immobilized enough for surgery to proceed, it was taken as evidence of a sufficient concentration of anesthetic in the brain to prevent recall.

With the use of relaxants in clinical practice, the situation has changed. Relaxants, as well as anticholinergics, abolish the clinical signs of depth of anesthesia, making it possible to have a motionless yet conscious patient in whom the time-honored clinical signs and stages are unreliable. And although awareness exists even in situations where the anesthetist believes there is adequate depth, there is still no reliable means of detecting awareness in real time. New approaches to monitoring the depth of anesthesia will be discussed.

Awareness per se is not really the issue, since patients undergoing surgery under local or regional anesthesia are aware of intraoperative events without experiencing ill effects. Intentional awakening for which the patient is prepared, such as during a Harrington rod procedure, does not seem to be painful or associated with psychological problems postoperatively. Instead, the problem occurs when the patient who expects to be unconscious awakens to experience passively a situation over which he has no control. The patient may have feelings that things are not going as expected, but because he is paralyzed, the patient cannot correct the situation by crying out for help.

Physiology of awareness and memory formation

The reticular activating system (RAS), discovered only 40 years ago, is the functional substrate of awareness via its cortical projections. Activated by collaterals from the sensory tracts—particularly pain and proprioceptive impulses—the RAS system provokes an arousal reaction in the cerebral cortex.

Memories are of three types—sensory, primary and secondary. Sensory memories are traces of sensory signals that persist for approximately one second in the sensory cortices. Primary, or short-term, memories last from a few seconds to a few minutes and are instantaneously available to consciousness, with new information permanently displacing old. Secondary, or long-term, memories sometimes are stored for years. Their content is unconscious, but it can be brought to consciousness by searching the memory stores. Preservation of data in secondary memory does not depend upon continuous activity within the central nervous system (CNS), since the brain can be inactivated by cooling, general anesthesia, hypoxia or ischemia and still retain secondary memories.

Secondary memories must then result from physiochemical changes in the synapses, a process referred to as consolidation. At least five to 10 minutes are required for minimum consolidation and 60 minutes for maximum consolidation.

In other words, if stimuli are presented and then followed within five to 10 minutes by concussion, the sudden application of deep anesthesia or the deepening of a light plane of anesthesia, consolidation is prevented. If the sudden inactivation of CNS function is delayed more than five to 10 minutes, some consolidation will have occurred, producing facilitated circuits within the brain which are referred to as engrams.

The brain has a natural tendency to rehearse new information, especially that which catches the mind’s attention. This rehearsal facilitates the consolidation process. Part of the storage process is codification; that is, the mind stores not just raw data but also seeks and stores similarities and differences between that data and information already present.

Whether a given input will be stored depends on its strength and the sensory threshold at the time. The memory trace formed has a gradual growth and decay pattern, depending on the strength of the initial input. Recall implies an engram of sufficient intensity to reach the conscious threshold. Weak memories may be recalled when the conscious threshold is lowered by, for example, hypnosis.

Anesthetic impact on memory formation

General anesthesia does not produce a complete absence of neural function. Increased depth of anesthesia decreases the intensity of sensory input and the engrams formed by slowing down sensory transmission and interfering with consolidation. Therefore, recall of operative events may reflect a transient lightening of anesthesia coincident with the presentation of a stimulus of high emotional content. However, it is important to note that
recall can occur during apparently adequate planes of anesthesia as well.8 The auditory pathway, particularly the inferior colliculus, is one of the most metabolically active portions of the CNS.9 Although CNS activity is reduced by most anesthetics, it continues to function during certain stages of anesthesia.8 Pain, sounds or conversation are recalled most often.18 Frequently, remarks that are recalled are those that are frightening to the patient. Even though hypnosis, which can enhance recall, is not completely understood, the fact that recall occurs in any state of consciousness proves that memories can be formed during general anesthesia.15

Each drug or combination of drugs produces different electroencephalographic (EEG) patterns14 and different effects at sites within the CNS. The intensity of the anesthetic effect varies, unless the agent is administered at a rate proportional to that of its elimination.

There is a considerable range of response between individuals and within any given individual under different conditions.14 For instance, patients may show very different responses to light anesthesia, with some showing somatic signs (movement) and others autonomic signs. Still others may be able to follow commands without any changes in vital signs.14

Somatic and autonomic responses to surgical stimulation are the anesthetist's main sources of information about the depth of anesthesia. However, these responses do not necessarily correlate with awareness.8 Increasing the dosage of anesthetic in an effort to prevent awareness is not the solution. Achievement of an effective concentration in 95% of individuals (EC95) leaves 5% who will be inadequately anesthetized, even though the EC95 represents an excessive concentration for most patients.14

Hearing is commonly considered the first function to return as general anesthesia lightens.8 There may be a scientific basis for this belief. While inhaled agents (halothane, enflurane, isoflurane) markedly reduce neuronal activity, particularly in the RAS and the spinal cord,16 brainstem auditory evoked potentials (BAERs) are well preserved during isoflurane anesthesia. Halothane and enflurane increase the latency of the BAER, decrease its amplitude or both.18

Anesthetic levels of narcotics with 70% nitrous oxide or low doses of volatile agents have little effect on evoked potentials.18 Although intravenous anesthetics and volatile agents abolish the cortical portion of the BAER, some spare the brainstem portion of the auditory pathway.8 Surgical anesthesia, then, is not a unique state with an immutable, single effect on memory. Rather, the occurrence of amnesia is probabilistic, and even without conscious recall memory traces amenable to hypnosis may form.13

Anesthesia increases sensory thresholds and decreases the late components of evoked potentials, causing the engrams formed to be weak and drop rapidly below the threshold of intensity necessary for recall. Anesthetic effects on memory are variable, depending on the agent used, the dose and the patient.18

Effects of awareness

In 1975, Blacher17 first described a syndrome of traumatic neurosis as the result of awakening paralyzed during surgery. The syndrome is characterized by irritability, a preoccupation with death, repetitive nightmares and a reluctance to speak of awakening during surgery for fear of being thought insane. This syndrome may be more common than is generally believed and represents evidence that some patients may be able to record and process stimuli even when they appear to be adequately anesthetized. Fortunately, explaining the situation to the patient produces a dramatic cure.

Routine administration of amnestic drugs, such as the benzodiazepines, may worsen the situation by suppressing recall and leaving the emotional content of the experience unacknowledged.14 Patients seem to need to discuss the situation before they are free of the symptoms. Therefore, rather than protecting the patient, amnestic drugs can prevent the anesthetist from learning about awareness.14

Methods of detecting awareness

There is no reliable means of predicting the risk of awareness in any given patient. The most common technique for detecting awareness is interviewing the patient. However, this approach suffers from the obvious disadvantage of offering only retrospective information.

Tunstall's isolated forearm technique6,6 involves application of a tourniquet to the upper limb to isolate it from muscle relaxants, then assessing the patient's ability to grasp on command. However, this technique does not correlate well with other clinical signs of light anesthesia, is somewhat cumbersome and is unreliable after 20 minutes.6 Further, the technique detects wakefulness, which does not correlate well with later recall.7 Another retrospective technique, Cormack's time
to first response, involves considering all patients who show some response to a command within 15 seconds after nitrous oxide is discontinued to have been at risk of awareness.

The EEG represents an expensive technology. It is difficult to interpret without training and its correlation with depth of anesthesia can be obscured unless all other factors that can influence it are held constant. Since cerebral ischemia, blood glucose, blood pressure, hypoxemia, changes in carbon dioxide tension, temperature, electrolytes and even surgical stimuli can alter the EEG, interpreting it in relation to intraoperative awareness would seem a herculean task. Consequently, several techniques for computer-assisted interpretation of the EEG have been developed, such as power spectrum analysis, the compressed spectral array and the cerebral function monitor. Sensory-evoked responses as a gauge of depth (and thus, risk of awareness) warrant further investigation. However, all these techniques are expensive and rare in use at few centers.

While hypnosis has been used extensively as a means of assessment for recall, it is not practical clinically. Some feel it is a valuable technique. Reportedly, statements that patients hear can have a great effect on their attitudes toward the surgeon and their own recoveries. Cheek emphasizes that hearing is preserved in general anesthesia, with the side from which the voice came and its attitude remaining distinct. Since the understanding of anesthetized patients is literal and predictable, intraoperative conversation can be misinterpreted.

**Effect of Inhaled agents**

Many intriguing studies have been conducted on the effects of volatile agents on recall that contradict the common clinical wisdom that it is only when using narcotic techniques that anesthetists must be concerned with awareness. Levinson used ether and nitrous oxide on 10 volunteers until a stable, irregular, slow, high-voltage EEG was induced, a pattern representative of stage IV sleep or surgical anesthesia. At that point, he said to each patient, "Just a moment. I don't like the patient's color. Much too blue. His (her) lips are very blue. I'm going to give a little more oxygen." One month later, none of the volunteers had any conscious recall of surgery, but under hypnosis four of the 10 repeated the anesthetist's words almost exactly. Another four remembered hearing something but became anxious and either awoke from hypnosis or blocked further questions. Interestingly, the operative EEG recordings in some of the patients showed responses as the words were spoken.

Dubovsky and Trustman, using letter-word pairs presented during light planes of halothane, enflurane or barbiturate-nitrous oxide anesthesia, found no recall except in one case where the patient opened her eyes and winked at the anesthesiologist intraoperatively. They concluded that there was no correlation between the agent used and recall and that recall could only take place during light anesthesia. They did concede, however, that information which is meaningful or associated with strong emotion is more likely to be remembered than the meaningless stimuli used in their study.

Saucier, Walts and Moreland reported a case of recall during halothane-nitrous oxide anesthesia in which gas delivery problems and light anesthesia were ruled out. Their patient had no changes in vital signs, no sweating, lacrimation or movement, and no relaxants were used. Halothane was titrated to changes in vital signs, balancing the level of surgical stimulation. Respirations were spontaneous and proved adequate by normal blood gases. Yet, the following day, the patient reported conversations that took place at the start of the operation (halothane 3.5%) and one hour after the start of the operation. He denied any pain. The authors could find no fault with the anesthetic and stressed the necessity for care in conversation among the operating room staff at all times.

Wilson, Vaughan and Stephen, in a prospective blinded study of 490 patients, found awareness in 1%, dreaming in 8% and hallucinations in 2% of their patients. They used an interview technique, asking the patients the last thing they recalled before induction and the first thing they remembered upon awakening. They tried not to lead the patients. Their study found no correlation between awareness and agent used, age, sex, and duration or type of surgical procedure.

Halothane, enflurane, fentanyl with droperidol, narcotics and ketamine all were associated with awareness, and no statistically significant difference was found between the inhaled and narcotic groups in the incidence of awareness. The diazepam premedication used in 44% of the patients was not effective in preventing awareness.

The authors concluded that changing from a balanced to an inhaled technique is not justified when trying to prevent awareness and that sacrificing the advantages of light anesthesia merely to obviate recall would be retrogressive.

In one of the most telling and recent studies on awareness, Bennett and Davis utilized a double-

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blind, placebo-controlled design to test whether learning accompanied by verbal amnesia occurs under general anesthesia. Fifty-five patients were anesthetized with thiopental-nitrous oxide plus either halothane or enflurane. The control group heard operating room sounds, while members of the experimental group heard a taped suggestion to touch their ears during the postoperative interview. None of the patients had verbal recall of intraoperative events when interviewed by a blinded two-person team. In the experimental group, 83% touched their ears during the interview, compared with 43% of the controls, which was highly significant statistically. When tested with hypnosis, 53% of the combined group had verbatim recall of intraoperative events.

The authors concluded that auditory evoked responses are preserved at all levels of anesthesia and that the CNS monitors the environment for significant information, even during clinically adequate anesthesia. They suggest that typical postoperative amnesia is dense and prevents verbal recall of intraoperative perceptions and their effects.

Balanced and narcotic anesthesia
Incomplete amnesia has been reported with low and high dose fentanyl, although reports of discomfort are infrequent. It is difficult to predict the appropriate dose of narcotic in any given patient, though dose requirements probably are higher in younger, healthier individuals with normal cardiac outputs. Smoking, ethanol consumption, altered protein binding and other kinetic factors produce unpredictable effects. Narcotics may cause profound analgesia and apnea without producing a loss of consciousness. Supplementation of narcotic anesthesia with other agents only increases the likelihood of amnesia but does not guarantee it.

Though the preponderance of case reports of incomplete amnesia have involved narcotic-based techniques, prospective studies have shown that the incidence of awareness with narcotic-based techniques is no higher than that obtained with inhaled agents. Although some practitioners are convinced of the increased risk of awareness associated with balanced and narcotic anesthesia, prospective studies have failed to document any such risk.

Other agents
Benzodiazepines are commonly used by anesthetists. They are reliable in producing amnesia, with midazolam perhaps more so than diazepam. Caution should be used when aminophylline is given concurrently, since it reverses the effects of the class. In addition, since recounting a traumatic event helps discharge the emotional tension associated with it, producing verbal amnesia with midazolam may worsen the syndrome associated with awakening while paralyzed during surgery.

Patient and surgery-related factors
Historically, anesthesia for cesarean section has been the area where incidence of awareness has been highest. However, the addition of 0.5% halothane or low doses of the other volatile agents to supplement nitrous oxide-thiopental anesthesia has resulted in most recent studies reporting the incidence of awareness to be less than 1%, without causing neonatal depression. A combination of morphine 0.2 mg/kg with diazepam 0.1 mg/kg given immediately after delivery also has been shown to be effective.

Pediatric anesthesia has received little attention. Awareness has been documented in children and may be more common than in adults. There are no prospective studies of awareness in children to the author's knowledge; thus the factors promoting pediatric awareness have not been explained. In children, anesthesia reversibly impairs long-term memory more than short-term memory.

A study of trauma patients was reported recently by Bogetz and Katz in an article that elicited much comment. Fifty-one patients having surgery for major trauma were seen postoperatively by an interviewer who was unaware of the anesthetic course and who did not use hypnosis. Among those who had received almost continuous anesthesia, 11% had been aware. In those where hemodynamic instability had necessitated interruptions in anesthetic delivery for 20 minutes or more, 43% reported awareness. The authors noted a tremendous variability in response. Of three factors known to decrease MAC—hypothermia, acute ethanol intoxication or hypotension—none did so reliably enough to prevent awareness.

Bogetz and Katz concluded that (1) awareness cannot be reliably predicted, (2) amnestic may not be safe in the hypovolemic patient, (3) operating room conversation should be respectful, (4) anesthesia should be given as soon as tolerated, and (5) the patient should be given an opportunity to discuss any instances of awareness in detail.

Alcohol consumption by a patient can affect the likelihood of awareness. In a case of awareness during high dose fentanyl anesthesia cited earlier, the patient's chronic alcohol use may have been a factor. One retrospective study documented an increased fentanyl requirement in alcoholics, and a
cross-tolerance between alcohol and thiopental also has been shown. Prospective studies are needed to investigate the common clinical beliefs that acute ethanol decreases MAC and that the sober chronic alcoholic requires increased anesthesia. Paradoxically, chronic alcohol consumption in rats that were sober when tested has been shown to decrease the brain concentration of halothane required to produce anesthesia.

**Strategies for the prevention of awareness**

Preventing awareness begins with an appreciation of the technical factors and associated conditions that may promote its development.

**Technical factors.** Several technique- and machine-related factors may promote the occurrence of awareness. The effect of ultra-short-acting intravenous barbiturates may lessen before volatile agents have built sufficient alveolar concentration, resulting in a period of lucidity. Insufficient time or ventilation with a volatile agent may be at fault. The barbiturates also have an intrinsic antianalgesic effect.

Low nitrous oxide concentration, or its omission, may be chosen for the critically ill patient. Critically ill or traumatized patients may exhibit cardiovascular instability requiring temporary lightening of anesthetic depth. Nitrous oxide relaxant techniques, when supplemented inadequately, may promote awareness. Nitrous oxide partial pressure sufficient to prevent awareness may be undeliverable without hypoxia at higher altitudes.

High volume anesthetic delivery systems may show a time lapse before the dialed-in concentration is actually being delivered. Air may dilute the anesthetic vapor if a hole in the ventilator bellows entrains it. The undetected failure of the nitrous oxide supply may occur.

**Associated conditions.** Awareness is more likely in obstetric anesthesia; in alcoholics; in chronic users of sedatives, tranquilizers and narcotics; in obese patients; in trauma patients; in patients with high metabolic rates and possibly in pediatric patients. Alcoholics are subject to both acute and chronic tolerance to anesthetics. Chronic tolerance occurs through induction of enzymes, whereas acute tolerance is the result of functional tolerance of the central nervous system to depressants. The mechanisms are similar for chronic users of sedatives, tranquilizers and narcotics. Awareness may be more likely in the obese patient secondary to altered pharmacokinetics and difficulties with intubation, which may necessitate a longer interval between induction and the introduction of maintenance agents.

**Strategies to lessen the incidence of awareness.** The fact that awareness is more likely in certain situations, and that its occurrence is not always preventable, leads to the construction of a protocol for lessening its incidence and ameliorating any ill effects for those patients who do experience it.

Anesthetists must be aware of those patient- and machine-related factors that promote the incidence of awareness. Awareness is more frequently reported following obstetric and cardiovascular procedures than in other areas of anesthetic practice. Informed consent for these patients should include a frank discussion of the possibility of awareness, though it is one of the less likely and less traumatic of the potential complications. Such discussion must be guided by information obtained during the preoperative assessment, as it may add to the patient's anxiety and may even increase the chances that he or she will have recall. If the possibility of awareness is discussed, the patient should be assured that it will be recognized if it occurs and managed appropriately.

Premedication may include amnestic agents, though the potential pitfalls of their use, as previously discussed, must be recognized. Scopolamine may be of benefit as part of the preoperative medication, though its value in preventing awareness is unproven. The use of a machine checklist to exclude the possibility of equipment-related failure of anesthetic delivery is mandatory.

Intraoperatively, the anesthetist should recognize that, though the clinical signs of light anesthesia may or may not be present during awareness, constant observation of the patient may help to detect those at risk. When awareness is detected, the patient's face can be stroked and the patient can be addressed reassuringly while the anesthesia is simultaneously deepened. As long as some level of anesthesia is already established, and the stimuli are not too unpleasant or vivid, deepening the level within 5 to 10 minutes after the stimuli are presented should prevent consolidation into secondary memories. The use of a mass spectrometer to monitor end-tidal anesthetic concentration may help to assure adequate depth.

The patient's auditory environment deserves consideration. The anesthetized patient should be treated with the respect he or she would be accorded if awake. Extraneous noise should be minimized. The anesthetist should recognize that auditory memories, especially those of hostile or threatening comments, are often the type of mem-
ory recalled. Many authors have suggested strategies to block these types of memories. These strategies include (1) carefully considering all conversation in the operating room, (2) offering positive suggestions via earphones, (3) playing soothing tapes or tapes of "white noise," or (4) simply blocking the external auditory canals. Discreet conversations in the postanesthesia area are also advisable, since patients may transpose memory for these events to the intraoperative period.

Many case reports of awareness during balanced techniques exist. Less well known are the case reports of awareness during inhalational anesthesia, and the prospective studies documenting the occurrence of awareness during clinically adequate inhalational anesthesia. Almost all prospective studies have failed to document an increased incidence of awareness when balanced techniques are used.

If using narcotic techniques, an induction with benzodiazepines has been suggested, or one may add sub-MAC (0.25-0.50 MAC) concentrations of an inhaled agent to help minimize recall. Skeletal muscle relaxants should be used in minimal doses and only when necessary, since they make judgment of depth more difficult. If they are used, advantage should be taken of periods when they are not necessary to assess depth. The use of relaxants without adequate sedation to facilitate ventilation in intensive care units should be condemned, as it leads to unpleasant, frightening recall.

Postoperatively, all interviewers should question the patient about possible awareness. The patient should be given an opportunity to discuss what happened, and allowed to explain his or her feelings. Defensiveness should be avoided, since one's reluctance to hear or accept what the patient has to say can result in conflict and litigation. Try to find and explain the reason for the occurrence without being overly apologetic, acting as though something terribly wrong occurred or as though one is afraid of being sued. Maintain a professional demeanor. An understanding, supportive, honest explanation, which does not invalidate the patient's experience, supplemented by a referral to a psychologist or social worker, if necessary, often serves to lessen any ill effects.

Research needs to address the concentration of agents that prevents memory formation and techniques to detect intraoperative awareness more reliably. The maintenance of anesthetic levels that are high enough to render virtually all patients unconscious (MAC x 1.3 = EC99) has the disadvantage of being a relative overdose in almost every patient, producing side effects and prolonging recovery.

Summary
Anesthesiists are legally liable and ethically bound to prevent awareness. It can occur in the absence of clinical signs of light anesthesia, even when inhaled anesthetics are used without muscle relaxants. To prevent awareness in their patients, anesthesiologists should understand the physiology of awareness and memory formation, the mechanisms of inhaled and injected general anesthetics in preventing awareness, the effects of intraoperative recall, the means of detecting awareness and the technical and surgical factors and associated conditions that may promote awareness. Anesthesiologists should also understand how to treat an episode of awareness if one occurs.

REFERENCES


**AUTHOR**

Michael P. Dosch, CRNA, MS, is a member of the didactic and clinical faculty of the Mount Carmel Mercy Hospital/Mercy College of Detroit Program of Nurse Anaesthesiology. He is a teaching nurse anesthetist at Samaritan Health Center in Detroit.