Awareness during anaesthesia

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Awareness during anaesthesia can be very distressing for a patient, particularly if accompanied by recall of the painful nature of surgery. This article explores the types, incidence, consequences, causes, management and avoidance of intraoperative awareness.

Types of awareness

The formation of explicit and implicit memories during anaesthesia and surgery (awareness) is considered potentially damaging to the human psyche. Explicit memory may be recalled spontaneously, or may be provoked by postoperative events or questioning. In contrast, implicit memory may not be consciously recalled, but may affect behaviour or performance at a later time. Awareness of conversations during surgery may be distressing for a patient, but awareness of total paralysis or the excruciating pain of surgical incision may alter a patient's life permanently. The consequences of intraoperative awareness are discussed below.

Incidence

Studies performed in the 1970s using 60–70% nitrous oxide as the sole anaesthetic agent revealed an incidence of awareness of up to 7% (1 in 14).[1] In recent times, the incidence of awareness with explicit recall of severe pain has been estimated at 0.03% of general anaesthetics (1 in 3000).[2] Conscious awareness without recall of pain is more common; it has been estimated at 0.1–0.7% (1 in 142–1000).[2,3] Awareness is almost twice as likely when neuromuscular block is used.[3]

Consequences

Awareness may have psychological sequelae for the patient, which include: insomnia, depression, anxiety and post-traumatic stress disorder (PTSD) with distressing flashbacks. The majority of patients who have suffered intraoperative awareness fears future surgery and anaesthesia.[4]

The occurrence of intraoperative awareness also has consequences for the anaesthetist. Recent examination of the American Society of Anesthesiologists' (ASA) Closed Claim Project revealed that 2% of all claims were for awareness.[5] Such claims are frequently successful, and poor anaesthetic technique is often blamed.

Causes

The risk of awareness correlates with depth of anaesthesia. Light anaesthetics, particularly where the patient is paralysed by a neuromuscular blocking agent, are associated with the highest risk of awareness. The depth of anaesthesia may be unduly light for several reasons. These are described below.

Selection of inadequate anaesthetic dose

Awareness is frequently associated with poor anaesthetic technique. Errors include the omission or late commencement of a volatile agent, inadequate dosing or failure to recognize the signs of awareness. Under-dosing of anaesthetic agent may occur during hypotensive episodes, when anaesthetic is withheld in an attempt to maintain arterial pressure. A number of surgical scenarios are associated with a higher risk of intraoperative awareness. These include: cardiac surgery, emergency surgery, surgery associated with significant blood loss and Caesarean section.

The selection of anaesthetic dose is based upon the patient's expected requirement. Patients vary significantly. Compared with young adults, there is a ~25% increase in minimum alveolar concentration (MAC) for volatile agents in young children, and a 25% reduction in the elderly (Table 1). These alterations are in relation to the published and commonly quoted values, which are true for an otherwise healthy and unmedicated population of 30–40-yr-olds. There is also a normally distributed variability in MAC that is independent of age (Fig. 1). There is evidence

Key points

Intraoperative awareness is associated with postoperative psychological sequelae for the patient and medico-legal consequences for the anaesthetist.

Awareness occurs after 1 in 3000 anaesthetics; it is twice as likely when neuromuscular block is used.

The most frequent cause of awareness is selection of an inadequate dose of anaesthetic agent. Assurance of >0.8 MAC end-tidal makes awareness unlikely.

The majority of the signs of awareness involve sympathetic nervous system activation; these may be masked by drugs or co-existing pathology.

In high-risk situations the use of a monitor of depth of anaesthesia is justified.

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Table 1 MAC values of commonly used inhaled anaesthetic agents (%)[10]

Anaesthetic agent	MAC aged 1 yr	MAC aged 40 yr	MAC aged 80 yr
Halothane	0.95	0.75	0.58
Enflurane	2.08	1.63	1.27
Isoflurane	1.49	1.17	0.91
Sevoflurane	2.29	1.8	1.4
Desflurane	8.3	6.6	5.1
Nitrous oxide	133	104	81

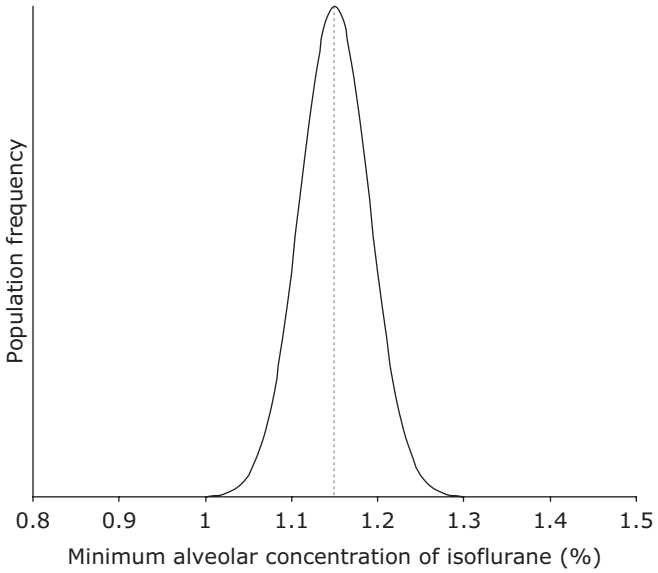

Fig. 1 Theoretical distribution of the minimum alveolar concentration (MAC) of isoflurane in a population of 30-yr-olds.

that the equivalent MAC concept for intravenous agents, i.e. minimum inhibitory concentration (MIC), has a greater variability. Thus, i.v. anaesthesia may be associated with an increased risk of under-dosage and awareness. A further reason that awareness may be more likely during total i.v. anaesthesia (TIVA) than during inhalational anaesthesia is that it is not possible currently to monitor, in real-time, the concentration of i.v. agents in the blood, while it is possible to monitor exhaled nitrous oxide and volatile agents.

A volatile agent's MAC value describes the concentration required, at 1 atm ambient pressure, to prevent 50% of subjects moving in response to a stimulus. It is clear that this definition does not embrace awareness or recall. Fortunately, clinical investigations have shown a reasonably reliable association between recall and MAC; patients exhaling more than 0.8 MAC are unlikely to recall intraoperative events, and spontaneous recall is virtually eliminated if >1 MAC is exhaled, except after a sudden increase in inspired concentration. Table 1 lists MAC values for the commonly used inhalational anaesthetic agents and describes the variation of these values with age.

End-tidal volatile concentration is not necessarily equivalent to brain partial pressure, and factors affecting this relationship will be discussed below.

Table 2 The clinical signs of awareness and factors that mask these signs

Sign of awareness	Factors masking the sign
Tachycardia	Heart block, β-blockers, hypothyroidism, autonomic neuropathy (e.g. diabetes, renal failure)
Hypertension	Heart block, β-blockers, hypothyroidism, vasodilators, epidural analgesia, blood loss, autonomic neuropathy
Sweating	Anti-muscarinic drugs (e.g. atropine, glycopyrrolate)
Tear production	Anti-muscarinic drugs, eye tape/ointment
Movement/grimacing	Neuromuscular blocking agents, sheets covering the patient
Tachypnoea	Neuromuscular blocking agents
Pupillary dilatation and reactivity to light	Anti-muscarinic drugs, opioids, ocular pathology, eye tape/ointment

Resistance to anaesthetic agents

Factors associated with a degree of resistance to anaesthetic agents include: pyrexia; hyperthyroidism; obesity; anxiety; young age; tobacco smoking; regular, heavy alcohol use; use of recreational drugs (e.g. opioids, amphetamines, cocaine); chronic use of sedatives (e.g. temazepam); and previous and repeated exposure to anaesthetic agents.[6–7] Factors associated with a reduction in MAC include: hypocapnia, pregnancy, hypothyroidism, hypothermia, hypotension, increased atmospheric pressure and old age. Increased atmospheric pressure does not alter brain sensitivity to anaesthetic agents, but increases the inspired and brain partial pressures for given inspired concentration. Depth of anaesthesia is related to brain partial pressure of the agent.

Equipment malfunction

Breathing system malfunctions and disconnections have been associated with awareness. Vaporizers may malfunction in a number of ways, each having the potential to deliver an inadequate dose of anaesthetic. These include: an empty vaporizer, miscalibration, impurities in the volatile agent (reducing its saturated vapour pressure) and disconnection from the anaesthetic machine. Blockage of an i.v. infusion pump or catheter, disconnection from the cannula or extravascular location of the cannula may risk awareness during TIVA.

Masking the signs of awareness

The clinical signs of awareness may be masked by some disease states and concurrent medications. These are described in Table 2.

Recognizing awareness

The signs of awareness are generated through sympathetic activation. These signs include: sweating, tachycardia, hypertension, tear formation, pupil dilatation and pupil reactivity to light (see Table 1). Apparently anaesthetized, unparalysed, patients experiencing noxious stimulation may move or grimace and this may be associated with postoperative recall of intraoperative events.

Awareness during anaesthesia may also be recognized through the use of a monitor of depth of anaesthesia (see below).

Monitoring depth of anaesthesia

Depth of anaesthesia may be assessed through clinical examination (Table 2). Intermittent checking for clinical signs has a low sensitivity and specificity for detecting awareness but, when used in combination with one of the other methods described below, the sensitivity and specificity are increased.

The most commonly used method of monitoring for awareness (or at least monitoring for the most important risk-factor for awareness) is measurement of the patient's end-tidal volatile agent concentration. Assurance of 0.8–1 MAC of exhaled anaesthetic agent is likely to assure lack of awareness. However, certain factors may cause the end-tidal concentration to misrepresent the brain partial pressure of volatile agent. Factors increasing alveolar deadspace (e.g. hypotension, bronchodilators, emphysema) cause the end-tidal concentration to tend towards the inhaled concentration because some of the inhaled gas is exhaled unchanged. Thus, if inhaled volatile concentration is higher than brain concentration, alveolar deadspace will cause end-tidal tension to overestimate brain tension. The difference between inhaled and brain tensions is greatest after step-changes in inhaled concentration and, in this situation, in the presence of significant alveolar deadspace, end-tidal tension may more closely represent inhaled tension than brain tension. Errors occur in measurement of volatile concentration and, while this error is usually $<10\%$ of the value, other gases (e.g. methane) in the exhaled gas mixture may cause erroneous results.

Specialized monitoring equipment has been developed to assist in the assessment of depth of anaesthesia. Such equipment includes processed electro-encephalography such as Bispectral Index Scale (BIS) and auditory evoked-potential assessment. These monitors have been shown to reduce the incidence of awareness, particularly in situations of high-risk. Forehead galvanometry, the isolated forearm technique and lower oesophageal motility assessment are of historical interest; they are unreliable techniques for routine monitoring of depth of anaesthesia.

Intraoperative management of awareness

If intraoperative clinical signs or monitored values suggest that a patient may be experiencing noxious stimuli that may be recalled, anaesthesia should be deepened immediately. If hypotension is present, despite insufficient anaesthetic agent, anaesthesia should be deepened whilst supporting arterial pressure with i.v. fluids, modification of ventilatory pattern or i.v. vasopressors. Administration of an i.v. benzodiazepine (e.g. midazolam 5 mg) may reduce postoperative recall. Retrograde amnesia has never been demonstrated in association with benzodiazepines (despite it being sought in several investigations), but further recall is made less likely through the anterograde amnesic effect.

Postoperative management

If a patient complains in the postoperative period of intraoperative awareness, the anaesthetist should visit the patient and obtain a detailed account of the patient's experience. The anaesthetist should establish the perioperative timing of the episode and distinguish between dreaming and awareness. The details of recalled events (e.g. hearing conversations, feeling the incision) should be noted in the patient's records. This information may be of great importance should medico-legal issues arise. While there have been fraudulent claims and confusion by patients between awareness and memories of events at induction or emergence, the vast majority of claims of awareness are genuine.[8] It is important that the patient's experience is taken seriously and that sympathy is expressed. Denial of the veracity of the patient's claim is very likely to worsen psychological outcome after awareness.[9] A formal and detailed interview should take place with the patient and this must be summarized in the records. It is also advisable to visit the patient daily after the event; onward referral to a psychologist/psychiatrist should not be delayed if the patient is suffering low mood, anxiety, sleep disturbance or flashbacks. Even if such a referral is not made, it is essential to offer follow-up counselling for the patient and to inform the patient's general practitioner.

Avoiding awareness

Premedication with benzodiazepines, or administration of benzodiazepines during induction, reduces the incidence of awareness, particularly in the high-risk period a few minutes after induction. Adequate doses of anaesthetic agents should be given. If cardiovascular or respiratory depression occurs then these systems may require support (e.g. mechanical ventilation, inotropes). Titration of anaesthetic agents to arterial pressure risks intraoperative awareness.

Assurance that at least 0.8–1 MAC of anaesthetic agent is exhaled greatly decreases the risk of awareness. Using the assumption of linear dose–response curves, it is usually considered acceptable to add together the MAC fractions of concurrently administered agents (e.g. 53% nitrous oxide + 0.58% isoflurane is considered to represent 1 MAC at 1 atm pressure in an otherwise healthy and unmedicated 30-yr-old). Adjusting MAC for the individual patient reduces the incidence of awareness and minimizes the risk of side-effects of anaesthetic agents. For example, a young, anxious patient requires more anaesthetic than an elderly, hypothyroid patient.

The use of neuromuscular blocking agents increases the risk of intraoperative awareness. They should be used only when necessary and in doses that provide sufficient neuromuscular block. Complete paralysis is very rarely required.

In high-risk situations, the use of a monitor of depth of anaesthesia (e.g. BIS) is probably justified. Such situations include Caesarean section, emergency surgery, surgery associated with large blood loss and patients with a history of previous intraoperative awareness. The use of such monitoring may also be advisable in patients in whom clinical signs of light anaesthesia may be masked (e.g. concurrent β-blockers, diabetes).

Occasionally, awareness occurs despite apparently excellent practice in the apparent absence of equipment malfunction.

Successful defence against litigation requires that the anaesthetist has made thorough records. It is advisable that the anaesthetist always records the timing and dose of anaesthetic agents, the exhaled concentrations of anaesthetic agents and the timing of the start and end of surgery.

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See multiple choice questions 134–136