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Memory of intraoperative events

Patients remember more than we think

Considerable public interest and anxiety exist about patients waking up during general anaesthesia with explicit memories of painful and terrifying intraoperative events. Using conventional clinical signs, anaesthetists find it almost impossible to recognise conscious awareness in patients with complete neuromuscular blockade.[1] In elective surgery such awareness is often due to the anaesthetists not realising that the delivery of anaesthetic has failed. Occasionally there are fictitious claims of conscious awareness, and rarely there are cases with no obvious explanation.

Fortunately, the incidence of conscious awareness with pain during surgery is only 0·01% during elective general anaesthesia.[2] The incidence has fallen considerably since the 1960s, when Hutchinson found that 0·6% of patients anaesthetised with unsupplemented nitrous oxide were awake and in pain.[3] The incidence is much higher during operations for major trauma, where anaesthetic concentrations are reduced to preserve cardiovascular function.[4]

The psychological consequences of conscious awareness with explicit memory of pain are not known. Moerman *et al* described the sequelae in 26 patients.[1] Eleven had a persistent fear of anaesthesia; seven had sleep disturbances, nightmares, anxiety, or mental distress; and eight had no ill effects. The proportion of such patients who take legal action is unknown, but the cases of the patients who do are well publicised.

Between 0·2% and 0·4% of patients have explicit memory of some intraoperative events but do not experience pain.[2] These memories often come to light only after careful postoperative questioning. This type of conscious awareness is caused by the combination of neuromuscular blockade with light general anaesthesia. Lyons and Macdonald showed that in obstetric anaesthesia a small increase in the dose of anaesthetic could reduce the incidence of this complication from 1·3% to less than 0·4%.[5] In their study there were few sequelae and patients rarely sought legal redress.

Isolating patients' arms from the neuromuscular blocking drugs by means of an inflated blood pressure cuff shows that up to half of patients are awake during some anaesthetic procedures. This can be judged by the fact that they move the isolated arm in response to the anaesthetist's commands.[6] These patients have no complaint of pain at the time of surgery, no obvious changes in physical signs, and no explicit memory of any intraoperative event when interviewed postoperatively. This method is, however, unsuitable for prolonged monitoring because of the risk of ischaemia in the isolated arm.

Patients who seem to be adequately anaesthetised and who have no explicit memory of intraoperative events may show implicit memory of such events when tested postoperatively. In contrast with explicit memory, which entails the conscious recollection of facts and events, implicit memory refers to non-conscious changes in performance or behaviour that are produced by experience.[7] There is conflicting evidence that implicit memory of intraoperative events can be registered by the brain.[7-9] Ghoneim and Block list 14 papers showing implicit memory during general anaesthesia, whereas Merikle and Rondi concluded that "there is not a single consistent finding indicating that adequately anaesthetised patients do in fact remember events during anaesthesia".[8 9] In many of the studies that show implicit learning during anaesthesia claims have been made about either the possible advantages or the deleterious effects on patient outcome. The conflicting findings, however, mean that many groups either are unconvinced that implicit memories can be registered during anaesthesia or regard this as a hypothetical possibility.

No objective measure

All these studies of implicit memory during anaesthesia are flawed by the lack of an objective measure of the anaesthetic state. Reviews by Schwender and by Thornton and Jones showed that the middle latency (or early cortical) auditory evoked potential in the electroencephalogram had a dose related fall in amplitude and increase in latency with most common general anaesthetics.[10 11] Surgical stimulation of the patient while keeping the anaesthetic concentration constant produced a change in the evoked potential similar to that seen by reducing the concentration of anaesthetic. This supports the idea that the middle latency auditory evoked potential is a dynamic measure of the anaesthetic state of the brain.

By combining psychological and electrophysiological techniques it might be possible to establish whether implicit memory of events during anaesthesia could be registered in apparently anaesthetised patients. Such a study

has been reported by Schwender *et al* in patients having cardiac surgery.[12] After sternotomy under general anaesthesia, and before cardiopulmonary bypass grafting, the patients' auditory evoked potentials were recorded and an audiotape of a short version of *Robinson Crusoe* was played to them. When interviewed postoperatively none of the patients had explicit memories of any intraoperative event. But in an implicit memory test using the code word Friday seven of the 30 patients given the tape associated the word Friday with the story of Robinson Crusoe.

These patients all had large amplitude middle latency auditory evoked potentials that were similar to those seen in lightly anaesthetised subjects. Those with no implicit memory of the story had the low amplitude potentials as seen in more deeply anaesthetised subjects. This study could resolve the disagreement about the likelihood of registering new implicit memories during anaesthesia because it suggests that the anaesthetised brain needs to be in a particular state of arousal to register these memories.

Auditory evoked potentials have now also been used to show the graded effects on the brain of many common general anaesthetics. Changes in auditory evoked potentials correlate with changes in explicit memory at low doses of anaesthesia,[13 14] and Schwender *et al* suggest that the technique could indicate the point where implicit memory of intraoperative events is ablated.[12]

It remains to be seen whether these results are confirmed in wider studies and whether the auditory evoked potentials will be a useful routine monitor of cognitive function in anaesthetised patients.

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Controlling occupational exposure to anaesthetic gases

Time to establish an exposure standard

For 25 years epidemiological studies have associated occupational exposure to anaesthetic gases with a range of health effects, including neurological, renal, and hepatic disease; reduction in mental performance and manual dexterity; and increased risk of spontaneous abortion and congenital abnormalities in offspring.[1] Most attention has been focused on studies in the 1970s into the outcome of pregnancy among theatre workers, and these undoubtedly stimulated the Department of Health's guidance recommending improvements in the ventilation of operating theatres and the introduction of scavenging systems.[2]

These environmental improvements, coupled with methodological criticisms of the early reports, have tended to dispel concern. A major 10 year prospective study of 11 000 women doctors in the United Kingdom, which followed them through 13 500 pregnancies till 1986, was also reassuring (R P Knill-Jones, personal communication, 1992). This study did not confirm the earlier work of the 1970s and showed no relation between hours spent in theatre, medical specialty, and reported miscarriages after confirmed pregnancy. Nor was any increase in congenital malformations observed.

In 1992, however, Rowland *et al* showed a significant risk of reduced fertility in female dental assistants exposed to unscavenged nitrous oxide for five hours or more a week.[3] They showed a 59% decrease in the probability of conception for any given menstrual cycle in the exposed assistants compared with unexposed assistants. In doing so they not only highlighted the value of an important reproductive outcome measure but also put assessment of the risk of exposure to anaesthetic gases firmly back on to the health and safety agenda.

A recent alert from the United States government's National Institute of Occupational Safety and Health advocates action to dispel any complacency and cites reports which suggest that health care workers may be at risk even when operating theatres are provided with scavenging equipment.[4] This confirms similar findings in studies of operating theatres in Britain, in which half the personal samples from anaesthetists exceeded an average concentration of nitrous oxide of 100 ppm during the period monitored.[5] The alert from the National Institute of Occupational Safety and Health emphasises that simply installing a ventilation system and scavenging equipment is not enough. Such technology must be supported by planned preventive maintenance, regular inspections for leaks and defective equipment, and good anaesthetic technique. This should be supported by a commitment to training so that all concerned understand the preventive measures required.

Atmospheric monitoring by personal and background sampling is also recommended as an essential means of checking the effectiveness of control measures. Yet without an agreed occupational exposure standard this becomes a weak link in the chain. An exposure standard is defined as the concentration of an airborne substance, averaged over a reference period, at which, according to current knowledge, there is no evidence that the substance is likely to be injurious to employees. All of the studies undertaken on anaesthetic gases lack precise exposure data, and in these circumstances the setting of standards can never be an exact science. Despite this there is no shortage of bids in this particular auction.

The National Institute of Occupational Safety and