EDUCATION IN ANAESTHETIC SAFETY

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While anaesthesia may appear to be an inherently dangerous process, it has a remarkably good safety record. Indeed, if the mortality attributable to anaesthesia was anything but small, it is doubtful if the administration of dangerous vapours would ever have gained acceptance, even in the last century. With its remarkable safety record and because few patients appear for anaesthesia alone, but always to allow some other therapeutic or diagnostic procedure, such deaths as do occur have always attracted considerable attention. When such untoward events are examined, it is customary for them to be described—in retrospect—as avoidable or as being associated with sub-standard care. Keats (1979) has taken a slightly different approach in emphasizing that any application of a drug or technique will almost certainly have an associated risk, and that such risks may lead to untoward events. Thus, whilst it is easy in looking back at events to see patterns that may lead to disaster, it is not so easy at the time when the events occur. Somewhat later, Keats re-emphasized the importance of a cost–benefit approach to safety studies and also the need for better quality information (Keats, 1983).

This essay is based on the hypothesis that more attention to education in safety should lead to an improved standard of care. In suggesting lines of approach, it is necessary first to survey the common types of anaesthetic accident, subsequently to examine the psychological factors in decisions attributable to human error and, finally, to suggest some strategies that might lead to a reduction in anaesthetic morbidity and mortality.

ANAESTHETIC MORBIDITY AND MORTALITY

In the 19th century, mortality resulting from anaesthesia with chloroform, administered usually by an open-drop method, was probably of the order 1:2000 administrations (Sykes, 1961). Accepting that the nature and extent of surgery has changed out of all recognition since then, and that many more elderly patients with grossly abnormal physiology are now anaesthetized, current estimates of deaths from anaesthesia are in the region of 1:8000 (Harrison, 1985). Caesarean section is well recognized to pose specific anaesthetic hazards. The latest Confidential Enquiry into Maternal Mortality in England and Wales suggested that anaesthetic mortality was of the order 1:8821 for the years 1979–82, compared with 1:5437 for the years 1970–72 (Turnbull et al., 1986). With such a low incidence it becomes almost impossible to demonstrate statistically that any one change in drug use or in technique is leading to an improvement.

Nevertheless, examination of reports such as those into maternal mortality reveals the commoner patterns associated with anaesthetic disaster. The list of events is depressingly familiar (table I) and suggests that human factors are usually the indirect cause. (It might be noted that the only cause listed in the first report (Walker et al., 1957) that is missing from the later ones, is death following the administration of chloroform!) Harrison (1985) gives a similar list of causes of anaesthetic-associated deaths for his surveys in Groote-Schurr—problems with: tracheal tubes, neuromuscular blocking drugs, inadequate postoperative supervision, vomiting and regurgitation, circulatory homeostasis, apparatus and human

<table>
<thead>
<tr>
<th>Table I. Events leading to maternal anaesthetic deaths 1979–81. (From Turnbull and colleagues (1986))</th>
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</thead>
<tbody>
<tr>
<td>Inhalation of stomach contents</td>
</tr>
<tr>
<td>With cricoid pressure</td>
</tr>
<tr>
<td>With Mg trisilicate</td>
</tr>
<tr>
<td>Difficulty with tracheal intubation</td>
</tr>
<tr>
<td>Misuse of drugs</td>
</tr>
<tr>
<td>Failure of postoperative care</td>
</tr>
<tr>
<td>Haemorrhage</td>
</tr>
<tr>
<td>Apparatus problems</td>
</tr>
</tbody>
</table>
TABLE II. Types of critical incident as percentages of total. (Data from Cooper, Newbower and Kitz (1984) in a survey of 1089 incidents)

<table>
<thead>
<tr>
<th>Type of Incident</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment failure</td>
<td>13.4%</td>
</tr>
<tr>
<td>Human error</td>
<td>68.2%</td>
</tr>
<tr>
<td>Disconnections</td>
<td>13.0%</td>
</tr>
<tr>
<td>Other</td>
<td>5.4%</td>
</tr>
</tbody>
</table>

TABLE III. Types of human error as percentages of total. (Data from Cooper, Newbower and Kitz (1984) in a survey of 583 reports)

<table>
<thead>
<tr>
<th>Type of Error</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrong drug administered</td>
<td>24.0%</td>
</tr>
<tr>
<td>Misuse of anaesthetic machine</td>
<td>22.0%</td>
</tr>
<tr>
<td>Problem with airway management</td>
<td>16.0%</td>
</tr>
<tr>
<td>Problem with breathing system</td>
<td>11.0%</td>
</tr>
<tr>
<td>Fluid therapy mismanagement</td>
<td>5.0%</td>
</tr>
<tr>
<td>I.V. infusion disconnection</td>
<td>6.0%</td>
</tr>
<tr>
<td>Failure of monitoring</td>
<td>4.0%</td>
</tr>
<tr>
<td>Other problems</td>
<td>12.0%</td>
</tr>
</tbody>
</table>

performance. Surprisingly, entities such as halothane hepatitis and malignant hyperpyrexia do not feature in such lists.

Mortality surveys are useful in defining the major hazards of anaesthesia and, provided they also can give the denominator in the equation, the incidence of such events. Because most of these reports suggest that there may have been a lack of sufficient anaesthetic care, it is important to establish how often anaesthetists make mistakes and how often these lead to harm.

Cooper and his colleagues in Boston (Cooper et al., 1978; Cooper, Newbower and Kitz, 1984) endeavoured to address these problems, using a technique in which anaesthetists report, in confidence, critical incidents (the technique is described in detail elsewhere in this issue by Derrington and Smith (1987)). The 1984 report summarizes some 1089 incidents, of which 70 led to some patient harm. The types of incident are summarized in table II and it is clear that human error is by far the commonest cause. The types of error reported are shown in table III. Of the 583 “human errors” reported 111 (19%) involved a disconnection of a breathing system, an I.V. line or a monitoring device. It is important to note that there were 25 deaths reported in this series; that is to say, if a critical incident was noted (1089 occasions) the risk of it being followed by death was 1:43.6. Death may be rare, but critical incidents are much more common. If education can minimize these it should follow that the overall results will improve.

Cooper’s group also were able to examine associated factors which contributed to the incident (table IV summarizes the more common ones). No one problem is outstanding, but all are familiar. Fatigue is often thought to be a common factor, but Cooper’s evidence suggests that it contributes to only approximately 5% of critical incidents.

Williamson, Webb and Pryor (1985) have carried out a similar survey in Australia with similar results. They estimated that with some 9500 anaesthetics there were 114 critical incidents—a rate of 1:83 anaesthetics. There were no deaths in the series, but they were also able to identify factors that might prevent or reduce the numbers of such incidents. These included: continuous checking of the patient and the equipment, the better use of monitors, better experience and supervision and additional training.

HUMAN FACTORS IN ERRORS

The evidence presented so far has been selected to reveal the commoner patterns of anaesthetic mishap and the predisposing factors. It often appears that these mishaps are potentially avoidable, especially with the provision of better equipment, better training and supervision and improvements in monitoring. However, it is easy to ignore the human factors involved. Wylie (1975) entitled his lecture “There, but for the grace of God…” which recognizes that anaesthetics are given by humans and that all humans are liable to err. Allnutt (1982) has reviewed these factors in the context of aviation safety and a more general account of his work is given elsewhere in this issue (Allnutt, 1987). However, it is worth reiterating some of the factors which may lead astray the most diligent of individuals.
Information processing. Whilst our sensors are picking up a vast amount of information, it is probable that our short term memories can hold, at most, some seven separate items. Of these seven, we can act on only one at a time—and the other six are forgotten. Thus it may not be surprising that an anaesthetist concentrates exclusively on finding the entrance to the larynx and becomes oblivious to the passage of time, the development of cyanosis and, ultimately, cardiac arrest. The addition of pulse oximetry with the continuous display of arterial oxygen saturation will not help unless the associated warning of low saturation is made in such a way as to override the normal attention being paid to intubation. Even an assistant maintaining cricoid pressure may not realize that an alarm was sounding if his attention was on the airway.

Visual illusions. Whilst these are important in three-dimensional activities such as flying, it is possible to misinterpret such simple devices as the pressure gauge on a gas cylinder (Blum, 1971).

False hypotheses. It is all too easy to erect a false hypothesis that all is well when in fact it is not. Anyone who has a continuous recording of arterial pressure can compare that with his anaesthetic chart. The anaesthetic record will usually record pressures nearer those expected by the anaesthetist than those printed out automatically. We write down what we expect, not necessarily what happens! If our behaviour is derived from our expectation rather than from reality, then errors may occur.

Habit. In a stressful situation we are likely to rely on our ingrained habits to get us out of trouble. Provided that these are appropriate, all is well, but it becomes important to ensure that good habits are built in as early as possible in anaesthetic training.

Motivation. This can raise a number of problems in difficult circumstances. Whilst the delivery of safe anaesthesia is vital, there are other pressures on the anaesthetist, including the number of patients still awaiting surgery on an operating schedule, a desire to finish work at a reasonable time, or a desire to prove oneself by handling a difficult problem without calling for help. All these factors may affect our decisions.

Stress and the environment. These are difficult areas in which to provide accurate information, but it would seem obvious to note that factors such as sleep deprivation, absence of refreshment and the presence of drugs or alcohol can impair performance and affect safety. If airline pilots are expected to refrain from alcohol for several hours before flying, should not anaesthetists?

EDUCATION IN SAFETY

Most educational activities in anaesthesia are directed at producing effective anaesthesia. The learner is taught, by apprenticeship, by academic instruction and by his own reading and experience, techniques that lead to the desired result. What does not receive so much attention is a consideration of what may go wrong in anaesthesia, and how such events may be prevented, detected and treated. Often the activities of the anaesthetist are compared with those of a pilot, sadly with the limited comparison that the most dangerous times are at the start and the end of any anaesthetic or flight. What is of more use in the context of safety training is that, from the beginning, pilots are taught safety procedures. Thus a private pilot licensee will learn at his first lesson the importance of checking his machine and before attaining a licence will be familiar with the drills necessary to cope with the dangers of stalling, spinning or engine failure. Obviously, the pilot has a vital interest in acquiring these skills—his life depends on having them.

Beard and Hartley (1984) provide much useful advice in teaching and learning in higher education. They evaluate much of modern methods and in particular suggest that any training programme should include fairly detailed statements of its aims, goals and objectives. Thus one aim of anaesthetic training must be to improve safety. More specific goals need to be defined in terms of what part of safety is being considered, in how the aim is to be achieved and what methods are to be used. There should also be a method of checking that the required standard has been met.

The following paragraphs provide some ideas on what may be specific goals with some more detailed objectives. These are derived from the lists of the commoner accidents.

Airway problems

There are two common disasters. Either tracheal intubation is difficult, delayed or impossible, or else the tube is placed in the oesophagus. Both events may be complicated by the aspiration of vomit or regurgitated stomach contents. Three specific goals can be identified. The first is the difficult intubation, the second the oesophageal
intubation and the third the problem of aspiration. The relevant objectives might be summarized:

**Difficult intubation.**

Preoperative assessment:
- Anatomy
- Pathology (especially pre-eclampsia)
- Previous anaesthetic record
- Equipment necessary

Failed intubation drill (Tunstall, 1975)
- Abandon repeated attempts
- Maintain cricoid pressure
- Head-down and left-lateral position
- Oxygenate by IPPV
- Suction
  - If obstructed, try release of cricoid pressure
- General anaesthesia by inhalation
- Abandon and use regional blockade

**Oesophageal intubation.**

Unless tracheal tube is seen to pass the cords, suspect oesophageal intubation.

If position of patient is changed, suspect that the tube may have become misplaced.

Check chest wall movement, auscultate the lung fields and the epigastrium. Realize that these may give false information.

Observe closely for the development of cyanosis or bradycardia.

Use a capnograph to detect carbon dioxide in the expired air.

If in any doubt at any stage, remove the tracheal tube.

**Aspiration.**

Assessment of patients at risk

Use of strategies to diminish risk
- Preoperative starvation
- Use of antacids
- Use of H₂-receptor blocking drugs
- Encouragement of gastric emptying
- Cricoid pressure (Sellick, 1961)

Management
- Suction
- Oxygen, IPPV, etc.
- Role of drugs such as diuretics, etc.

Such objectives and procedures require learning both in theory and in practice. The assessment of their effectiveness should be a function of the local teachers, but in any case will be a likely component of any professional examination.

It is also important to realize that safety strategies change over the years. For example, Sellick (1961) described the posture of the patient for his manoeuvre as "the patient lies supine with a slight head-down tilt. The head and neck are fully extended. This increases the anterior convexity of the cervical spine, stretches the oesophagus and prevents its lateral displacement...". Later he described cricoid pressure as being applied using one hand only of the assistant. Turnbull and his colleagues (1986) now describe the manoeuvre as needing both hands of the assistant, one to maintain cricoid pressure and one to maintain extension of the head at the atlanto-occipital joint.

**Apparatus problems**

Better use of anaesthetic apparatus should improve safety. The educational goals should encompass the following points:

**Understanding.** The increasing variety and complexity of modern equipment demands that none should be used without instruction in principles of working of any equipment, in its practical use and in the ways in which its performance is to be checked before use.

**Routine checking.** In a modern anaesthetic environment, the anaesthetist will be using an anaesthetic machine, a ventilator, a variety of i.v. infusion methods and an increasing number of monitors. All need to be checked before use, although much is extremely reliable. Check lists are becoming popular and the Australian Faculty of Anaesthetists has published a comprehensive list for anaesthetic machines (Faculty Documents, 1984). The main sections are easy to remember:
- Gas Supplies; Flowmeters; Vaporizers; Precircuit Leaks; Breathing System; Circle Absorber. However, the 61 steps into which these six sections are divided cannot be memorized easily and the objective of always using a check list before starting an operating list may only be achieved if the full check list is written down and available.

**Monitoring**

Close and continuous monitoring of the anaesthetized patient is an obvious goal in improving safety. What is of concern is the profusion of electrical devices which can now be used to monitor an increasing number of physiological and pharmacological parameters. The addition of another transducer with its associated controls, displays and alarms may not increase safety. Those interested might wish to compare the
TABLE V. Minimal monitoring standards for anaesthesia (Harvard recommendations (Eichhorn et al., 1986))

<table>
<thead>
<tr>
<th>No.</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Continuous presence of anaesthetist throughout procedure.</td>
</tr>
<tr>
<td>2</td>
<td>Arterial pressure and heart rate measured at least every 5 min where not clinically impractical.</td>
</tr>
<tr>
<td>3</td>
<td>An ECG to be displayed continuously, where not clinically impractical.</td>
</tr>
</tbody>
</table>
| 4   | Continuous monitoring of:  
|     | (a) Ventilation. One of: palpation or observation of reservoir bag, auscultation of breath sounds, monitoring of ventilatory gases such as carbon dioxide or monitoring of expired gas flow.  
|     | (b) Circulation. One of: palpation of a pulse, auscultation of heart sounds, monitoring of direct arterial pressure, pulse plethysmography/arterial saturation or ultrasound pulse monitoring.  
|     | The monitoring should consist of at least one method each for ventilation and circulation. |
| 5   | Breathing system disconnection monitoring when ventilation is controlled. |
| 6   | Oxygen analyser. During every anaesthetic involving the use of an anaesthetic machine, the oxygen concentration in the breathing system to be monitored with a device incorporating a low concentration alarm. |
| 7   | Temperature. Facilities to measure body temperature to be readily available. |

profusion of dials, switches and alarms in the cockpit of an aircraft such as the Boeing 747 with the relative simplicity of the company’s later aircraft such as the 767.

There are moves to introduce acceptable minimal standards of monitoring for all anaesthetized patients. Eichhorn and his colleagues (1986) have described the system currently used in the Harvard group of hospitals. The system is summarized in Table V. It is useful as a benchmark for others to evaluate and modify. The author’s own preference is to add, as with temperature monitoring, an option that neuromuscular transmission can be checked in any anaesthetic location. This should reduce substantially the incidence of ventilatory problems following misuse or inadequate antagonism of neuromuscular blockers.

THE ROLE OF RESEARCH

Research into anaesthetic safety is an essential part of the education process. Current efforts are directed at the nature of anaesthetic hazards and, increasingly, at their incidence. The study being conducted by the Association of Anaesthetists of Great Britain and Ireland and the Association of Surgeons is welcome, not only for looking at anaesthetic and surgical factors, but because it will also provide the denominator and thereby permit an overall assessment of risk. What are also needed are studies of the effectiveness of education in safety matters. Will there be fewer anaesthetic deaths or fewer critical incidents as a result of an education programme, and which elements of such programmes are the most effective? Research is also needed into the use of such educational methods as the use of stimulators, which may well give insight to the psychological factors in anaesthetic mishaps.

CONCLUSION

Anaesthesia has a good safety record but, as with all human endeavour, accidents do occur. Investigation of these untoward events has often concentrated on determining what occurred and whether or not the accident was inevitable. In designing an education programme to reduce avoidable accidents, attention should be directed to three areas: what are the common patterns of events; what factors precipitate them, including the human considerations in the anaesthetic and surgical team; and, finally, what strategies can be devised to prevent (preferably), recognize and treat them?

REFERENCES


