On error management: lessons from aviation

Robert L Helmreich

Pilots and doctors operate in complex environments where teams interact with technology. In both domains, risk varies from low to high with threats coming from a variety of sources in the environment. Safety is paramount for both professions, but cost issues can influence the commitment of resources for safety efforts. Aircraft accidents are infrequent, highly visible, and often involve massive loss of life, resulting in exhaustive investigation into causal factors, public reports, and remedial action. Research by the National Aeronautics and Space Administration into aviation accidents has found that 70% involve human error. 1

In contrast, medical adverse events happen to individual patients and seldom receive national publicity. More importantly, there is no standardised method of investigation, documentation, and dissemination. The US Institute of Medicine estimates that each year between 44 000 and 98 000 people die as a result of medical errors. When error is suspected, litigation and new regulations are threats in both medicine and aviation.

Error results from physiological and psychological limitations of humans. 2 Causes of error include fatigue, workload, and fear as well as cognitive overload, poor interpersonal communications, imperfect information processing, and flawed decision making. 3 In both aviation and medicine, teamwork is required, and team error can be defined as action or inaction leading to deviation from team or organisational intentions. Aviation increasingly uses error management strategies to improve safety. Error management is based on understanding the nature and extent of error, changing the conditions that induce error, determining behaviours that prevent or mitigate error, and training personnel in their use. 4 Though recognising that operating theatres are not cockpits, I describe approaches that may help improve patient safety.

Summary points

In aviation, accidents are usually highly visible, and as a result aviation has developed standardised methods of investigating, documenting, and disseminating errors and their lessons

Although operating theatres are not cockpits, medicine could learn from aviation

Observation of flights in operation has identified failures of compliance, communication, procedures, proficiency, and decision making in contributing to errors

Surveys in operating theatres have confirmed that pilots and doctors have common interpersonal problem areas and similarities in professional culture

Accepting the inevitability of error and the importance of reliable data on error and its management will allow systematic efforts to reduce the frequency and severity of adverse events

10 Cooper JB, Nev文书Her RS, Kite RJ. An analysis of major errors and equipment failures in anaesthesia management considerations for prevention and detection. Anaesthesia 1984;60:34-42.

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Managing error in aviation

Given the ubiquity of threat and error, the key to safety is their effective management. One safety effort is training known as crew resource management (CRM). This represents a major change in training, which had previously dealt with only the technical aspects of management, and behaviours identified as critical in preventing accidents. Confidential data have been collected on more than 3,500 domestic and international airline flights—an approach supported by the Federal Aviation Administration and the International Civil Aviation Organisation.

The results of the line operations safety audit confirm that threat and error are ubiquitous in the aviation environment, with an average of two threats and two errors observed per flight. The box shows the major sources of threat observed and the five categories of error empirically identified; fig 1 shows the relative frequency of each category. This error classification is useful because different interventions are required to mitigate different types of error.

Proficiency errors suggest the need for technical training, whereas communications and decision errors call for team training. Procedural errors may result from human limitations or from inadequate procedures that need to be changed. Violations can stem from a culture of non-compliance, perceptions of invulnerability, or poor procedures. That more than half of observed errors were violations was unexpected. This lack of compliance is a source of concern that has triggered internal reviews of procedures and organisational cultures. Figure 1 also shows the percentage of errors that were classified as consequential—that is, those errors resulting in undesired aircraft states such as near misses, navigational deviation, or other error. Although the percentage of proficiency and decision errors is low, they have a higher probability of being consequential. Even non-consequential errors increase risk: teams that violate procedures are 1.4 times more likely to commit other types of errors.

Data requirements for error management

Multiple sources of data are essential in assessing aviation safety. Confidential surveys of pilots and other crew members provide insights into perceptions of organisational commitment to safety, appropriate teamwork and leadership, and error. Examples of survey results can clarify their importance. Attitudes about the appropriateness of juniors speaking up when problems are observed and leaders soliciting and accepting inputs help define the safety climate. Attitudes about the flying job and personal capabilities define pilots' professional culture. Overwhelmingly, pilots like their work and are proud of their profession. However, their professional culture shows a negative component in denying personal vulnerability. Most of the 30,000 pilots surveyed report that their decision making is as good in emergencies as under normal conditions, that they can leave behind personal problems, and that they perform effectively when fatigued. Such inaccurate self perceptions can lead to overconfidence in difficult situations.

A second data source consists of non-punitive incident reporting systems. These provide insights about conditions that induce errors and the errors that result. The United States, Britain, and other countries have national aviation incident reporting systems that remove identifying information about organisations and respondents and allow data to be shared. In the United States, aviation safety action programmes permit pilots to report incidents to their own companies without fear of reprisal, allowing immediate corrective action. Because incident reports are voluntary, however, they don't provide data on base rates of risk and error.

A third data source has been under development over 15 years by our project (www.psyc.utexas.edu/psy/helreich/nasaut.htm). It is an observational methodology, the line operations safety audit (LOSA), which uses expert observers in the cockpit during normal flights to record threats to safety, errors and their consequences.

<table>
<thead>
<tr>
<th>Sources of threat and types of error observed during line operations safety audit</th>
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<tr>
<td><strong>Sources of threat</strong></td>
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<tr>
<td>Terrain (mountains, buildings)—58% of flights</td>
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<td>Aircraft malfunctions—15% of flights</td>
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<tr>
<td>External errors (air traffic control, maintenance, cabin, dispatch, and ground crew)—8% of flights</td>
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<td><strong>Types of error—with examples</strong></td>
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<td>Violation (conscious failure to adhere to procedures or regulations)—performing a checklist from memory</td>
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<td>Communications (missing or wrong information exchange or misinterpretation)—misunderstood altitude clearance</td>
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<td>Decision (decision that unnecessarily increases risk)—unnecessary navigation through adverse weather</td>
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**Fig 1** Percentage of each type of error and proportion classified as consequential (resulting in undesired aircraft states)
those found in the cockpit. Behaviours seen in a Euro-

Simultaneous also plays an important role in crew
resource management training. Sophisticated simula-
tors allow full crews to practice dealing with error
inducing situations without jeopardy and to receive
feedback on both their individual and team perform-
ance. Two important conclusions emerge from evalu-
ations of crew resource management training: firstly,
such training needs to be ongoing, because in the
absence of recurrent training and reinforcement,
atitudes and practices decay; and secondly, it needs to
be tailored to conditions and experience within
organisations.

Understanding how threat and error and their
management interact to determine outcomes is critical
to safety efforts. To this end, a model has been
developed that facilitates analyses both of causes of
mishaps and of the effectiveness of avoidance and miti-
gation strategies. A model should capture the
treatment context, including the types of errors, and
classify the processes of managing threat and error.
Application of the model shows that there is seldom a
single cause, but instead a concatenation of contribut-
ing factors. The greatest value of analyses using the
model is in uncovering latent threats that can induce
error.10

By latent threats we mean existing conditions that
may interact with ongoing activities to precipitate
error. For example, analysis of a Canadian crash
caused by a take-off with wing icing uncovered 10
latent factors, including aircraft design, inadequate
oversight by the government, and organisational char-
acteristics including management disregard for
de-icing and inadequate maintenance and training.9
Until this post-accident analysis, these risks and threats
were mostly hidden. Since accidents occur so
infrequently, an examination of threat and error under
routine conditions can yield rich data for improving
safety margins.

Applications to medical error
Discussion of applications to medical error will centre
on the operating theatre, in which I have some experi-
ence as an observer and in which our project has
collected observational data. This is a milieu more
complex than the cockpit, with differing specialties
interacting to treat a patient whose condition and
response may have unknown characteristics.11 Aircraft
tend to be more predictable than patients.

Though there are legal and cultural barriers to the
disclosure of error, aviation’s methodologies can be
used to gain essential data and to develop comparable
interventions. The project team has used both survey
and observational methods with operating theatre
staff. In observing operations, we noted instances of
suboptimal teamwork and communications paralleling
those found in the cockpit. Behaviours seen in a Euro-

pean hospital are shown in the box, with examples of
negative impact on patients. These are behaviours
addressed in crew resource management training.

In addition to these observations, surveys confirm
that pilots and doctors have common interpersonal
problem areas and similarities in professional
culture.11 12 In response to an open ended query about
what is most needed to improve safety and efficiency
in the operating theatre, two thirds of doctors and
nurses in one hospital cited better communications.11
Most doctors deny the deleterious effects of stressors
and proclaim that their decision making is as good in
emergencies as in normal situations. In data just
collected in a US teaching hospital, 30% of doctors
and nurses working in intensive care units denied
committing errors.15

Further exploring the relevance of aviation
experience, we have started to adapt the threat and
error model to the medical environment. A model of
threat and error management fits within a general

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**Fig 2** Threat and error model, University of Texas human factors research project
Case study: synopsis
An 8 year old boy was admitted for elective surgery on the eardrum. He was anaesthetised and an endotracheal tube inserted, along with internal stethoscope and temperature probe. The anaesthetist did not listen to the chest after inserting the tube. The temperature probe connector was not compatible with the monitor (the hospital had changed brands the previous day). The anaesthetist asked for another but did not connect it; he also did not connect the stethoscope.
Surgery began at 08 20 and carbon dioxide concentrations began to rise after about 30 minutes. The anaesthetist stopped entering CO2 and pulse on the patient's chart. Nurses observed the anaesthetist nodding in his chair, head bobbing; they did not speak to him because they "were afraid of a confrontation."
At 10 15 the surgeon heard a gurgling sound and realised that the airway tube was disconnected. The problem was called out to the anaesthetist, who reconnected the tube. The anaesthetist did not check breathing sounds with the stethoscope.
At 10 30 the patient was breathing so rapidly the surgeon could not operate; he notified the anaesthetist that the rate was 60/min. The anaesthetist did nothing after being alerted.
At 10 45 the monitor showed irregular heartbeats. Just before 11 00 the anaesthetist noted extreme heartbeat irregularity and asked the surgeon to stop operating. The patient was given a dose of lignocaine, but his condition worsened.
At 11 02 the patient's heart stopped beating. The anaesthetist called for code, summoning the emergency team. The endotracheal tube was removed and found to be 50% obstructed by a mucous plug. A new tube was inserted and the patient was ventilated. The emergency team anaesthetist noticed that the airway heater had caused the breathing circuit's plastic tubing to melt and turned the heater off. The patient's temperature was 108°F. The patient died despite the efforts of the code team.

"input-process-outcomes" concept of team performance, in which input factors include individual, team, organisational, environmental, and patient characteristics. Professional and organisational cultures are critical components of such a model.

Threats are defined as factors that increase the likelihood of errors and include environmental conditions such as lighting; staff related conditions such as fatigue and norms of communication and authority; and patient related issues such as difficult airways or diseases, and medical specialties. Anxiety can be classified into three categories: latent threat, typical threat, and professional threat to the system predisposing threat or error, such as staff who continue operating even after the anaesthetist failed to respond to the boy's deteriorating condition. More importantly, latent organisational and professional threats were revealed, including failure to act on reports about the anaesthetist’s previous behaviour, lack of policy for monitoring patients, pressure to perform when fatigued, and professional tolerance of peer misbehaviour.

Establishing error management programmes
Available data, including analyses of adverse events, suggest that aviation's strategies for enhancing teamwork and safety can be applied to medicine. I am not suggesting the mindless import of existing programmes; rather, aviation experience should be used as a template for developing data driven actions reflecting the unique situation of each organisation.

This can be summarised in a six step approach. As in the treatment of disease, action should begin with:
• History and examination; and
• Diagnosis.

The history must include detailed knowledge of the organisation, its norms, and its staff. Diagnosis should include data from confidential incident reporting systems and surveys, systematic observations of team performance, and details of adverse events and near misses.

Further steps are:
• Dealing with latent factors that have been detected, changing the organisational and professional cultures, providing clear performance standards, and adopting a non-punitive approach to error (but not to violations of safety procedures);
• Providing formal training in teamwork, the nature of error, and in limitations of human performance;
• Providing feedback and reinforcement on both interpersonal and technical performance; and
• Making error management an ongoing organisational commitment through recurrent training and data collection.

Some might conclude that such programmes may add bureaucratic layers and burden to an already overtaxed system. But in aviation, one of the strongest proponents of the measures is an airline that eschews anything bureaucratic, learns from everyday mistakes, and enjoys an enviable safety record.

Funding for research into medical error, latent factors in the system, incident reporting systems, and development of training is essential for implementation of such programmes. Research in medicine is historically specific to diseases, but error cuts across all illnesses and medical specialties.

I believe that if organisational and professional cultures accept the inevitability of error and the importance of reliable data on error and its management, systematic efforts to improve safety will reduce the frequency and severity of adverse events.

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Anaesthesiology as a model for patient safety in health care

David M Gaba

Although anaesthesiologists make up only about 5% of physicians in the United States, anaesthesiology is acknowledged as the leading medical specialty in addressing issues of patient safety. Why is this so?

Firstly, as anaesthesia care became more complex and technological and expanded to include intensive care it attracted a higher calibre of staff. Clinicians working in anaesthesiology tend to be risk averse and interested in patient safety because anaesthesia can be dangerous but has no therapeutic benefit of its own. Anaesthesiology also attracted individuals with backgrounds in engineering to work either as clinicians or biomedical engineers involved in operating room activities. They and others found models for safety in anaesthesia in other hazardous technological pursuits, including aviation.

Secondly, in the 1970s and ’80s the cost of malpractice insurance for anaesthesiologists in the United States soared and was at risk of becoming unavailable. The malpractice crisis galvanised the profession at all levels, including grass roots clinicians, to address seriously issues of patient safety. Thirdly, and perhaps most crucially, strong leaders emerged who were willing to admit that patient safety was imperfect and that, like any other medical problem, patient safety could be studied and interventions planned to achieve better outcomes.

Accomplishments in patient safety in anaesthesiology

Anaesthesia: safer than ever

It is widely believed that anaesthesia is much safer today (at least for healthy patients) than it was 25 or 50 years ago, although the extent of and reasons for the improvement are still open to debate. Traditional epidemiological studies of the incidence of adverse events related to anaesthesia have been conducted periodically from the 1950s onwards. Many of these studies were limited in scope, had methodological constraints, and cannot be compared with each other because of differing techniques. An important outcome has been the emergence of non-traditional investigative techniques that aim not to find the true incidence of adverse events but to highlight underlying characteristics of mishaps and to suggest improvements in patient care.

Summary points

Anaesthesiology is acknowledged as the leading medical specialty in addressing patient safety

Anaesthesia is safer than ever owing to many different types of solutions to safety problems

Solution strategies have included incorporating new technologies, standards, and guidelines, and addressing problems relating to human factors and systems issues

The multidisciplinary Anesthesia Safety Foundation was a key vehicle for promoting patient safety

A crucial step was institutionalising patient safety as a topic of professional concern

Although anaesthesiology has made important strides in improving patient safety, there is still a long way to go.

Such techniques have included the “critical incident” technique adapted by Cooper from aviation; the analysis of closed malpractice claims; and the Australian incident monitoring study (AIMS). These approaches analyse only a small proportion of the events that occur but attempt to glean the maximum amount of useful information from the data.

Technological solutions

Once the range of patient safety problems in anaesthesiology had been defined, several strategies have been used to improve safety. One is to apply technological solutions to clinical problems. Anaesthesiologists have become expert at realtime monitoring of patients (both electronically and via physical examination). In the industrialised world electrocardiography, pulse oximetry, and capnography (analysis of carbon dioxide in exhaled gas) have become standards and are thought to have contributed substantially to safety. No study to date, however, has had sufficient power to prove an outcome benefit from the use of these...