Errors in Medicine: A Human Factors Perspective

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INTRODUCTION

"The real problem isn't how to stop bad doctors from harming, even killing, their patients. It's how to prevent good doctors from doing so".[1]

The past decade has seen an increasing focus on the issue of errors in medicine. In particular, errors made by doctors, nurses and para-medical staff in hospitals have received significant attention. The report by the Institute of Medicine in the USA, aptly titled "To Err is Human", estimated that between 44,000 to 98,000 hospitalised patients die annually in the USA as a result of medical errors.[2]

The Quality in Australian Healthcare Study[3] found adverse events (unintended injury or complication caused by healthcare) occurred in 16.6% of hospital admissions, with 51% of these adverse events judged to be "highly preventable". Death occurred in 4.9% of patients suffering an adverse event, and permanent disability in 13.7%.

In 2000, a report from the United Kingdom[4] found that medical errors caused harm (death and injury) to in excess of 850,000 patients admitted to National Health Service Hospitals annually. This represents 10% of total admissions.[4]

Although there has been much discussion and controversy about the methodologies of some of these studies,[5, 6, 7, 8] it is now widely accepted that the risks to patients from medical errors are significant.

HUMAN FACTORS

"Human factors" can be defined as the study of the interrelationships between humans, the tools we use and the environment in which we live and work.[9] It focuses on the cognitive and physical abilities of people as they interact with technology. This is an interdisciplinary field, drawing on knowledge from industrial and software engineering, psychology, ergonomics, design and management. Collaboration between human factors scientists and medical professionals developed around the work of anaesthetists and intensivists, because of similarities between these fields and some of the industries traditionally studied in human factors.[10] A significant consequence of this collaboration has been the application of human factors models of accident causation to health care.[10]

Anaesthetists have been rightly recognised to be leaders in the area of patient safety. In particular, the specialty has led the way in developments such as the application of technology to monitoring patients, implementation of safety guidelines, analysis of closed malpractice claims, simulation and the application of human factors principles to analysis of errors.[11, 12] Human error has been considered to contribute to critical incidents in anaesthesia in between 64-83% of incidents, figures based on nine studies between 1981 and 1993.[13] These are similar results to those found in aviation.[13, 14] The high incidence of human error in critical incidents and accidents has led to the application of particular human factors principles to improve safety in the aviation industry. It has been recognised that more than just technical training is required to produce safe aircraft crews!

The causes of human error include: fatigue, workload, limitations of human cognitive processes, poor interpersonal communications, flawed decision making processes, leadership problems and team work issues.[15] In aviation, this led to several developments, including Crew Resource Management (CRM) training, to optimise the utilisation of human resources on the flight deck and decrease errors.[16] It is interesting to note that whilst CRM today is embraced by aviation, there was initial resistance to learning non-technical skills by some pilots. They denounced CRM courses as "charm schools" and "psychobabble".[16] However, acceptance grew after analysis of aircraft crashes continued to reveal CRM issues as causative factors and as CRM training became more sophisticated.[16]

Similarly, in anaesthesia, there is increasing recognition of the importance of non-technical factors, as well as technical skills and knowledge, in ensuring safe practice. This has led to research into methods to assess non-technical skills in anaesthesia and to developing methods for teaching them to anaesthesia trainees. For example, the Anaesthetists' Non-Technical Skills (ANTS) behavioural markers system considers four skill categories (task management, team working, situation awareness and decision-making) and has been shown to be a valid and reliable method of assessing these skills.[17]

"HIGHLY COMPLEX, TIGHTLY COUPLED"

Anaesthesia is described as being a highly dynamic, complex and tightly coupled activity, similar to aviation. The Operating Room can be considered to be more complex than a flight deck, because different specialties are interacting to treat a patient whose state and responses can have unknown characteristics.[18] "Aircraft tend to be more predictable than patients."[19]

Complex systems are characterised by having components that interact with multiple other components in many and often unpredictable ways.[20] In anaesthesia, not only do we interact with highly specialised equipment and technology, but we also interact with the complexity and unpredictability of our patients' physiology. The term "tightly coupled" has been adapted from its original definition in mechanics. Tightly coupled systems have more time-dependent processes, which cannot wait or stand by until attended to.[20] In anaesthesia, this means that the actions of the anaesthetist will have an impact on the patient in an immediate, time dependent way. For example, an intravenous drug is given and there is a quick physiological response by the patient. Similarly, failure to secure an airway in a paralysed patient leads to prompt, adverse physiological consequences.

There are also more invariant sequences in tightly coupled systems; for instance, B must follow A.[20] One cannot dawdle off to do XY and Z, whilst leaving B unattended, without dire consequences. To return to our airway example, one cannot induce and muscle relax the patient and then leave the airway unattended, whilst proceeding to insert a central line in the patient or write up a post-operative drug chart.

Accidents are more likely to happen with complex, tightly coupled systems.[20] These systems can "spring nasty surprises".[21]

TRADITIONAL VERSUS MODERN APPROACH TO ERROR

The traditional approach to error has been to assume that if people could only be made to be more careful, to pay more attention and be better motivated, then the incidence of errors could be greatly reduced and their effects mitigated.[22] This approach puts great emphasis on training, admonition, supervision, punishment and ever more detailed rules and regulations.[22] Blame is attached to those who make errors. Although this might, at the outset, seem a logical and obvious approach to reduce errors and improve safety, it has not worked.

The analysis of accidents in industry, the military and transport systems has led to an understanding of accident and incident generation which is much broader and all-encompassing than just focusing on the particular individuals involved. Improvements in safety in industry have not resulted from admonishing workers and exhorting them to "try harder". Accidents are rarely the result of one, single unsafe act, but rather are often the product of many factors, including organizational, situational, task-related and personal.[10]

A more modern approach to error considers that most errors are the result of an interaction between the design of activities, procedures and objects, such as equipment, with known patterns of human behaviour. These behavioural patterns include well-known cognitive limitations of human beings. The psychological precursors of an error (distraction, preoccupation, forgetfulness, fatigue, stress) are often the last links in a chain of events leading to an accident or adverse event.[10]

The term "normal accidents" was used by Perrow[20] to illustrate that accidents are likely to occur inevitably in complex and tightly coupled activities, and should be viewed as an integral characteristic of these systems.

"Naming, blaming and shaming"

Traditionally, health care has taken what has been called the "person approach" to errors, with an emphasis on "naming, blaming and shaming" the individual seen as responsible for the error. As noted earlier, with this approach errors and unsafe acts have been viewed as reflecting carelessness, inattention, negligence, forgetfulness or poor motivation.[23] Focusing on individuals as being the causes of errors means the "big picture" is lost.

Doctors are socialized throughout their training to strive for error-free practice. Mistakes are seen as being unacceptable and are often interpreted as a failure of character, where one wasn't "careful enough" or "hadn't tried hard enough".[24] This need to be infallible can make it very difficult to admit to errors. There may be a tendency to cover up mistakes rather than admit to them.[25] This happens for many reasons, including the fear that one's colleagues will view one as incompetent or careless. The corollary of this "myth of infallibility" is that when doctors make errors, particularly if there is a serious adverse outcome, considerable feelings of shame, guilt, fear and isolation can occur.[26, 27] Indeed, these feelings can be so overwhelming that the doctor has been referred to as "the second victim".[28] It has been said that, "… medicine is often driven by the idea that perfection is possible and that mistakes are a personal and professional failure. This perfection mind-set … is laudable, admirable, and unworkable".[29]

A more reliable way to improve safety is to accept the limitations on human performance, accept that errors will occur and, as far as possible, design systems that promote safety. As Reason states, in discussing aviation safety, "human fallibility is like gravity, weather, and terrain, just another foreseeable hazard"[30]

MYTHS ABOUT ERRORS AND BIASES

Some of the myths about errors discussed by Reason[31] include:

1. Bad people make errors

Errors can be seen to represent a moral issue, where bad people make errors.[23] In psychology, the terms "attribution theory" and "just world hypothesis" refer to our tendency to think that if something bad has happened (for example, if an anaesthetist has made a serious or "bad" error) then that person "deserves" what happened to them and must have "brought it upon themselves". In fact, the best people can sometimes make the worst mistakes, as the "best" people may be performing the most difficult tasks. Most errors are actually made by "good" people having a bad day.

2. Errors are random and highly variable

This assumes errors occur "out of the blue" and are unpredictable. Actually, most errors fall into known categories or types of errors, which are similar for a wide spread of human occupations and endeavours.

3. The errors of highly trained professionals are very rare

Errors are actually very common, but are mainly inconsequential. In aviation, a study involving observations of errors made by flight crews during scheduled passenger flights, with extrapolation to worldwide aviation, estimated that each year around one hundred million errors are made by flight crews, but statistics show there are about 100 major incidents and 25-30 aircraft hull losses per year.[32]

4. The errors of highly trained professionals are usually sufficient to cause bad outcomes

Professionals make frequent errors, yet rarely have bad outcomes. This is predominantly due to:

a. the ability to detect and recover from errors before they cause harm; and,
b. the systems in place to assist professionals in doing this, for example alarms on anaesthesia monitoring equipment.

There are also biases which affect the way errors are viewed.

1. Outcome bias

Outcome bias is the tendency to attribute blame more readily when there has been a serious adverse outcome, than if the same set of circumstances had occurred but the outcome was relatively minor in severity.[33] This was shown in a study of 112 practising anaesthesiologists, who were asked to judge the appropriateness of care in 21 cases they were given to review, where there had been adverse anaesthetic outcomes. Some anaesthesiologists were given the case details coupled with an adverse outcome involving permanent harm, whilst the others received the same case details coupled with an adverse outcome involving temporary harm. A significant inverse relationship was observed between the severity of the outcome and the judgment of appropriate care in 71% of the matched pairs of cases. Being told that permanent harm had occurred as a result of the case resulted in the reviewer of the case being more likely to be critical of the standard of care, versus being told the harm was only temporary, even though the facts presented were identical in each case.[34]

2. Hindsight bias

For those analysing another's errors or disasters, blessed with the benefit of hindsight, it is tempting to ask how could the person who made the error have been so blind? So stupid? So ignorant? A number of psychology studies have demonstrated this phenomenon of hindsight bias. One aspect of this is the "knew it all along" effect, where observers of past events exaggerate what other people should have been able to anticipate in foresight.[21] With hindsight, the events that occurred appear to have unfolded logically, one event leading to another in a linear manner. This is very different to the experience of the person involved with the incident at the time it occurred, where this linkage of events leading to the disaster was far from evident:

"Before beholding the mote in his brother's eye, the retrospective observer should be aware of the beam of hindsight bias in his own."[21]

SYSTEMS APPROACH

A system can be defined as a collection of components and the relations between them. In health care there are human components (staff and patients), hardware components (computers, monitors, paper records, buildings, beds, drugs), management components (policies and procedures) and financial components (financial decisions and budgets). A systems approach to errors involves looking for sources of error generation inherent in the systems within which humans work. This can include, for example, looking at: the design of equipment, the way in which the work is structured, procedural aspects, information availability and communication networks within organisations. Even though humans may be acting with good intentions, and be skilled and experienced in their particular work, problems within systems can "call forth" error behaviour in these workers.[22]

A misunderstanding of taking a systems approach to errors is that it absolves the individual of any responsibility. This is absolutely incorrect. In so-called High Reliability Organizations, which will be discussed later, there is not only a consistent emphasis on addressing systemic factors to reduce errors, but individuals working in those organizations are acutely aware of their own individual contributions to safety.[29] Doctors and other health care professionals obviously have to uphold the expected highest standards of performance, and have an obligation to participate in continuing education to ensure their skills and knowledge are up to date. A systems approach to safety does not mean staff can simply deny responsibility and "blame the system". On the other hand, it does mean that when errors occur, the "big picture" must be examined.

Constraints on Behaviour

A systems approach to error recognises that there are many "behaviour-shaping factors" that influence the occurrence of an error. These influences on behaviour are also known as "constraints",[22] and include:

1. Constraints from Physical Ergonomics

This will include design of equipment such as monitors (size, shape, legibility of displays, quality of alarms), anaesthesia machines, infusion pumps, and theatre layout. These constraints can be used to prevent errors. An example of this is non-interchangeable gas specific pipeline connectors, which prevent misconnections.

2. Constraints from Availability of Equipment

For example, airway adverse events have occurred when oesophageal intubation has gone unnoticed in situations, such as Emergency Departments and ICUs, where no capnography equipment was available.

3. Constraints in Teams

Individual behaviour is influenced by dynamics within teams. For example, the quality of communication between team members within an operating room can contribute to errors and adverse events occurring.

4. Constraints from Organisation and Management

These will influence issues such as production pressure, staffing levels, rostered hours of work, availability of adequate supervision of trainees and budgets influencing equipment purchasing.

5. Constraints within the Individual

Humans have limitations in accuracy of perception, memory, attention and motor skills. The interactions between judgment, motivation, emotion and decision-making processes are complex.

Our day-to-day activities as anaesthetists are thus impacted upon by many factors, including at an over-arching level decisions made by hospital administrators and government. For example, the funding available to purchase equipment, the level of staffing in theatre, rostering and so on are influenced by these types of decisions, which are made temporally and spatially distant from the point of immediate patient care.

WHAT ARE ERRORS?

An error can be defined as a failure of a planned action to be completed as intended (an error of execution) or the use of a wrong plan to achieve an aim (error of planning).[2] An error can also be an act of commission or omission. Errors are generally considered to be unintentional and not deliberate. This distinguishes errors from what are called “violations”, in which usually a choice has been made to deviate from accepted rules and norms or standards of practice.[33]

Examples of violations in anaesthesia would include ignoring fasting guidelines for elective surgery, omitting to perform a pre-operative assessment, and failing to check the anaesthetic machine prior to commencing an anaesthetic. However, whilst in some circumstances violations may involve a deliberate flouting of rules, in many situations there have been contributing factors, such as time and production pressures.

Classification of Errors

1. Active and latent errors

Errors may be classified into two broad categories: active and latent.[21]

Active errors are the events occurring immediately before an incident or accident.

These are the actions of the people on the front line interacting directly with the patient, such as doctors and nurses.

Latent errors are problems lurking within systems, which under certain conditions will contribute to an error occurring. Latent errors may lie dormant in systems for some time, but given a certain set of circumstances become evident. They are usually the result of decisions made by managers and administrators, designers of equipment and maintenance staff. In a sense, latent errors "set the scene" to make it more likely that an active error will occur. For example, picking up the incorrect ampoule of a drug out of an anaesthetic drug trolley and administering it is an active error. That a potentially dangerous drug could come in an ampoule the same size, shape and colour as a more innocuous drug, and be stored directly next to it in a drug trolley, is a latent error, as it increases the likelihood of an error ultimately occurring.

2. Types of active errors: slips, lapses and fixation errors

Active errors have been classified into a number of different categories.[13,21] Common errors are what are called "slips" and "lapses". These involve errors in both conscious and subconscious (or automatic) cognition[13] and are usually the result of attentional capture associated with either distraction or pre-occupation.[21]

Slips: The terminology of "slip" is familiar from everyday life, when we have a "slip of the tongue" or "slip of the pen", where we say or do something that we had not intended. In anaesthesia, an example of a "slip" would be turning the wrong knob on a piece of equipment. This is illustrated by, for example, turning on the nitrous oxide rotameter rather than the air rotameter which one had intended to turn on. Norman[35] described various types of slips, including sequence errors (performing the elements of a task but in the wrong order), description errors (using the correct action but on the incorrect object) and mode errors (correct action used but with equipment in the wrong mode).

Examples of these slips in anaesthesia would be:

— *sequence error:* giving muscle relaxant prior to giving the induction agents
— *description error:* turning off the oxygen instead of the nitrous oxide
— *mode error:* attempting to ventilate a patient with a circuit by squeezing the breathing bag, when the switch to change the circuit from ventilator mode to breathing bag mode is in fact set to ventilator mode.

Lapses: On the other hand, a "lapse" involves the omission of some intended action. In everyday life, this could be something such as leaving one's house without locking the door.

In anaesthesia, an example of a "lapse" would be failing to give a particular drug that one had intended to give. Another example would be placing the non-invasive blood pressure cuff on the patient, taking a "stat" reading but forgetting to set it to cycle regularly, so that one is reassured by a consistently "normal" blood pressure (until the lapse is recognised!)

Fixation errors: Certain types of errors in cognition are more likely to occur at times of crisis and stress. "Coning of attention"[36] under stress is the tendency in a crisis or emergency to concentrate on a single source of information as the "first come, best preferred" solution. An illustration of this is seen with passengers in an aircraft crash persistently struggling to open an aircraft door while ignoring a large hole in the fuselage a metre away through which they could escape.[24] This tendency to get "cognitively stuck", as it were, is also called "fixation error". A fixation error can be considered to be the persistent failure to revise a diagnosis or plan, in the face of evidence that suggests revision is necessary.[37]

There are three main types of fixation errors:

"This and only this": Here, there is a persistent failure to revise a diagnosis or plan despite evidence to the contrary. Available evidence is interpreted to fit this initial diagnosis.

"Everything but this": This is the persistent failure to commit to the definitive treatment of a major problem. A simplistic way to think about this is that it is almost as if one's brain is saying "I don't want this situation to be a major problem so I will deny that possibility".

"Everything's okay": This is the persistent belief that no problem is occurring despite plentiful evidence that it is. Abnormalities may be attributed to artefacts or transient variations. There can be failure to declare an emergency, or accept help when facing a major crisis.

Fixation errors have been implicated in a number of disasters in other industries. For example, in 1972 a very experienced flight crew inadvertently flew Eastern Flight 401 into the ground, killing 103, after they became fixated on an indicator light on their instrument panel that failed to come on after they engaged the landing gear on approach to the airport in Miami. With the crew's attention focused on the light, including looking at it, jiggling and tapping it, removing it and talking about it, they failed to notice the autopilot had become disengaged and they were losing altitude, until the instant prior to slamming into the ground.

Fixation error is frequently observed in simulated anaesthesia critical incidents,[38, 39] and occurs with both trainee and experienced anaesthetists. This can actually be a very useful experience in simulation, particularly for developing the awareness in oneself that this can occur, and what techniques to use to help avoid getting "stuck".

ERROR SCRIPTS: "All the men and women merely players"

Bogner[40] describes a particular way of understanding how serious errors can occur repeatedly, via what is called an "error script", where certain events precede and set the stage for adverse outcomes. This is likened to the script for a play, in which those who commit the active errors can be seen as the "actors" within the particular "error script". Focusing on punishing the particular individuals who committed the error, and removing them from the system, does not fix the problem if the error-provoking and error-inducing conditions or "script" remain the same.

For example, patients have had chemotherapeutic drugs meant for intravenous use inadvertently injected into their intra-thecal space. The circumstances in which this has occurred have usually been situations where a patient was to have received two chemotherapy agents, one to be administered intravenously and the other intra-thecally. This error has occurred at least ten times in British hospitals[33] and on a number of different occasions in Australia. This is despite these cases being well publicised, sometimes with considerable punishment of those involved, up to and including manslaughter conviction.[33]

Why has this error re-occurred? If we apply the "error-script" approach to this, we can see the "script" for this error scenario is in fact the presentation of two drugs, one intended for intrathecal use and the other for intravenous use, in similar small volumes and in similar packaging, delivered at the same time to the doctor for administration. Although a changing cast of "players" has been involved, the error has been repeated.

One of the human factors approaches to this problem is to "re-write the script", for instance by ensuring the drug for intravenous use is only presented in, for example, a distinctively labelled 50 ml volume bag for intravenous infusion. This would make it extremely unlikely that a doctor would inject this into the intra-thecal space. Similarly, multiple drug errors have occurred with potassium, presented in ten or twenty ml plastic ampoules, being injected inadvertently as a bolus intravenously and even into the epidural space. An effective solution to this is to present potassium only in a 50-100 ml bag for infusion, making it much less likely to be confused with other drugs packaged in ampoules.

THE ERROR TROIKA

The "Error Troika" is a three-stage model for error management using error countermeasures[16] including:

1. Avoiding error
2. Trapping incipient errors
3. Acting to mitigate the effects of those errors which do occur

This area of how we detect and prevent incipient errors and mitigate the potential consequences of errors is one in which further information and study is needed. Although we know a considerable amount as to what constitutes safe practice, and what sorts of errors can occur, we know less about perceptual and cognitive strategies that enable us to detect and correct errors in our actions.

Who among us has not picked up the incorrect syringe, and detected that we have done so, perhaps just at the point where we were about to inject the drug? We then replace that syringe back on the drug tray and pick up the correct syringe. This is an example of "error trapping". Who among us has not been too generous with the dose of induction agent, and have corrected the resultant hypotension with a judicious dose of vasopressor? This is an example of "error mitigation".

Near misses: free lessons

A near miss can be defined as an act of commission or omission that could have harmed the patient, but was prevented from completion through a planned or unplanned recovery.[41] Near misses occur with greater frequency than events that result in actual harm. They are thus a rich source of information about both system vulnerabilities and our abilities to trap and mitigate errors. There are now over 500,000 confidential near miss reports that have been logged by aviation safety reporting systems.[42] Data from these reports have been utilised in redesigning aircraft, air traffic control systems, airports and pilot training methods. Research into near misses in anaesthesia has the potential to yield invaluable information.

HIGH RELIABILITY ORGANISATIONS

Whilst the majority of our patients would consider that when they walk through the front door of a hospital they are entering a "high reliability organisation", in fact they are not.

Successful outcomes rarely call attention to themselves.[23] What is it that allows certain organizations and industries to have excellent safety records? Research over the past 20 years has focussed on studying safety successes in organisations that undertake hazardous activities, yet have very low incidences of adverse events. Through this research, the defining features of High Reliability Organisations (HROs) have been elucidated.[43] HROs include, for example, aircraft carriers, Western nuclear power stations and air traffic control systems. On a carrier, powered by a nuclear reactor, aircraft are fuelled whilst their engines are running, on a deck that is pitching with the sea!

The features of these organisations include that their staffs are performing complex tasks under time pressure, and that they carry out these demanding activities with low incident rates and almost no catastrophic failures over several years. It has been said that "safety is a dynamic non-event".[44] This means that the continuing absence of adverse events is a consequence of all the work and energy devoted by these organizations to creating safety. These organisations are successful at developing safety "mindfulness",[29] whereby all staff are acutely aware of safety issues and view their individual work as contributing to this quest for safety. Safety is everybody's job, and this is not just a slogan but is woven into all activities from management to workers at the front line.

HROs make excellent use of a systems approach to errors. They expect errors to occur, and endeavour to build in robust defences against errors into their systems. Safety becomes an over-whelming feature of the organisation's culture.

CONCLUSION

A modern approach to errors in medicine affords us the opportunity to apply many of the hard-won approaches to error management from other industries, whilst recognising the unique aspects of health care. Solutions may lie in a simple re-design of a piece of equipment or packaging of a drug. Solutions may also lie in more complex strategies involving, for example, decisions on staffing levels, supervision of junior staff and simulation training for operating room personnel.

"Just as complex systems threaten to bring us down … so do complex systems bring us unimagined and probably undeserved bounty."[20]

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