Error in Medicine

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FOR YEARS, medical and nursing students have been taught Florence Nightingale's dictum—first, do no harm.[1] Yet evidence from a number of sources, reported over several decades, indicates that a substantial number of patients suffer treatment-caused injuries while in the hospital.[2-6]

In 1964 Schimmel[2] reported that 20% of patients admitted to a university hospital medical service suffered iatrogenic injury and that 20% of those injuries were serious or fatal. Steel et al[3] found that 36% of patients admitted to a university medical service in a teaching hospital suffered an iatrogenic event, of which 25% were serious or life threatening. More than half of the injuries were related to use of medication.[3] In 1991 Bedell et al[4] reported the results of an analysis of cardiac arrests at a teaching hospital. They found that 64% were preventable. Again, inappropriate use of drugs was the leading cause of the cardiac arrests. Also in 1991, the Harvard Medical Practice Study reported the results of a population-based study of iatrogenic injury in patients hospitalized in New York State in 1984.[5,6] Nearly 4% of patients suffered an injury that prolonged their hospital stay or resulted in measurable disability. For New York State, this equaled 98 609 patients in 1984. Nearly 14% of these injuries were fatal. If these rates are typical of the United States, then 180 000 people die each year partly as a result of iatrogenic injury, the equivalent of three jumbo-jet crashes every 2 days.

When the causes are investigated, it is found that most iatrogenic injuries are due to errors and are, therefore, potentially preventable.[4,7,8] For example, in the Harvard Medical Practice Study, 69% of injuries were due to errors (the balance was unavoidable).[8] Error may be defined as an unintended act (either of omission or commission) or one that does not achieve its intended outcome. Indeed, injuries are but the "tip of the iceberg" of the problem of errors, since most errors do not result in patient injury. For example, medication errors occur in 2% to 14% of patients admitted to hospitals,[9-12] but most do not result in injury.[13]

Aside from studies of medication errors, the literature on medical error is sparse, in part because most studies of iatrogenesis have focused on injuries (eg, the Harvard Medical Practice Study). When errors have been specifically looked for, however, the rates reported have been distressingly high. Autopsy studies have shown high rates (35% to 40%) of missed diagnoses causing death.[14-16] One study of errors in a medical intensive care unit revealed an average of 1.7 errors per day per patient, of which 29% had the potential for serious or fatal injury.[17] Operational errors (such as failure to treat promptly or to get a follow-up culture) were found in 52% of patients in a study of children with positive urine cultures.[18]

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Given the complex nature of medical practice and the multitude of interventions that each patient receives, a high error rate is perhaps not surprising. The patients in the intensive care unit study, for example, were the recipients of an average of 178 "activities" per day. The 1.7 errors per day thus indicate that hospital personnel were functioning at a 99% level of proficiency. However, a 1% failure rate is substantially higher than is tolerated in industry, particularly in hazardous fields such as aviation and nuclear power. As W. E. Deming points out (written communication, November 1987), even 99.9% may not be good enough: "If we had to live with 99.9%, we would have: 2 unsafe plane landings per day at O'Hare, 16 000 pieces of lost mail every hour, 32 000 bank checks deducted from the wrong bank account every hour."

WHY IS THE ERROR RATE IN THE PRACTICE OF MEDICINE SO HIGH?

Physicians, nurses, and pharmacists are trained to be careful and to function at a high level of proficiency. Indeed, they probably are among the most careful professionals in our society. It is curious, therefore, that high error rates have not stimulated more concern and efforts at error prevention. One reason may be a lack of awareness of the severity of the problem. Hospital-acquired injuries are not reported in the newspapers like jumbo-jet crashes, for the simple reason that they occur one at a time in 5000 different locations across the country. Although error rates are substantial, serious injuries due to errors are not part of the everyday experience of physicians or nurses, but are perceived as isolated and unusual events—"outliers." Second, most errors do no harm. Either they are intercepted or the patient's defenses prevent injury. (Few children die from a single misdiagnosed or mistreated urinary infection, for example.)

But the most important reason physicians and nurses have not developed more effective methods of error prevention is that they have a great deal of difficulty in dealing with human error when it does occur.[19-21] The reasons are to be found in the culture of medical practice.

Physicians are socialized in medical school and residency to strive for error-free practice.[19] There is a powerful emphasis on perfection, both in diagnosis and treatment. In everyday hospital practice, the message is equally clear: mistakes are unacceptable. Physicians are expected to function without error, an expectation that physicians translate into the need to be infallible. One result is that physicians, not unlike test pilots, come to view an error as a failure of character—you weren't careful enough, you didn't try hard enough. This kind of thinking lies behind a common reaction by physicians: "How can there be an error without negligence?"

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Cultivating a norm of high standards is, of course, highly desirable. It is the terpart of another fundamental goal edical education: developing the ysician's sense of responsibility for patient. If you are responsible for erything that happens to the patient, it follows that you are responsible for any errors that occur. While the logic may be sound, the conclusion is absurd, because physicians do not have the power to control all aspects of patient care.[22] Nonetheless, the sense of duty to perform faultlessly is strongly internalized.

Role models in medical education reinforce the concept of infallibility. The young physician's teachers are largely specialists, experts in their fields, and authorities. Authorities are not supposed to err. It has been suggested that this need to be infallible creates a strong pressure to intellectual dishonesty, to cover up mistakes rather than to admit them.[23] The organization of medical practice, particularly in the hospital, perpetuates these norms. Errors are rarely admitted or discussed among physicians in private practice. Physicians typically feel, not without reason, that admission of error will lead to censure or increased surveillance or, worse, that their colleagues will regard them as incompe- t or careless. Far better to conceal a stake or, if that is impossible, to try shift the blame to another, even the ient.

Yet physicians are emotionally devastated by serious mistakes that harm or kill patients.[19-21] Almost every physician who cares for patients has had that experience, usually more than once. The emotional impact is often profound, typically a mixture of fear, guilt, anger, embarrassment, and humiliation. However, as Christensen et al[20] note, physicians are typically isolated by their emotional responses; seldom is there a process to evaluate the circumstances of a mistake and to provide support and emotional healing for the fallible physician. Wu et al[21] found that only half of house officers discussed their most significant mistakes with attending physicians.

Thus, although the individual may learn from a mistake and change practice patterns accordingly, the adjustment often takes place in a vacuum. Lessons learned are shared privately, if at all, and external objective evaluation of what went wrong often does not occur. As Hilfiker[19] points out, "We see the horror f our own mistakes, yet we are given permission to deal with their enor- us emotional impact.... The medical ofession simply has no place for its mistakes."

Finally, the realities of the malpractice threat provide strong incentives against disclosure or investigation of mistakes. Even a minor error can place the physician's entire career in jeopardy if it results in a serious bad outcome. It is hardly surprising that a physician might hesitate to reveal an error to either the patient or hospital authorities or to expose a colleague to similar devastation for a single mistake.

The paradox is that although the standard of medical practice is perfection—error-free patient care—all physicians recognize that mistakes are inevitable. Most would like to examine their mistakes and learn from them. From an emotional standpoint, they need the support and understanding of their colleagues and patients when they make mistakes. Yet, they are denied both insight and support by misguided concepts of infallibility and by fear: fear of embarrassment by colleagues, fear of patient reaction, and fear of litigation. Although the notion of infallibility fails the reality test, the fears are well grounded.

THE MEDICAL APPROACH TO ERROR PREVENTION

Efforts at error prevention in medicine have characteristically followed what might be called the perfectibility model: if physicians and nurses could be properly trained and motivated, then they would make no mistakes. The methods used to achieve this goal are training and punishment. Training is directed toward teaching people to do the right thing. In nursing, rigid adherence to protocols is emphasized. In medicine, the emphasis is less on rules and more on knowledge.

Punishment is through social opprobrium or peer disapproval. The professional cultures of medicine and nursing typically use blame to encourage proper performance. Errors are regarded as someone's fault, caused by a lack of sufficient attention or, worse, lack of caring enough to make sure you are correct. Punishment for egregious (negligent) errors is primarily (and capriciously) meted out through the malpractice tort litigation system.

Students of error and human performance reject this formulation. While the proximal error leading to an accident is, in fact, usually a "human error," the causes of that error are often well beyond the individual's control. All humans err frequently. Systems that rely on error-free performance are doomed to fail.

The medical approach to error prevention is also reactive. Errors are usually discovered only when there is an incident—an untoward effect or injury to the patient. Corrective measures are then directed toward preventing a recurrence of a similar error, often by attempting to prevent *that* individual from making a repeat error. Seldom are underlying causes explored.

For example, if a nurse gives a medication to the wrong patient, a typical response would be exhortation or training in double-checking the identity of both patient and drug before administration. Although it might be noted that the nurse was distracted because of an unusually large case load, it is unlikely that serious attention would be given to evaluating overall work assignments or to determining if large case loads have contributed to other kinds of errors.

It is even less likely that questions would be raised about the wisdom of a system for dispensing medications in which safety is contingent on inspection by an individual at the end point of use. Reliance on inspection as a mechanism of quality control was discredited long ago in industry.[24,25] A simple procedure, such as the use of bar coding like that used at supermarket checkout counters, would probably be more effective in this situation. More imaginative solutions could easily be found—if it were recognized that both systems and individuals contribute to the problem.

It seems clear, and it is the thesis of this article, that if physicians, nurses, pharmacists, and administrators are to succeed in reducing errors in hospital care, they will need to fundamentally change the way they think about errors and why they occur. Fortunately, a great deal has been learned about error prevention in other disciplines, information that is relevant to the hospital practice of medicine.

LESSONS FROM PSYCHOLOGICAL AND HUMAN FACTORS RESEARCH

The subject of human error has long fascinated psychologists and others, but both the development of theory and the pace of empirical research accelerated in response to the dramatic technological advances that occurred during and after World War II.[26] These theory development and research activities followed two parallel and intersecting paths: human factors research and cognitive psychology.

Human factor specialists, mostly engineers, have been largely concerned with the design of the man-machine interface in complex environments such as airplane cockpits and nuclear power plant control rooms. Cognitive psychologists concentrated on developing models of human cognition that they subjected to empirical testing. Lessons from both spheres of observation have greatly deepened our understanding of mental functioning. We now have reasonably coherent theories of why humans err, and a great deal has been learned about how to design work environments to minimize the occurrence of errors and limit their consequences.

A THEORY OF COGNITION

Most errors result from aberrations in mental functioning. Thus, to understand why errors occur we must first understand normal cognition. Although many theories have been espoused, and experts disagree, a unitary framework has been proposed by Reason[26] that captures the main themes of cognitive theory and is consistent with empirical observation. It goes as follows.

Much of mental functioning is automatic, rapid, and effortless. A person can leave home, enter and start the car, drive to work, park, and enter the office without devoting much conscious thought to any of the hundreds of maneuvers and decisions that this complex set of actions requires. This automatic and unconscious processing is possible because we carry a vast array of mental models, "schemata" in psychological jargon, that are "expert" on some minute recurrent aspect of our world. These schemata operate briefly when required, processing information rapidly, in parallel, and without conscious effort. Schemata are activated by conscious thought or sensory inputs; functioning thereafter is automatic.

In addition to this automatic unconscious processing, called the "schematic control mode," cognitive activities can be conscious and controlled. This "attentional control mode" or conscious thought is used for problem solving as well as to monitor automatic function. The attentional control mode is called into play when we confront a problem, either de novo or as a result of failures of the schematic control mode. In contrast to the rapid parallel processing of the schematic control mode, processing in the attentional control mode is slow, sequential, effortful, and difficult to sustain.

Rasmussen and Jensen[27] describe a model of performance based on this concept of cognition that is particularly well suited for error analysis. They classify human performance into three levels: (1) skill-based, which is patterns of thought and action that are governed by stored patterns of preprogrammed instructions (schemata) and largely unconscious; (2) rule-based, in which solutions to familiar problems are governed by stored rules of the "if X, then Y" variety; and (3) knowledge-based, or synthetic thought, which is used for novel situations requiring conscious analytic processing and stored knowledge.

Any departure from routine, ie, a problem, requires a rule-based or knowledge-based solution. Humans prefer pattern recognition to calculation, so they are strongly biased to search for a prepackaged solution, ie, a "rule," before resorting to more strenuous knowledge-based functioning.

Although all three levels may be used simultaneously, with increasing expertise the primary focus of control moves from knowledge-based toward skill-based functioning. Experts have a much larger repertoire of schemata and problem-solving rules than novices, and they are formulated at a more abstract level. In one sense, expertise means seldom having to resort to knowledge-based functioning (reasoning).

MECHANISMS OF COGNITIVE ERRORS

Errors have been classified by Reason and Rasmussen at each level of the skill-, rule-, and knowledge-based model.[26] Skill-based errors are called "slips." These are unconscious glitches in automatic activity. Slips are errors of action. Rule-based and knowledge-based errors, by contrast, are errors of conscious thought and are termed "mistakes." The mechanisms of error vary with the level.

Slips

Skill-based activity is automatic. A slip occurs when there is a break in the routine while attention is diverted. The actor possesses the requisite routines; errors occur because of a lack of a timely attentional check. In brief, slips are monitoring failures. They are unintended acts.

A common mechanism of a slip is *capture,* in which a more frequently used schema takes over from a similar but less familiar one. For example, if the usual action sequence is ABCDE, but on this occasion the planned sequence changes to ABCFG, then conscious attention must be in force after C or the more familiar pattern DE will be executed. An everyday example is departing on a trip in which the first part of the journey is the same as a familiar commuting path and driving to work instead of to the new location.

Another type of slip is a *description error,* in which the right action is performed on the wrong object, such as pouring cream on a pancake. *Associative activation errors* result from mental associations of ideas, such as answering the phone when the doorbell rings. *Loss of activation errors* are temporary memory losses, such as entering a room and no longer remembering why you wanted to go there. Loss of activation errors are frequently caused by interruptions.

A variety of factors can divert attentional control and make slips more likely. Physiological factors include fatigue, sleep loss, alcohol, drugs, and illness. Psychological factors include other activity ("busyness"), as well as emotional states such as boredom, frustration, fear, anxiety, or anger. All these factors lead to preoccupations that divert attention. Psychological factors, though considered "internal" or endogenous, may also be caused by a host of external factors, such as overwork, interpersonal relations, and many other forms of stress. Environmental factors, such as noise, heat, visual stimuli, motion, and other physical phenomena, also can cause distractions that divert attention and lead to slips.

Mistakes

Rule-based errors usually occur during problem solving when a wrong rule is chosen—either because of a misperception of the situation and, thus, the application of a wrong rule or because of misapplication of a rule, usually one that is strong (frequently used), that seems to fit adequately. Errors result from misapplied expertise.

Knowledge-based errors are much more complex. The problem solver confronts a novel situation for which he or she possesses no preprogrammed solutions. Errors arise because of lack of knowledge or misinterpretation of the problem. Pattern matching is preferred to calculation, but sometimes we match the wrong patterns. Certain habits of thought have been identified that alter pattern matching or calculation and lead to mistakes. These processes are incompletely understood and are seldom recognized by the actor. One such process is *biased memory.* Decisions are based on what is in our memory, but memory is biased toward overgeneralization and overregularization of the commonplace.[28] Familiar patterns are assumed to have universal applicability because they usually work. We see what we know. Paradoxically, memory is also biased toward overemphasis on the discrepant. A contradictory experience may leave an exaggerated impression far outweighing its statistical importance (eg, the exceptional case or missed diagnosis).

Another mechanism is the *availability heuristic,*[29] the tendency to use the first information that comes to mind. Related are *confirmation bias,* the tendency to look for evidence that supports an early working hypothesis and to ignore data that contradict it, and *overconfidence,* the tendency to believe in the validity of the chosen course of action and to focus on evidence that favors it.[26]

Rule-based and knowledge-based functioning are affected by the same physiological, psychological, and environmental influences that produce slips. A great deal of research has been devoted to the effects of stress on performance. Although it is often difficult to establish causal links between stress and specific accidents, there is little question that errors (both slips and mistakes) are increased under stress. On the other hand, stress is not all bad. It has long been known that "a little anxiety improves performance." In 1908, Yerkes and Dodson[30] showed that performance is best at moderate levels of arousal. Poor performance occurs at both extremes: boredom and panic.[31] *Coning of attention* under stress is the tendency in an emergency to concentrate on one single source of information, the "first come, best preferred" solution.[31] (A classic example is the phenomenon of passengers in a crashed aircraft struggling to open a door while ignoring a large hole in the fuselage a few feet away.) *Reversion under stress* is a phenomenon in which recently learned behavioral patterns are replaced by older, more familiar ones, even if they are inappropriate in the circumstances.[31]

The complex nature of cognition, the vagaries of the physical world, and the inevitable shortages of information and schemata ensure that normal humans make multiple errors every day. Slips are most common, since much of our mental functioning is automatic, but the rate of error in knowledge-based processes is higher.[26]

LATENT ERRORS

In 1979, the Three-Mile Island incident caused both psychologists and human factors engineers to reexamine their theories about human error. Although investigations revealed the expected operator errors, it was clear that prevention of many of these errors was beyond the capabilities of the human operators at the time. Many errors were caused by faulty interface design, others by complex interactions and breakdowns that were not discernible by the operators or their instruments. The importance of poor system design as a cause of failures in complex processes became more apparent.[32] Subsequent disasters, notably Bhopal and Chernobyl, made it even clearer that operator errors were only part of the explanation of failures in complex systems. Disasters of this magnitude resulted from major failures of design and organization that occurred long before the accident, failures that both caused operator errors and made them impossible to reverse.[26,32]

Reason[26] has called these *latent errors*, errors that have effects that are delayed, "accidents waiting to happen," in contrast to active errors, which have effects that are felt immediately. While an operator error may be the proximal "cause" of the accident, the root causes were often present within the system for a long time. The operator has, in a real sense, been "set up" to fail by poor design, faulty maintenance, or erroneous management decisions.

Faulty design at Three-Mile Island provided gauges that gave a low pressure reading both when pressure was low and when the gauge was not working and a control panel on which 100 warning lights flashed simultaneously. Faulty maintenance disabled a safety back-up system so the operator could not activate it when needed. Similarly, bad management decisions can result in unrealistic workloads, inadequate training, and demanding production schedules that lead workers to make errors.

Accidents rarely result from a single error, latent or active.[26,32] System defenses and the abilities of frontline operators to identify and correct errors before an accident occurs make single-error accidents highly unlikely. Rather, accidents typically result from a combination of latent and active errors and breach of defenses. The precipitating event can be a relatively trivial malfunction or an external circumstance, such as the weather (eg, the freezing of O-rings that caused the Challenger disaster).

The most important result of latent errors may be the production of psychological precursors, which are pathologic situations that create working conditions that predispose to a variety of errors.[26] Inappropriate work schedules, for example, can result in high workloads and undue time pressures that induce errors. Poor training can lead to inadequate recognition of hazards or inappropriate procedures that lead to accidents. Conversely, a precursor can be the product of more than one management or training failure. For example, excessive time pressure can result from poor scheduling, but it can also be the product of inadequate training or faulty division of responsibilities. Because they can affect all cognitive processes, these precursors can cause an immense variety of errors that result in unsafe acts.

The important point is that successful accident prevention efforts must focus on root causes—system errors in design and implementation. It is futile to concentrate on developing solutions to the unsafe acts themselves. Other errors, unpredictable and infinitely varied, will soon occur if the underlying cause is uncorrected. Although correcting root causes will not eliminate all errors—individuals still bring varying abilities and work habits to the workplace—it can significantly reduce the probability of errors occurring.

PREVENTION OF ACCIDENTS

The multiplicity of mechanisms and causes of errors (internal and external, individual and systemic) dictates that there cannot be a simple or universal means of reducing errors. Creating a safe process, whether it be flying an airplane, running a hospital, or performing cardiac surgery, requires attention to methods of error reduction at each stage of system development: design, construction, maintenance, allocation of resources, training, and development of operational procedures. This type of attention to error reduction requires responsible individuals at each stage to think through the consequences of their decisions and to reason back from discovered deficiencies to redesign and reorganize the process. Systemic changes are most likely to be successful because they reduce the likelihood of a variety of types of errors at the end-user stage.

The primary objective of system design for safety is to make it difficult for individuals to err. But it is also important to recognize that errors will inevitably occur and plan for their recovery.[26] Ideally, the system will automatically correct errors when they occur. If that is impossible, mechanisms should be in place to at least detect errors in time for corrective action. Therefore, in addition to designing the work environment to minimize psychological precursors, designers should provide feedback through instruments that provide monitoring functions and build in buffers and redundancy. Buffers are design features that automatically correct for human or mechanical errors. Redundancy is duplication (sometimes triplication or quadruplication) of critical mechanisms and instruments, so that a failure does not result in loss of the function.

Another important system design feature is designing tasks to minimize errors. Norman[28] has recommended a set of principles that have general applicability. Tasks should be *simplified* to minimize the load on the weakest aspects of cognition: short-term memory, planning, and problem solving. The power of *constraints* should be exploited. One way to do this is with "forcing functions," which make it impossible to act without meeting a precondition (such as the inability to release the parking gear of a car unless the brake pedal is depressed). *Standardization* of procedures, displays, and layouts reduces error by reinforcing the pattern recognition that humans do well.

Finally, where possible, operations should be easily *reversible* or difficult to perform when they are not reversible.

Training must include, in addition to the usual emphasis on application of knowledge and following procedures, a consideration of safety issues. These issues include understanding the rationale for procedures as well as how errors can occur at various stages, their possible consequences, and instruction in methods for avoidance of errors. Finally, it must be acknowledged that injuries can result from behavioral problems that may be seen in impaired physicians or incompetent physicians despite well-designed systems; methods for identifying and correcting egregious behaviors are also needed.

THE AVIATION MODEL

The practice of hospital medicine has been compared, usually unfavorably, to the aviation industry, also a highly complicated and risky enterprise but one that seems far safer. Indeed, there seem to be many similarities. As Allnutt observed,

> Both pilots and doctors are carefully selected, highly trained professionals who are usually determined to maintain high standards, both externally and internally imposed, whilst performing difficult tasks in life-threatening environments. Both use high technology equipment and function as key members of a team of specialists . . . both exercise high level cognitive skills in a most complex domain about which much is known, but where much remains to be discovered.[31]

While the comparison is apt, there are also important differences between aviation and medicine, not the least of which is a substantial measure of uncertainty due to the number and variety of disease states, as well as the unpredictability of the human organism. Nonetheless, there is much physicians and nurses could learn from aviation.

Aviation—airline travel, at least—is indeed generally safe: more than 10 million takeoffs and landings each year with an average of fewer than four crashes a year. But, it was not always so. The first powered flight was in 1903, the first fatality in 1908, and the first midair collision in 1910. By 1910, there were 2000 pilots in the world and 32 had already died.[32] The US Air Mail Service was founded in 1918. As a result of efforts to meet delivery schedules in all kinds of weather, 31 of the first 40 Air Mail Service pilots were killed. This appalling toll led to unionization of the pilots and their insistence that local field controllers could not order pilots to fly against their judgment unless the field controllers went up for a flight around the field themselves. In 1922, there were no Air Mail Service fatalities.[32] Since that time, a complex system of aircraft design, instrumentation, training, regulation, and air traffic control has developed that is highly effective at preventing fatalities.

There are strong incentives for making flying safe. Pilots, of course, are highly motivated. Unlike physicians, their lives are on the line as well as those of their passengers. But, airlines and airplane manufacturers also have strong incentives to provide safe flight. Business decreases after a large crash, and if a certain model of aircraft crashes repeatedly, the manufacturer will be discredited. The lawsuits that inevitably follow a crash can harm both reputation and profitability.

Designing for safety has led to a number of unique characteristics of aviation that could, with suitable modification, prove useful in improving hospital safety.

First, in terms of system design, aircraft designers assume that errors and failures are inevitable and design systems to "absorb" them, building in multiple buffers, automation, and redundancy. As even a glance in an airliner cockpit reveals, extensive feedback is provided by means of monitoring instruments, many in duplicate or triplicate. Indeed, the multiplicity of instruments and automation have generated their own challenges to system design: sensory overload and boredom. Nonetheless, these safeguards have served the cause of aviation safety well.

Second, procedures are standardized to the maximum extent possible. Specific protocols must be followed for trip planning, operations, and maintenance. Pilots go through a checklist before each takeoff. Required maintenance is specified in detail and must be performed on a regular (by flight hours) basis. Third, the training, examination, and certification process is highly developed and rigidly, as well as frequently, enforced. Airline pilots take proficiency examinations every 6 months. Much of the content of examinations is directly concerned with procedures to enhance safety.

Pilots function well within this rigorously controlled system, although not flawlessly. For example, one study of cockpit crews observed that human errors or instrument malfunctions occurred on the average of one every 4 minutes during an overseas flight.[32] Each event was promptly recognized and corrected with no untoward effects. Pilots also willingly submit to an external authority, the air traffic controller, when within the constrained air and ground space at a busy airport.

Finally, safety in aviation has been institutionalized. Two independent agencies have government-mandated responsibilities: the Federal Aviation Administration (FAA) regulates all aspects of flying and prescribes safety procedures, and the National Transportation Safety Board investigates every accident. The adherence of airlines and pilots to required safety standards is closely monitored. The FAA recognized long ago that pilots seldom reported an error if it led to disciplinary action. Accordingly, in 1975 the FAA established a confidential reporting system for safety infractions, the Air Safety Reporting System (ASRS). If pilots, controllers, or others promptly report a dangerous situation, such as a near-miss midair collision, they will not be penalized. This program dramatically increased reporting, so that unsafe conditions at airports, communication problems, and traffic control inadequacies are now promptly communicated. Analysis of these reports and subsequent investigations appear as a regular feature in several pilots' magazines. The ASRS receives more than 5000 notifications each year.[32]

THE MEDICAL MODEL

By contrast, accident prevention has not been a primary focus of the practice of hospital medicine. It is not that errors are ignored. Mortality and morbidity conferences, incident reports, risk management activities, and quality assurance committees abound. But, as noted previously, these activities focus on incidents and individuals. When errors are examined, a problem-solving approach is usually used: the cause of the error is identified and corrected. Root causes, the underlying systems failures, are rarely sought. System designers do not assume that errors and failures are inevitable and design systems to prevent or absorb them. There are, of course, exceptions. Implementation of unit dosing, for example, markedly reduced medication dosing errors by eliminating the need for the nurse to measure out each dose. Monitoring in intensive care units is sophisticated and extensive (although perhaps not sufficiently redundant). Nonetheless, the basic health care system approach is to rely on individuals not to make errors rather than to assume they will.

Second, standardization and task design vary widely. In the operating room, it has been refined to a high art. In patient care units, much more could be done, particularly to minimize reliance on short-term memory, one of the the weakest aspects of cognition. On-time and correct delivery of medications, for example, is often contingent on a busy nurse remembering to do so, a nurse who is responsible for four or five patients at once and is repeatedly interrupted, a classic set up for a "loss-of-activation" error.

On the other hand, education and training in medicine and nursing far exceed that in aviation, both in breadth of content and in duration, and few professions compare with medicine in terms of the extent of continuing education. Although certification is essentially universal, including the recent introduction of periodic recertification, the idea of periodically testing *performance* has never been accepted. Thus, we place great emphasis on education and training, but shy away from demonstrating that it makes a difference.

Finally, unlike aviation, safety in medicine has never been institutionalized, in the sense of being a major focus of hospital medical activities. Investigation of accidents is often superficial, unless a malpractice action is likely; noninjurious error (a "near miss") is rarely examined at all. Incident reports are frequently perceived as punitive instruments. As a result, they are often not filed, and when they are, they almost invariably focus on the individual's misconduct.

One medical model is an exception and has proved quite successful in reducing accidents due to errors: anesthesia. Perhaps in part because the effects of serious anesthetic errors are potentially so dramatic—death or brain damage—and perhaps in part because the errors are frequently transparently clear and knowable to all, anesthesiologists have greatly emphasized safety. The success of these efforts has been dramatic. Whereas mortality from anesthesia was one in 10 000 to 20 000 just a decade or so ago, it is now estimated at less than one in 200 000.[33] Anesthesiologists have led the medical profession in recognizing system factors as causes of errors, in designing fail-safe systems, and in training to avoid errors.[34-36]

SYSTEMS CHANGES TO REDUCE HOSPITAL INJURIES

Can the lessons from cognitive psychology and human factors research that have been successful in accident prevention in aviation and other industries be applied to the practice of hospital medicine? There is every reason to think they could be. Hospitals, physicians, nurses, and pharmacists who wish to reduce errors could start by considering how cognition and error mechanisms apply to the practice of hospital medicine. Specifically, they can examine their care delivery systems in terms of the systems' ability to discover, prevent, and absorb errors and for the presence of psychological precursors.

Discovery of Errors

The first step in error prevention is to define the problem. Efficient, routine identification of errors needs to be part of hospital practice, as does routine investigation of all errors that cause injuries. The emphasis is on "routine." Only when errors are accepted as an inevitable, although manageable, part of everyday practice will it be possible for hospital personnel to shift from a punitive to a creative frame of mind that seeks out and identifies the underlying system failures.

Data collecting and investigatory activities are expensive, but so are the consequences of errors. Evidence from industry indicates that the savings from reduction of errors and accidents more than make up for the costs of data collection and investigation.[31] (While these calculations apply to "rework" and other operational inefficiencies resulting from errors, additional savings from reduced patient care costs and liability costs for hospitals and physicians could also be substantial.)

Prevention of Errors

Many health care delivery systems could be redesigned to significantly reduce the likelihood of error. Some obvious mechanisms that can be used are as follows:

Reduced Reliance on Memory.—Work should be designed to minimize the requirements for human functions that are known to be particularly fallible, such as short-term memory and vigilance (prolonged attention). Clearly, the components of work must be well delineated and understood before system redesign. Checklists, protocols, and computerized decision aids could be used more widely. For example, physicians should not have to rely on their memories to retrieve a laboratory test result, and nurses should not have to remember the time a medication dose is due. These are tasks that computers do much more reliably than humans.

Improved Information Access.—Creative ways need to be developed for making information more readily available: displaying it where it is needed, when it is needed, and in a form that permits easy access. Computerization of the medical record, for example, would greatly facilitate bedside display of patient information, including tests and medications.

Error Proofing.—Where possible, critical tasks should be structured so that errors cannot be made. The use of "forcing functions" is helpful. For example, if a computerized system is used for medication orders, it can be designed so that a physician cannot enter an order for a lethal overdose of a drug or prescribe a medication to which a patient is known to be allergic.

Standardization.—One of the most effective means of reducing error is standardizing processes wherever possible. The advantages, in efficiency as well as in error reduction, of standardizing drug doses and times of administration are obvious. Is it really acceptable to ask nurses to follow six different "K-scales" (directions for how much potassium to give according to patient serum potassium levels) solely to satisfy different physician prescribing patterns? Other candidates for standardization include information displays, methods for common practices (such as surgical dressings), and the geographic location of equipment and supplies in a patient care unit. There is something bizarre, and really quite inexcusable, about "code" situations in hospitals where house staff and other personnel responding to a cardiac arrest waste precious seconds searching for resuscitation equipment simply because it is kept in a different location on each patient care unit.

Training.—Instruction of physicians, nurses, and pharmacists in procedures or problem solving should include greater emphasis on possible errors and how to prevent them. (Well-written surgical atlases do this.) For example, many interns need more rigorous instruction and supervision than is currently provided when they are learning new procedures. Young physicians need to be taught that safe practice is as important as effective practice. Both physicians and nurses need to learn to think of errors primarily as symptoms of systems failures.

Absorption of Errors

Because it is impossible to prevent all error, buffers should be built into each system so that errors are absorbed before they can cause harm to patients. At minimum, systems should be designed so that errors can be identified in time to be intercepted. The drug delivery systems in most hospitals do this to some degree already. Nurses and pharmacists often identify errors in physician drug orders and prevent improper administration to the patient. As hospitals move to computerized records and ordering systems, more of these types of interceptions can be incorporated into the computer programs. Critical systems (such as life-support equipment and monitors) should be provided in duplicate in those situations in which a mechanical failure could lead to patient injury.

Psychological Precursors

Finally, explicit attention should be given to work schedules, division of responsibilities, task descriptions, and other details of working arrangements where improper managerial decisions can produce psychological precursors such as time pressures and fatigue that create an unsafe environment. While the influence of the stresses of everyday life on human behavior cannot be eliminated, stresses caused by a faulty work environment can be. Elimination of fear and the creation of a supportive working environment are other potent means of preventing errors.

INSTITUTIONALIZATION OF SAFETY

Although the idea of a national hospital safety board that would investigate every accident is neither practical nor necessary, at the hospital level such activities should occur. Existing hospital risk management activities could be broadened to include all potentially injurious errors and deepened to seek out underlying system failures. Providing immunity, as in the FAA ASRS system, might be a good first step. At the national level, the Joint Commission on Accreditation of Healthcare Organizations should be involved in discussions regarding the institutionalization of safety. Other specialty societies might well follow the lead of the anesthesiologists in developing safety standards and require their instruction to be part of residency training.

IMPLEMENTING SYSTEMS CHANGES

Many of the principles described herein fit well within the teachings of total quality management.[24] One of the basic tenants of total quality management, statistical quality control, requires data regarding variation in processes. In a generic sense, errors are but variations in processes. Total quality management also requires a culture in which errors and deviations are regarded not as human failures, but as opportunities to improve the system, "gems," as they are sometimes called. Finally, total quality management calls for grassroots participation to identify and develop system modifications to eliminate the underlying failures.

Like total quality management, systems changes to reduce errors require commitment of the organization's leadership. None of the aforementioned changes will be effective or, for that matter, even possible without support at the highest levels (hospital executives and departmental chiefs) for making safety a major goal of medical practice.

But it is apparent that the most fundamental change that will be needed if hospitals are to make meaningful progress in error reduction is a cultural one. Physicians and nurses need to accept the notion that error is an inevitable accompaniment of the human condition, even among conscientious professionals with high standards. Errors must be accepted as evidence of systems flaws not character flaws. Until and unless that happens, it is unlikely that any substantial progress will be made in reducing medical errors.

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