Human Errors in Medical Practice: systematic classification and reduction with automated information systems

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Abstract

We review the general nature of human error(s) in complex systems and then focus on issues raised by Institute of Medicine (IOM) report in 1999. From this background we classify and categorize error(s) in medical practice, including medication, procedures, diagnosis and clerical error(s). We also review the potential role of software and technology applications in reducing the rate and nature of error(s).

Keywords: medical errors, human errors, information systems, systems, error(s) classification.

1. INTRODUCTION

Skilled physicians, trained nurses, and qualified administrators combine to make the medical field one of the 20 largest industries in the United States. Nevertheless, in recent years ongoing reports of problems with medical practice have gained a critical mass of attention resulting in the **The Institute of Medicine Report** [1,2,3,4,5,6,7]. The Institute of Medicine (IOM) report [2] pointed out very important issues related to the health care system. Errors committed by medical professionals in the health care system draw public and international attention. According to the IOM report, somewhere between 44,000 and 98,000 people die in different American hospitals every year due to 'errors committed by medical professionals.'

Experts have concluded that health care lags at least a decade behind aviation in safeguarding consumers' lives and health. The Department of Veterans Affairs [8], the largest health care system in the United States, counted almost 3000 errors -- along with some 700 deaths related to them -- within its health network between June, 1997 and December, 1998. All these reports suggest that the health care system requires more attention to improve this situation [1,2,3,4,5,6,7].

A. Research Objectives

Human error in medical practice can be reduced if a culture of awareness emphasizing when and how errors are prone to occur, in part by implementing machine-aided checking mechanisms, is effected.

> **Despite ideal circumstances, an occasional human error occurs, indicating the importance of incorporating defense mechanisms into a system to prevent the error(s) from harming the patient. How much**

money should be spent for defense systems (production versus safety) will obviously vary with specific problems. (FC Spencer p. 415) [3].

Our primary goal is to identify and classify human errors that are encountered in current medical practice. In addition, we would like to make recommendations for the design of a new type of "preventative software" that will introduce a new "gold" standard for medical software systems. A subsidiary goal of our research is to determine the human factors which may have led to a number of these adverse events or errors, and consider how automated information systems might help to prevent those errors. Many hospitals already use automated systems [3,4,5,7,9,10]. Impressive achievements in reducing adverse outcomes have occurred in anesthesia machines with appropriate alarms and monitors [11]. Otherwise, there are only isolated success stories for decreasing some types of hospital injuries. Most reports simply record the frequency of the problem, but provide little specific data [3].

B. Terminology

We use the term "medical practitioners" to include license health care workers that prescribe medication orders, perform medication procedures, diagnose diseases and assist in the care of patients. In our research we have found that the incidence of error included and affected all types of medical professionals at different stages of administration of medical care. This includes physicians, physician's assistants, pharmacists, nurses, and administrative personnel.

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C. Study Selection Criteria

Our review material includes studies which present errors in diverse domains of the medical field, as well as studies which evaluate the application of software technology in diverse areas of medical practice. To analyze the human factors in medical errors we have used a diverse group of information sources related to medical informatics and information science, including electronic databases such as MEDLINE, EMBASE, and EBSCO to search for cases of medical error from 1990-2000.

2. Discussion

As a result of the Institute of Medicine Report [p.52-53], the work of Perrow [12], Donald Berwick [13] and others, it is fairly clear that errors in the medical field and by medical practitioners need to be addressed in the same manner that errors in any complex system are addressed, e.g., air traffic and aviation control, nuclear power stations, space travel, etc. Medical errors can be analyzed in the framework of Perrow's DEPOSE (Design, Equipment, Procedures, Operators, Supplies and materials, and Equipment) [12].

A system is defined as "A set of independent elements interacting to achieve a common aim. The elements may be both human and non-human (equipment, technology, etc.)[14]." Perrow [12] uses the term "Normal Accident" to define a series of multiple failures of seemingly independent components which are *tightly coupled de facto* (dependent upon one another) but may not seem related. Faults (failures) in a system may occur without meriting the term "accident." However when multiple faults occur their accumulation is an accident. Perrow goes on to state: “An accident is an event that involves damage to a defined system that disrupts the ongoing or future output of the system [12].” In complex systems the best (and most common) way to analyze a major accident is by careful reconstruction of the conditions and circumstances that led to the accident. This leads to “hindsight bias” [14] and helps researchers to better understand the multiple factors which may have interacted and contributed to the accident.

A. Errors Committed by Humans and Machines

Errors by humans can come in many forms. They can be *slips,* because an action conducted is not what is intended, or they may be *lapses*, such as memory failures or omissions [14]. Mistakes can involve errors in planning, although action may proceed as intended. The situation could have been inadequately assessed, and/or could have involved a lack of knowledge [2].

In the medical field all kinds of errors are significant, and can have potentially devastating effects. A slip of the hand by a surgeon may be just as serious as writing 10mg. instead of 1mg. as a dosage, or a wrong diagnosis resulting in the selection of the wrong drug. The IOM report defines “*errors as the failure of a planned action to be completed as intended (e.g., error of execution) or the use of a wrong plan to achieve an aim (e.g., error of planning).* [2, p. 54]. This report is primarily concerned with errors of execution.

Reason [14] distinguishes between two kinds of human errors – active and latent ones. *Active* errors are the ones which are immediately discernible, while *latent* errors are much harder to detect, and may require considerable analysis to discover or understand. "The car hit the lamppost" is an example of an active error. If the driver had been under the influence of alcohol, or was driving 15 miles over the speed limit, these would be related but latent errors. The latent errors which were deemed to have caused the *Challenger* accident were traced back nine years, and in the case of the Accident at Three Mile Island, the latent errors were traced back two years [14]. The active errors (like the errors in security which occurred in the attacks of September 11th, 2001) draw our attention, but the actual long-term improvements in system design and safety will only occur after the detailed latent analysis which must follow.

Other researchers, as opposed to concentrating on errors, have focused on what makes certain industries such as military aircraft carriers or chemical processing highly reliable [15]. Their findings emphasize that accidents can be prevented through good organizational design and management [16]. Success factors include a high organizational commitment to safety, high levels of redundancy in personnel and safety measures, and a strong organizational culture for continuous learning and willingness to change [16]. The IOM report recognizes that "Safety is more than just the absence of errors. Safety has multiple dimensions, including the following:

- an outlook that recognizes that health care is complex and risky and the solutions are found in the broader systems context;
- a set of processes that identify, evaluate, and minimize hazards and are continuously improving, and

- an outcome that is manifested by fewer medical errors and minimized risk or hazard [17]."

In complex systems, when one component of a system which serves multiple functions, fails, all of the dependent functions may fail as well. As the dependency on technology in complex systems increases and systems become more tightly coupled in time and sequence, so does the likelihood of accidents. Operators become less prone to intervene, speedy recovery from error(s) is less likely, and small failures can more easily grow into major catastrophes [12]. Technology changes human tasks, shifts workloads, and tends to reduce or eliminate human decision-making. Hence, there tend to be peak periods, when human operators must be particularly alert, as opposed to more quiet times, typically handled by automation. Given that automated systems rarely fail, when unforeseen circumstances arise, due to lack of practice, operators may not possess, the basic skills which may be required [18,19,20].

Automation makes systems more "opaque" to people who manage, maintain, and operate them [Reason, 1990]. In addition, automated processes are less visible when machines intervene between people and the tasks at hand. Hence, people end up in more supervisory and planning roles, with less hands-on contact. Risks of information overload also exist (as discussed on (p. 28) with regard to the Accident at Three Mile Island).

A study by Wallace and Kuhn [21] identified and analyzed 383 medical software recalls between the years 1983 and 1997. The number of software-related medical errors identified in recent years is increasing, but this is consistent with the fact that reliance on software by medical devices is doubling every two to three years. The device type and their distributions were categorized as follows: Anesthesiology (10%), Cardiology (21%), Diagnostic (19%), General Hospital (10%), Other (7%), Radiology (30%) and Surgery (3%). Fault classification was gradually refined into 13 categories distributed as follows: Calculation (24%), Change Impact (6%). Configuration Management (CM) (1%), Data (5%), Fault Tolerance (1%), Initialization (2%), Interface (2%), Logic (43%), Omission (3%), Other (3%), Quality Assurance (3%), Requirements (4%), and Timing (3%). Wallace and Kuhn produced tables defining methods for preventing and detecting faults in medical devices. They also provide some insights into the need for formal requirements specification and for improved testing of complex hardware-software systems. This study offers valuable lessons and an affirmation of quality practices appropriate for the medical domain.

The use of computer software to alleviate some of the problems we have discussed is commonplace. Nonetheless, it should be emphasized that software in itself represents no panacea. One common problem is information overload, which was one of the primary reasons for the operators' faulty decisions in the case of the Accident at Three Mile Island (TMI) [22]. Kemeny called the control room "the greatest tinker toy you have every seen" … and criticized the misplacement of some key indicators.

When system failures occur due to human error it is common to blame the operators [22,23]. Operators are the easiest targets to blame in the post-mortem of a major system failure, although the real problem will often lie in poor system design. In the case of TMI so many alarms had to be printed, that the printer fell as much as two hours behind in recording them [22]. " A current trend is to provide "smart" alarms and warning systems that, among other things, prevent obvious false alarms and assign priorities to alarms [24,25]. The problem with "smart alarms" is that the real system failures may become somewhat masked behind the alarms. Operators may not be sufficiently trained to interpret or understand the underlying causes of failure. One of the other major conclusions of the Kemeny Commission is that system operators (in this case nuclear power station operators) need to be well-trained and well-paid professionals who have a deep theoretical and practical understanding of the system they are operating.

A report entitled *Physician decision-making -- evaluation of data used in a computerized ICU* [26] addresses the possibility of information overload affecting ICU (Intensive Care Unit) clinicians. The ICU at LDS Hospital is almost entirely computerized, including each patient's physiologic, laboratory, drug, demographic, fluid input/output and nutritional data in the computer patient record. For their study Bradshaw et. al. evaluated data usage in decision-making in the two situations where it takes place: during rounds and on-site. The data items used in decision-making were tabulated into the categories: bedside monitor, laboratory findings, drugs, input/output and IV chart, blood gas laboratory, observations and other. Comparisons were made between the portion of the computerized database occupied by a category and its use in decision-making. Combined laboratory data (clinical, microbiology and blood gas) made up 38 to 41% of the total patient data reviewed and occupied 16.3% of the database. Observations made up 21-22% of the data reviewed and occupied 6.8% of the database. Drugs, input/output and IV data usage ranged from 13% to 23%, but occupied 36% of the database. Bedside monitor data usage was 12.5% to 22%, and occupied 32.5% of the database. The 'other' category, used 2.5% to 5% of the time, made up 8.4% of the database. These results indicate that patient data collection and storage should be evaluated and consideration should be given to how accessible, perceivable, and usable the data is. This study suggests that implementation of a computerized ICU Rounds Report developed for optimal data presentation can help physicians evaluate patient status, and should facilitate effective decision making. Dr. Spencer [3] stated, that in the future, with the plethora of new drugs regularly marketed, this frequency would increase. Upon review of all of the above cases as well as the published causes of errors related to medication, we believe that the limitations of human beings are the main factor contributing to this type of error.

3. Types and Cases of Errors in the Medical Field

In the landmark 1993 report, Kohn et. al. **[2]** presented a classification of medical errors. In that classification, medication related errors are listed under the categorization of “Treatment Error” and errors related to clerical procedure(s) are listed under the categorization of “Other”. However, in our analysis we have found that medication-related errors and errors related to clerical procedure(s) are abundant (see, discussion ‘Errors Related to Medication’ p. 8, ‘Errors Related to Clerical Procedure(s)’ p. 18) in medical practice. While expanding this classification we have kept in mind the possibilities for reducing these types of errors with software automation. Hence we have expanded the original IOM classification by specifically identifying and addressing these two types of errors **(See Figure 3, p.)**. Continuing along this framework, we have further classified medication errors into what we feel are appropriate subgroups. We have also classified ‘Errors Related to Diagnosis’ into two clinical subgroups (as opposed to the four subgroups of the IOM) as shown in Figure 1. The remainder of our classification system is essentially the same as the IOM classification.

Space for Figure 1

4. Errors Related to Medication

The topic of medication-related errors is popular in the medical literature, because such errors comprise the most common category of error in the medical profession.

The **IOM** [2] estimates that preventable medication errors result in more than 7000 deaths each year in hospitals alone, and tens of thousands more in outpatient facilities. **Bates and colleagues** [27] reported that about 30% of patient injuries occurring in a teaching hospital resulted from preventable ADE's (Adverse Drug Effect). Estimated excess hospital costs attributable per ADE were $4700 in a year. Based on this estimate, they calculated the cost related to preventable ADE's to be about $2.8 million per year for a 700-bed hospital. According to this data the cost of preventable ADE's would extrapolate to about $2 billion across the nation's hospitals. **Classen** [28] reported that 2.4 ADE's occurred per 100 hospitals admissions and estimated that about 50% of these events were preventable. **Lesar** [29] determined that there are approximately 3.99 prescription errors per 100 medications ordered. **Edmondson** [30] reported that 0.35% of 80,000 patients in New York State hospitals suffer a disabling injury caused by medication during hospitalization. She also stated that there is an average of 1.4 medication errors per patient per stay; of these errors, 0.9 percent leads to serious drug complications. **In the Harvard Medical practice study** [31], ADE's accounted for 19% of injuries to hospitalized patients, and represented the single most common cause of injury. The study said, " nationally, ADE's occurring after hospitalization have been projected to cost hospitals $2 billion per year, not including malpractice costs or the costs of injuries to patients." Dr. Spencer [3] stated that with the plethora of new drugs regularly marketed this frequency will increase in the future.

The American Hospital Association [8] listed the following etiology of categories of medication error(s):

a) Incomplete patient information

b) Unavailable drug information

c) Miscommunication of drug orders

d) Lack of appropriate labeling

e) Environmental factors

In order to be more specific, we have divided each group into subgroups, where deemed appropriate. Cases for every category are provided as examples. Cases are relevant. Obviously not all ADE's get published.

A. Misuse of medication: An appropriate medication is selected, but a preventable complication occurs and the patient does not receive the full potential benefit of the medication. Misuse of medication by physician and by nurse can also occur due to miscommunication with the physician's order.

1. **Incorrect Medication**

Case 1.1 A patient was given a lidocaine drip [32] instead of heparin. While as many as six health professionals had close involvement in this case, only one realized that an error had occurred.

Case 1.2 An internist administered potassium chloride [33] instead of 3.8% of sodium citrate to restart a clogged intravenous catheter.

2. **Incorrect route**

Case 2.1 A young patient with leukemia had vincristine injected by an intrathecal route instead of by the intravenous route by the physician [34].

3. **Incorrect dose**

Case 3.1 An 8-month-old child with heart failure secondary to arrythmia was given 0.09 milligrams of digoxin [35] rather than .90 micrograms due to an arithmetic conversion error by the resident physician.

Case 3.2 In November, 1994, in the Dana Farber Cancer Institute in Boston [8], Besty Lehman, age 29, and another woman, both suffering from breast cancer, received a (single) four-day dose of the anti-cancer drug cyclophosphamide instead of the dosage divided into the intended four daily doses for each woman.

4. Incorrect administration

Administration of a drug to which a patient known to be allergic.

B. Over-use of medication: Using too much of a drug or prescribing a drug when not indicated.

Case: A healthy 30-year-old woman [35] with a simple respiratory tract infection is inappropriately prescribed antibiotics.

C. Under-use of medication: Failure to provide medication when it would have produced a favorable patient outcome.

Case: A patient develops [35] measles at 26 months of age due to failure to administer the vaccine at 12 months of age, though there are vaccination programs available.

Several medical software systems contain protocols or defense mechanisms that help reduce error(s). These programs interact with medical professionals to facilitate their ability to make better decisions, rather than to make decisions for them. Such systems are already on the market today, and are being successfully being used by hospital professionals. One example occurs when a medical doctor orders a prescription using the Gopher POE system. If the wrong drug is accidentally prescribed, the system will quickly notify him/her [10]. Hospital management should only select those products on the market that exhibit the highest levels of concern for patient safety. Also hospital management should ascertain the extent to which suppliers evaluate their products for the purpose of improving their safety profile. Furthermore, even though in the US some hospitals use automated systems, many are still using manual procedures.

An early step towards automated systems was RMRS (Regenstrief Medical Record System), whereby providers hand-wrote their patient notes on encounter forms generated specifically for each patient [36]. Prescriptions were written on either standard prescription forms, or on paper medication forms generated by RMRS, and test orders were written longhand in a designated area of the encounter form. Data entry personnel manually abstracted selected data, such as vital signs, and recorded them in the RMRS. Finally, office personnel completed test requisitions [36]. The complexity of the physician order entry procedure, and its separation of routine management tasks into several smaller tasks that are handled by various hospital personnel, exemplify two of the most noteworthy causes of medical error that can occur on a daily basis. Multiple smaller tasks handled by diverse medical personnel such as ordering, preparation, and dispensing of medication provide multiple opportunities for incurring errors. Such errors can occur at all stages of the drug administration process --- from the initial writing of the prescription by the physician, to the transcription and preparation of the prescription by the pharmacy, finally followed by the administration of the medicine by a nurse to a patient [3].

5. **Preventing Medication Errors**

Organizing medical data to reduce information overload is a primary goal of automated medical databases. At a minimum, a complete up to date patient database including patient clinical history and medications prescribed, with entries providing information on allergic reactions and treatment response, would be an effective tool to reduce medication errors. Experimental research performed in different hospitals supports the use of database software for reducing the frequency of many of the medical errors discussed in this paper. Study results reported below will give credence to this statement.

The limitations of human information processing are a factor leading to many medication-related errors. With categorization and real-time record keeping of vital patient information and data, appropriately designed software can reduce the information overload experienced by medical decision-makers. For example, computer software systems have been implemented that monitor clinical laboratory data as well as prescribed medications, nutritional data, and fluid input/output. Advances in wireless technology already allow physicians to update or retrieve patient information at the patient's bedside with a hand-held device.

6. Study Results: use of software to prevent medication errors

David W Bates MD et al. [37] showed, using a POES, that non-intercepted serious medication errors decreased by 55%, from 10.7 events per 1000 patient days to 4.86 events per 1000(p=. 01). The decline occurred for all stages of the medication use process. Preventable ADE's declined 17%, from 4.69 to 3.88 per 1000, while non-intercepted potential ADE's declined 84%, from 5.99 to 0.98 per 1000 patient days (p=. 0002).

A. Economic Impact

Brigham and Women's Hospital in Boston [38] projected an annual savings of about $480,000 which could be attributed to the effectiveness of their POES. This figure does not include the costs of injuries borne by patients due to drug errors, malpractice suits, or of the extra work generated by other medication errors.

One-time costs associated with the development and implementation of a POES system have been estimated to be $1.9 million per year. Yearly maintenance costs for the system have been estimated to be $500,000 per year [38]. While these are rough estimates, they suggest that POES's not only improve the quality of care, but could also save money when one factors in the average malpractice awards involving medication errors.

Ashis K JHA [39] stated that a computerized monitoring strategy identified 2620 alerts, of which 275 were determined to be ADE's. The chart review found 398 ADE's, whereas voluntary reports detected 23. The computer monitor identified 45%; chart review, 65%; and voluntary report, 4%. They also showed that use of a computer-based monitor is much less expensive than chart review.

In the study **by Classen** [28] on ADE's in hospitalized patients, it was found that the most effective approach for reducing medication errors appeared to be computer programs that continually monitored drug use for appropriate selection and dosage, with intervention through disease management programs

Evans [40] found that prospective surveillance of computer-based medical records for known drug allergies and appropriate drug administration significantly reduced the number of all ADE's. **In another study by this group**, [46] a computer-assisted management program for antibiotics and other anti-infective agents was associated with significant reductions in prescriptions to which the patient had reported allergies, excessive drug doses, and other adverse events associated with anti-infective agents. The patients in the latter study had significantly shorter hospital stays and lower hospital costs.

The **Veterans Affairs Health Care System** [8] has taken steps to improve its safety record by employing a new bar coding system to prevent and track medical errors. This system features ID strips that are worn by nurses and patients and attached to medications. Before a nurse gives a patient a drug, all three ID strips are scanned into a computer, that verifies that the drug is being administered correctly and will not cause adverse drug interactions. If the program identifies a potential problem, it flashes a warning, while the rest of the time it just keeps a record of activity. The system has proven quite effective. In a test of the bar coding technology at two VA hospitals in Kansas, the medication error rate dropped 70 percent over a five-year period.

Since the fatal miscommunication in November, 1994, The **Dana-Farber Cancer Institute** updates its systems regularly to avoid the possible recurrence of such errors. The Institute has installed a $1.7 million computer system to take over many tasks involving prescriptions. Doctors no longer have to hand-write prescriptions, but fill out an electronic form instead, with the patient's personal information, as well as the name of the drug, the requested dosage and the number of the days for which the medicine is to be given. This information goes into the institute's computer system, which compares the information with the upper dosage limits for the drug and other pre-programmed guidelines. If the doctor seems to have made a mistake, the computer signals the error.

Secondly, a nurse checks the information in the computer before ordering the drug from the pharmacy. The pharmacist conducts yet another computerized review for potential drug interactions with other drugs, foods, or the patient's allergies.

After being prepared at the pharmacy, the drug next goes to the nurses' station, where two nurses check the drug's label and the patient's wristband to make sure that the drug is administered to the right person. These changes effectively brought about what the Institute has described as a "dramatic increase "in error prevention. These Measures, in effect, provide 5 levels of error checking. **Robert A Raschke MD MS, Bea Gollihare** et. al. [41] studied "a computer alert system to prevent injury from adverse drug events." During the 6-month study period the alert system fired 1116 times, and 596 were true positive alerts (positive predictive value of 53%). The alert identified opportunities to prevent patient injury secondary to ADE at a rate of 64 per 1000 admissions. A total of 265 (44%) of the 596 true-positive alerts were unrecognized by physicians prior to alert notification. The researchers came to the conclusion that, "clinicians can use hospital information systems to detect opportunities to prevent patient injuries secondary to a broad range of ADE's."

7. Medical Errors Related to Treatment Procedures

Errors in treatment procedure(s) constitute another category of common medical errors. By 'treatment procedure' we mean any treatment procedure other than treatment by medication.

Errors of this kind usually occur in surgical procedures, with physicians as the primary responsible parties. This type of error is generally a result of faulty actions taken by surgeons or anesthesiologists.

The following are four cases of this type of error:

Case 1: During cataract surgery [42] on a 12-year-old boy, the surgeon ruptured the lens capsule due to a slip of his hand.

Case 2: An orthopedic surgeon [42] operated on the wrong intervertebral disc.

Case 3: In Stamos v. Davis [42], a pulmonologist, in attempting a lung biopsy, mistakenly biopsied the patient's spleen.

Case 4: A surgeon [42] left an abdominal roll in a patient's upper abdomen during a laparotomy and presacral neurotomy.

8. Prevention of Errors in Treatment Procedures

For more successful surgeries, the highest possible skills and training, coupled with continuous systemic procedural improvements, adhering to state-of-the-art methods, are recommended. Using software to effect a series of checkpoints to ensure that:

1) the proper patient is being treated, and 2) that the correct surgical procedure is being performed on the correct patient organ, would be a desirable improvement to current practices. This can be done interactively with a physician prior to any treatment procedure.

9. Error(s) Related to Clerical Procedures

Clerical error is another common type of error that is amenable to prevention by software technology. As human beings, medical professionals commit this type of error despite having the most noble intentions. Some people are unable to perform this simple role because they are lazy, self centered and thoughtless.

In their research on human errors in hospitals, Sussman and Haug [43] became interested in "processing errors," those that occur in entering data for scientific reports and their eventual analysis. They studied three groups of records and found that on average 1.2 to 2.9 % of the data entered was erroneous. The highest error rate was 26.1 % [43]. Looking at these figures, we can assume that up to a quarter of the information that a hospital processes will be inaccurate, which can cause many potential hazards for patients. Koepke [44] produced a simple study of copying errors. He asked the participating laboratory to copy an eleven-digit laboratory identification number from the front of the answer sheet to the back. Almost 5% of 181 laboratories made mistakes in this copying.

A. Cases of Clerical Error(s)

Blood transfusion is the area where clerical errors most commonly occurred. In their article, **Myhre and D. McRure** [32] compared studies of errors in blood transfusions presented as **Table 1** below.

Space For Figure 2

Table 1 illustrates that errors occurred due to drawing specimens from the wrong patient (error by medical technologist), change of specimen in the laboratory (error by laboratory staff or medical technologist), and transfusion of blood into the wrong patient (errors by physician/nurse). **Figure 2** below **Table 1** illustrates the same data in a pie chart format. This type of error is committed by a wide variety of medical practitioners, in addition to physicians.

10. Prevention of Clerical Errors

The application of patient information systems, computerized alarm systems, and physician order entry systems, has the potential to prevent these types of errors.

We did not find any studies of computerized alarm systems specifically on blood transfusions, but studies on computerized alarm systems on adverse drug events [42], computerized laboratory alarm systems [45], and physician order entry systems [10] proved their effectiveness in cases of information mismatch.

11. Errors Related to Diagnosis

An accurate diagnosis is essential for effective patient care. The ramifications and consequences of diagnostic errors can be far-reaching.

A. Delayed Diagnosis

Case A 37-year-old woman [42] with an unremarkable medical history visited her physician for her physical examination. As the physician was about to enter the examination room, a nurse noticed that the patient's last pap smear, done three years earlier, showed adenocarcinoma in situ. The report, although filed in the patient's chart, was a complete surprise to the physician, as well. This occurred despite the fact that the patient had been seen several times in the clinic since the test was done.

B. Missed Diagnosis

Case In 1993, a 34-year-old woman [46] pregnant with her third child, told her obstetrician that she had found a lump in her right breast. The physician diagnosed the lump as a clogged milk duct. At the woman's first postpartum visit, she again mentioned the lump to the obstetrician. He then diagnosed a sebaceous cyst, and continued to refer to it in the same way 4 months later. A year later, the obstetrician sent that woman to a surgeon for removal of the "sebaceous cyst," and pathology revealed a malignancy consistent with ductal carcinoma. The patient had three masses in her right breast, with positive lymph nodes, and underwent a mastectomy.

C. Wrong Diagnosis

There are also cases where people are told they have a disease/problem when they don't. According to a study of the biopsy slides of 6,171 patients referred to the John Hopkins Medical Institution for Cancer Care, sometimes it is becomes clear that neither a disease or a medical problem was present [47]. Eighty-six patients, or 1.4 percent, had diagnoses that were significantly wrong and would have led to unnecessary or inappropriate treatment. Magnified across the country, that error rate translates into 30,000 missed pathology analyses a year.

12. Prevention of Errors in Diagnosis

Although software applications for medical diagnosis are limited at present, progress is being made. Studies show that in some situations the use of computers (as tools) can lead to more accurate diagnoses than diagnosis by physicians alone. In a series of studies at the Department of Emergency Medicine**,** at the **University of Pennsylvania** [47], a neural network detected myocardial infarction from electrocardiograms 20% more accurately than did the emergency room doctor. One application of this artificial neural network was based on a retrospective study of a set of 356 patients admitted to a cardiac intensive care unit, of which one hundred and twenty had sustained myocardial infarctions. The network was trained, using back propagation, on half of the patients with and without myocardial infarction, and it was tested on the remaining patients, who had not been exposed to the network. The process was then reversed and the data were pooled. Sensitivity was 92%, and specificity 96%. Several similar retrospective studies were followed by prospective study of 320 patients who came to the Emergency Department with acute chest pain. This study compared the diagnostic accuracy of the artificial neural network with that of the physicians taking care of the same patients. The network was trained on the 356 patients from the first study and then prospectively tested on 320 patients. For the physicians, sensitivity was 78% and specificity 85%, while the network had a sensitivity and specificity of 97% and 96%, respectively. Current work is devoted to validating the network by extending studies to more patients. Over 1000 patients are presently in the study and the network still outperforms physicians. Neural networks have also been developed to diagnose appendicitis, dementia, psychiatric emergencies, and sexually transmitted diseases.

In her book ***A Gift of Fire, Sara*** Baase [48] discusses a number of areas for using computers to diagnose diseases. The vision field analyzer, a device that tests for glaucoma using computer-generated images, is more accurate than its non-computer predecessor. A new computer program predicts the results of biopsies for prostate cancer with 87% accuracy; doctors typically can predict the results with 35% accuracy. A computer system for analyzing mammograms does a better job than do most doctors. A new ultrasound device uses computers to analyze echoes from sound waves bounced off a lump in a woman's breast. It can determine whether or not the lump is benign, and eliminate the need for 40% of surgical biopsies for breast cancer. A new computer tomography scanning method using virtual reality techniques is being developed as a screening test for colon cancer.

13. Conclusion

The domain of errors by medical practitioners has received considerable attention in recent years. Yet there is substantial disagreement amongst experts as to whether the number of deaths caused by these errors has been either under or over-estimated. Regardless, the number of deaths cause by such errors is alarming.

Therefore we analyzed the nature of medical errors, including errors in medications, treatment procedures, diagnosis, and clerical functions. This naturally led to our endeavor to extend the

IOM classification of medical errors (See Figure 1 and Figure 3). In addition we have discussed the possible past and future roles of computer software applications in reducing the rates of such errors. Developments and changes in software applications today present incredible opportunities for "error-prevention and error-reduction." Hence we are optimistic that great progress can and will be made in this field.

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References

1. Brennan TA, The Institute of Medicine Report on Medical Errors Could It Do Harm? April 13, 2000, 342:1123-1125.

2. Kohn LT, Corrigan JM, Donaldson MS, eds. To err is human: building a safer health system. Washington, D.C.: National Academy Press, 2000.

3. Spencer FC, Human Error in Hospitals and Industrial Accidents: Current Concepts, Journal of American College of Surgeons, 191: 410 – 8, October 2000.

4. Ballas EA, Information Systems Can Prevent Errors and Quality, Journal of the American Medical Informatics Association: JAMIA, 8:398-9, July – Aug 2001.

5. Bates DW, Reducing the Frequency of Errors in Medicine using Information Technology, Journal of the American Medical Informatics Association: JAMIA, 8:299-308, July – Aug 2001.

6. Richardson WC, The Institute of Medicine Report on Medical Errors, The New England Journal of Medicine, 343:663-665, August 31, 2000.

7. Berner ES, Webster GD, Shugerman AA, Performance of four Computer-Based Diagnostic Systems, The New England Journal of Medicine, 330:1792-1796, June 23, 1994.

8. Tamar Nordenberg MAKE NO MISTAKE! Medical Errors Can Be Deadly Serious FDA consumers, p-13-18, September-October 2000.

9. Kassirer JP, A Report Card on Computer-Assisted Diagnosis – The Grade: C, 330:1824-1825, June 23, 1994.

10. Overhage JM, Perkins S, Tierney MW, controlled Trial of Direct Physician Order Entry, Journal of the American Medical Informatics Association: JAMIA, 8:361-71, July-August 2001.

11. Luginbuhl, M, and Schnider, T. Anesthesiology, V96, No 1, pp.241-243, Jan 2002.

12. Perrow, C., *Normal Accidents*, Princeton University Press, Princeton, N.J, 2nd ed.,1999.

13. Berwick, D., Eleven Worthy Aims for Clinical Leadership of Health System Reform. JAMA, Vol. 272(10) : 797-802, Sept. 14, 1994.

14. Reason, J., *Human Error*, Cambridge: Cambridge University Press: 1990

15. Roberts, K., Risk, Regulation, Litigation and Organizational Issues in Safety in High-Hazard Industries, position paper for Workshop on Organizational Analysis in High Hazard Production Systems: An Academy/Industry Dialogue," MIT Endicott House, NSF Grant No. 9510883-SBR, April 15-18, 1997.

16. Sagan, S. D., *The Limits of Safety*, Princeton: Princeton University Press, 1993.

17. Kizer, K. ,VHA's Patient Safety Improvement Initiative, presentation to the National Health Policy Forum by , Under Secretary for Health, Department of Veterans Affairs, Washington, D.C, May 14, 1999."

18. Van Cott, H., "Human Errors: Their Causes and Reductions", in *Human Error in Medicine*, ed., Marilyn Sue Bogner, Hillsdale, NJ: Lawrence Erlbaum Associates, 1994.

19. Kopec, D. & Michie, D. *Mismatch between machine representations and human concepts: dangers and remedies.* Report to the EEC under subprogram FAST (**F**orecasting and **A**ssessment in **S**cience and **T**echnology), Brussels, Belgium, 1992.

20. Kopec, D., *Human and Machine Representations of Knowledge.* Ph.D. Thesis. University of Edinburgh, Edinburgh, Scotland, 1983.

21. Wallace, D. R., and Kuhn, R., K, Software Quality Lessons from Medical Device Failure Data, Dept of Commerce, US Govn. NIST, Nov. 1999

22. Kemeny, J.J. et.al. Report of the President's Commision on the Accident at Three Mile Island, Vol. 1, Washington, DC.: U.S. Government Printing Office, 1979.

23. Bates, D.W., et. al., Reducing the Frequency of Errors in Medicine Using Information Technology, JAMIA. Vol 8, No 4, p. 301, July/Aug 2001.

24. Leveson, N, SAFEWARE, Addison Wesley, pp 114-115, , 1995.

25. Weiner, E.L, and Renwick, E. C. Flight-deck automation: Promises and problems. Ergonomics, 23(10): 995-1011,1980.

26. Bradshaw KE, Gardner RM, Clemmer TP, Orme JF, Thomas F, West B.J. Int J Clin Monit Comput 1(2):81-91, 1984.

27. Bates DW, Spell N, Cullen DJ, et al. The cost of adverse drug events in hospitalized patients. Adverse Drug Events Prevention Study Group. JAMA 277:307-11, 1997.

28. Classen DC, Pestotnik SL, Evans RS, et al. Adverse drug events in hospitalized patients. Excess length of stay, extra cost and attributable mortality. JAMA 277:301-6, 1997.

29. Lesar TS, Briceland L, Stein DS. Factors related to errors in medication prescribing. JAMA, 277:312-7, 1997.

30. Edmonson A.C. Learning from mistake is easier said than done: group and organizational influences on the detection and correction of human errors. J Appl Behav Sci, 32:5-28, 1996.

31. Brenan T. A., Leape L.L, Laird N, et al. Incidence of adverse events and negligence in hospitalized patients. N. Eng J Med, 324:370-376, 1991.

32. Myhre, B.A. and McRure D. Human error-a significant cause of transfusion mortality TRANSFUSION, vol 40:879-85, July 2000.

33. George D., Soundings: A medical error, BMJ, 6; 320 (7244): 1283, 2000.

34. Editorial, Not again! BMJ USA, vol1:155-6, April 2001.

35. Yeltman, R.J., MD Preventing Misuse Errors in Health Care Organizations. JCOM, vol. 8, No. 8:29-33, August 2001.

36. Boenheimer T, The American Health Care System: the movement for improved quality in health care, The New England Journal of Medicine, 340: 488-92, 1999.

37. Bates D.L., MD; Leape, L.L. MD, Cullen D.J, MD et.al. Effect of Computerized Physician Order Entry and a Team Intervention on Prevention of Serious Medication Errors JAMA, Vol 280 No.15, October 21, 1998.

38. Rose, Joan R Medical Economics, Vol 73 No11, June 10,1996.

39. Ashish K. Jha MD, Gilad Kuperman M.D Ph.D., Jonathan M Tech MD PhD., et. al., Identifying Adverse Drug Events: JAMIA 5(3): 305-314, May/June 1998.

40. Evans R.S., Pestotnik S.L., Clssen D.C., et al. Preventing adverse drug events in hospitalized patients. Ann Pharmacother, 28:523-7, 1994.

41. Robert A. Raschke MD, MS; Bea Gollihare MS RN; Thomas A Wunderlich RPh James R Guidry PharmD BCPS et el. A Computer Alert System to prevent Injury From Adverse Drug Events; Development and Evaluation in a Community Teaching Hospital. JAMA vol 280(15):1317-20, October1998.

42. Hebert, P.C. Levin A.V., G. sad Rothers, G. Bioethics for clinician: 23. Disclosure of medical error CMAJ, vol 164(4):509-13, February 2001.

43. Sussman M.B., Haug M.R. Human and mechanical error -- an unknown quantity in research. Am Behav Sci 11:55-6, 1967.

44. Koepke J.A., Some comments on errors on survey questionnaires, Pathologist. 25:193-4, 1971.

45. Bradshaw K.E., Gardner R.M. , Pryor T.A. Development of a Computerized Alerting System Computer and Biomedical Research 22:575-587, 1989.

46. Collins D., MALPRACTICE. (Wrong diagnosis of a breast mass) (Failure to diagnosis breast cancer claimed)(Unrecognized chorioamnionitis charged) (Death from cervical cancer) (Failure to monitor anesthesia level) (Death of an infant following placental abruption) Contemporary *OB/GYN*, 46(10): 124, Oct 2001.

47. Joseph D. Kronz, William H. Westra, Jonathan I. Epstein Mandatory Secondary Opinion Surgical Pathology at a Large Refferal Hospital *Cancer*, p -2426 December 1999.

48. Baxt W.G. Application of artificial neural networks to clinical medicine. Lancet 346:1135-38, 1995.

49. Baase. S., *A GIFT OF FIRE*, Prentice-Hall, Saddle River, NJ, computer in medicine, p 21-24, 1997.

Space for Figure 3

1

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Figure Captions

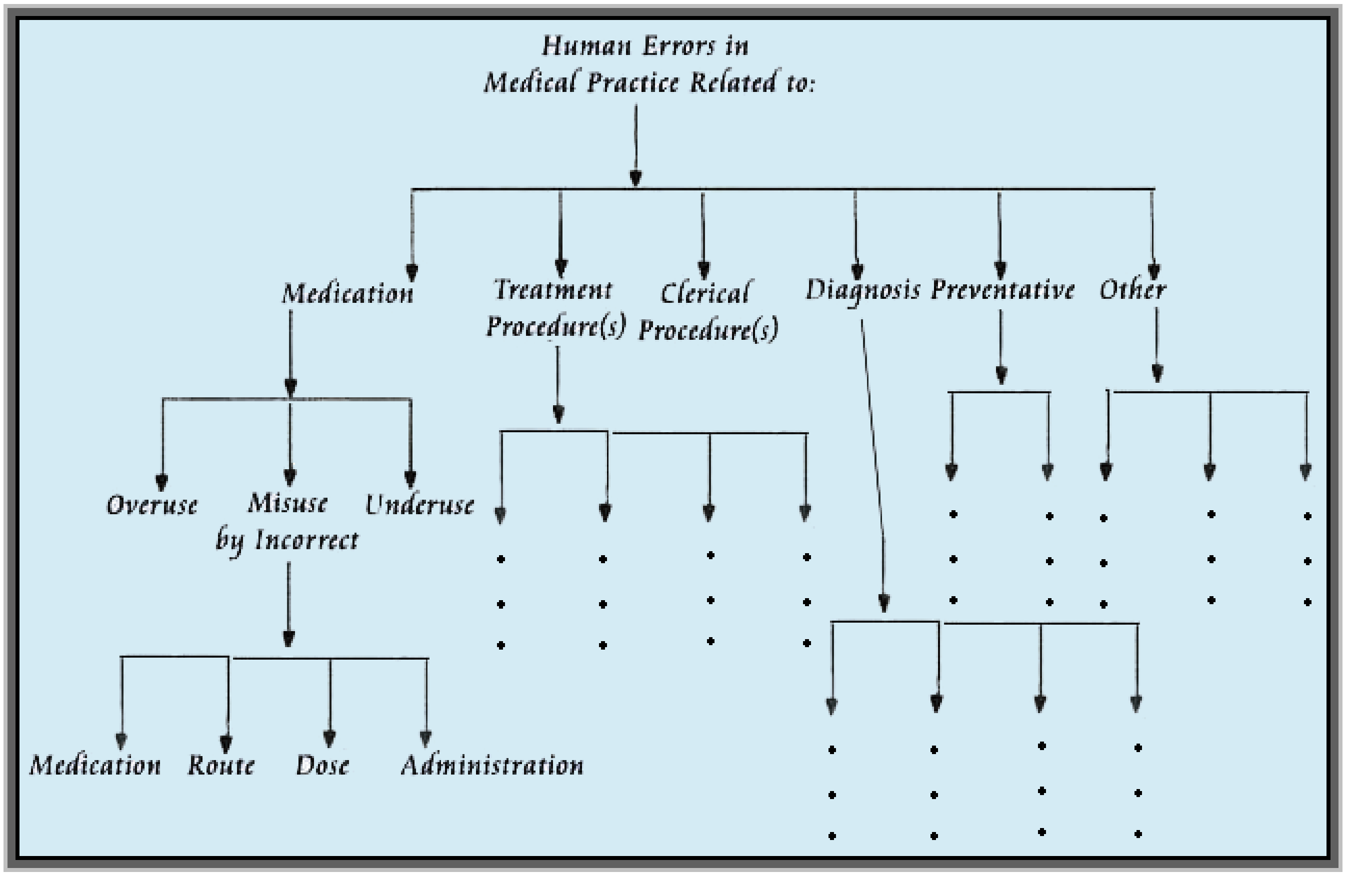
Figure 1: Classification of Human Medical Errors based on Leape et. al. [1993] (See Figure 3, p.) for details of our suggested additional categories of error).

Table 1: The Table (developed by Myhre and D. McRure [32]) shows the distribution of clerical errors according to their study of 699 cases.

Figure 2: Pie Chart representation of the information in Table 1.

Figure 3: This figure indicates the new categories of medication error which we have identified (highlighted in yellow) over the IOM classification of categories [Source: IOM Report, p. 36, and Leape, Lucian; Lowethers, Ann G; Brennan, Troyen A., et. al. Preventing Medical Injury. Qual. Rev. Bull. 19(5): 144-149, 1993.]

Figure 1.



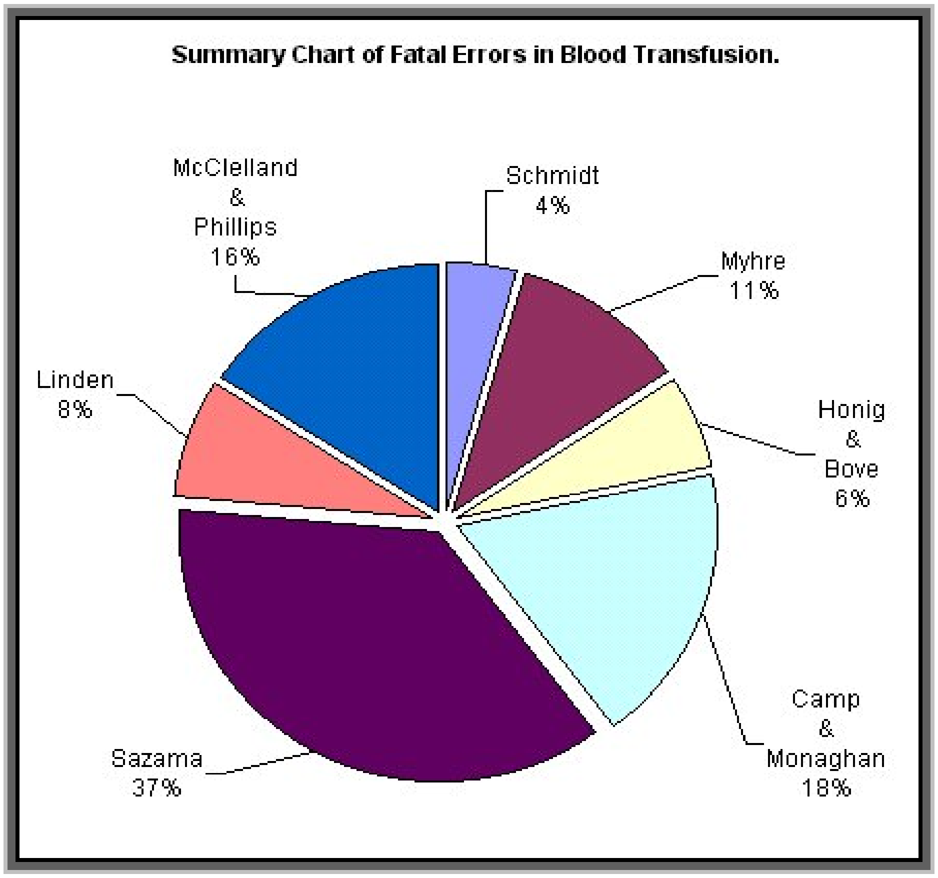
Human Errors in
Medical Practice Related to:
Medication
Treatment
Procedure(s)
Clerical
Procedure(s)
Diagnosis
Preventative
Other
Overuse
Misuse
by Incorrect
Underuse
Medication
Route
Dose
Administration

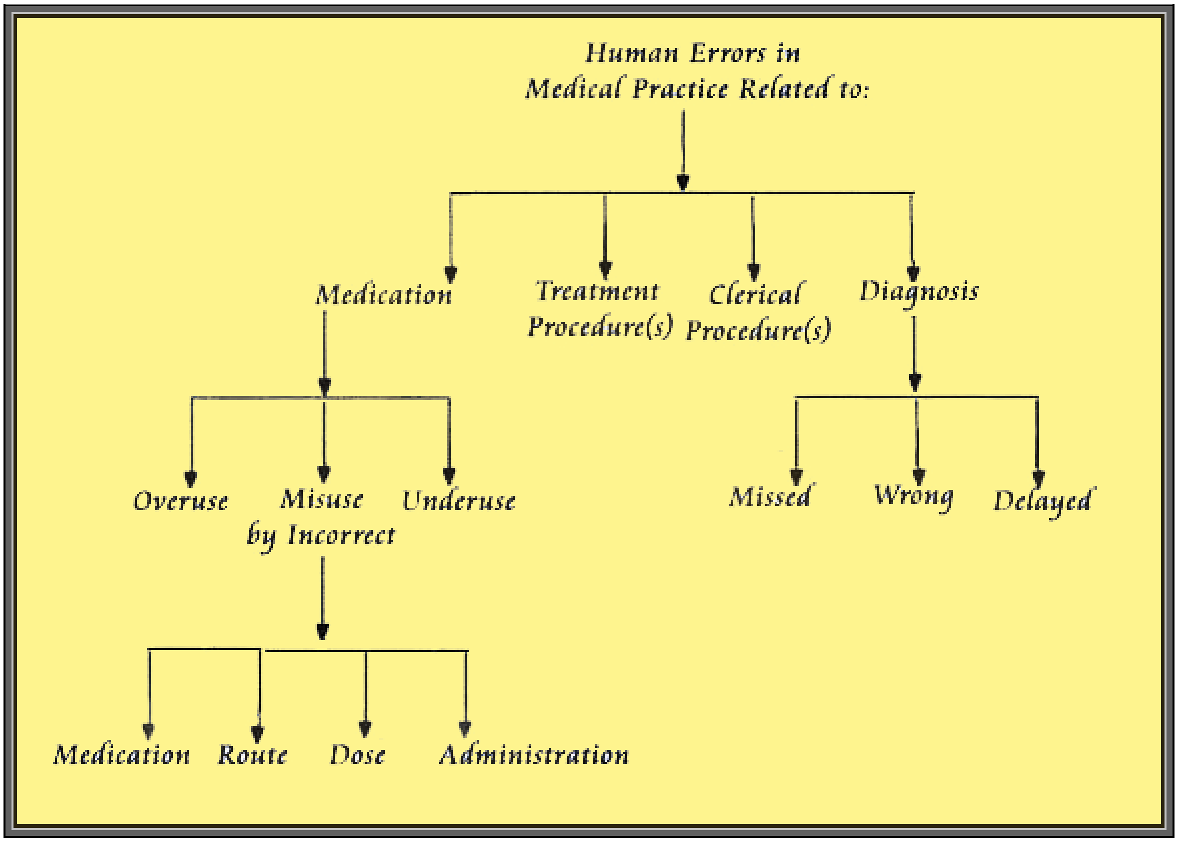
Summary and Comparison of Various Reports of Fatal Errors in Blood Transfusion.

	Schmidt	Myhre	Honig & Bove	Camp & Monagha	Sazama	Linden	McClelland & Phillips	
Drawing Specimen								
Wrong Specimen	0	7(10%)	7(16%)	1(1%)	13(5%)	10(19%)	23(20%)	
Other	0							
Laboratory								
Specimen Exchange	5(16%)	9(12%)	9(21%)	10(8%)	25(10%)	10(19%)	6(5%)	
Other			8(10%)	4(10%)	27(22%)	20(8%)	7(13%)	
Transfusion								
Wrong patient	17(55%)	30(39%)	17(38%)	25(20%)	77(30%)	24(44%)	82(75%)	
Other	3(10%)	1(1%)	1(2%)	1(1%)	10(4%)			
Other causes	19%	28%	13%	48%	43%	NS	NS	
Total	31	77	44	126	256	54	111	699

Table 1.

Figure 2.


Summary Chart of Fatal Errors in Blood Transfusion.
McClelland & Phillips 16%
Schmidt 4%
Myhre 11%
Linden 8%
Honig & Bove 6%
Camp & Monaghan 18%
Sazama 37%


Human Errors in
Medical Practice Related to:
Medication
Treatment
Procedure(s)
Clerical
Procedure(s)
Diagnosis
Overuse
Misuse
by Incorrect
Underuse
Missed
Wrong
Delayed
Medication
Route
Dose
Administration