Errors in Medical Practice: Identification, Classification and Steps Towards Reduction

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Abstract. We present a new taxonomy of medical errors, with emphasis on human errors. We illustrate errors due to medication, errors due to diagnosis, errors due to hospital treatment procedures, and errors related to clerical procedures. We also discuss a database of 143 papers on medical errors which we have developed.

Introduction

Continued concern with the identification and prevention of errors in medical practice has been clearly articulated in the famous 1999 report published by the Institute of Medicine (IOM) [1-7]. These research findings indicate that medical professionals in the United States commit errors in hospitals and other medical facilities that result in as many as 98,000 deaths per year [2]. Additional studies conducted by the Agency for Healthcare Research and Quality (AHCRQ) indicate that many of the erroneous actions and related complications are preventable. Failure to identify and correct the factors that lead to preventable medical errors appears to result in longer in-patient stays, increased mortality and increased health related expenditure, which is estimated by some experts to be in excess of $9 billion annually [40]. When considering the cost of preventable medical errors in terms of patient well-being and mortality, in addition to the increased costs associated with preventable medical errors, practical solutions must be found.

1. Research Goal

Our primary goal is to identify and refine the classification of human errors that are encountered in current medical practice with the hope that this will help reduce some of them.

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Currently an abundance of taxonomies exist to describe the mechanisms behind human errors. Taking the IOM taxonomy as an example, we will suggest an improved way to classify, distribute and update medical information. We will then propose a new taxonomy of medical errors with emphasis on human errors. In addition, we will make recommendations for the design of improved medical error prevention software. Human factors which may have led to a number of these adverse events or errors, will also be evaluated with a view towards specifying the design of automated information systems that can potentially reduce the incidence of such medical errors.

2. Medical Errors Taxonomy

2.1 Types and Cases of Errors in the Medical Field

At present a number of taxonomies exist to describe the mechanisms behind human errors, whereas very little is known about the mechanisms underlying error detection and recovery [36].

The American Hospital Association listed the following etiology of categories of medication errors [8]:

a) Incomplete patient information
b) Unavailable drug information
c) Miscommunication of drug orders
d) Lack of appropriate labelling
e) Environmental factors

The five error types most often observed and reported by U.S. family physicians were:
(1) Errors in prescribing medications; (2) errors in getting the right laboratory test done for the right patient at the right time; (3) filing system errors; (4) errors in dispensing medications; and (5) errors in responding to abnormal laboratory test results. "Errors in prescribing medications" was the only one of these five error types that was also commonly reported by family physicians in other countries [45]. A review of surgeries performed in U.S. doctors' offices has also concluded that death or injury is 10 times more likely in that setting than at outpatient clinics [47].

In an influential 1993 report, Kohn et. al. [2] developed a classification of medical errors. This report classifies medication-related errors under "Treatment Error, etc.", but in our analysis we have found that medication-related errors and errors related to clerical procedure are abundant in medical practice. Therefore, we have altered the original IOM classification by specifically identifying and addressing these two types of errors, by including the NCC MERP [42] taxonomy. We have also classified 'Errors Related to Diagnosis' into three clinical subgroups ("delayed", "missed", and "wrong", as opposed to the four subgroups of the IOM). Specifically, we have divided each type into subtypes, numbered according to the NCC MERP [42], and provide these as examples below

2.2 E.1. Errors Related to Medication

E.1.70. 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 can also occur due to miscommunication with the ordering physician.

E.1.70.2. Improper Dose

E.1.70.2.1. Over-use of medication: Using too much of a drug or prescribing a drug when not indicated.

Case 1. Millions of U.S. senior citizens have been subjected to over-medication as they get an increasing number of prescriptions ordered by a number of different providers [37].

E.1.70.2.2. Under-use of medication: Failure to provide sufficient medication when it would have produced a favourable patient outcome.

Case 1. An 8-month-old child with heart failure secondary to arrhythmia was given 0.09 milligrams of digoxin [20] rather than 0.90 mcg due to an arithmetic conversion error by the resident physician.

E.1.70.4. Wrong Drug

Case 1. A patient was given a lidocaine drip [17] instead of heparin. While as many as six health care professionals had close involvement in this case, only one realized that an error had occurred.

Case 2. An internist administered potassium chloride [18] instead of 3.8% of sodium citrate to restart a clogged intravenous catheter.

E.1.70.7. Wrong Route of Administration

Case 1. A physician injected vincristine into a young patient with leukemia, by intrathecal rather than by an intravenous route [19].

E.1.70.12. Monitoring Error Incorrect Administration

E.1.70.12.3. Administration of a drug to which a patient is known to be allergic.

2.3 E.2. Medical Errors Related to Hospital Treatment Procedures:

Errors in treatment procedures constitute another category of common medical errors. “Treatment procedure” is defined as any treatment procedure other than treatment by medication. This type of error is generally a result of faulty actions taken by surgeons or anaesthesiologists. The following are two cases of this type of error:

Case 1. An orthopaedic surgeon [26] operated on the wrong intervertebral disc.

Case 2. A 17-year-old girl received a heart and lung transplant from a donor with the wrong blood type [35].

2.4 E.3. Errors Related to Clerical Procedures:

Clerical error is another common type of error that is amenable to prevention by software technology. Research conducted on human errors by Sussman and Haug [27] focused on "processing errors," a type of error that tends to occur during data entry in preparation for report generation. Their findings indicate that on average from 1.0 % to 3.0 % of the data was incorrectly entered. Koepke [28] studying copy errors ascertained that about 5% of 181 laboratories made mistakes in copying an eleven-digit laboratory identification number from the front of the answer sheet to the back. Blood transfusion was found to be the most common source of clerical errors. In their article, Myhre and D. McRure [17] compared studies of errors in blood transfusions.

E.4. Errors Related to Diagnosis:

The negative implications of diagnostic error for patient mortality, care and well-being is an important subset of medical error that must be analyzed and evaluated carefully.

E.4.1. Delayed Diagnosis

Case 1. A 37-year-old woman [26] with an unremarkable medical history visited her physician for her physical examination. A nurse noticed that the patient's last pap smear, done three years earlier, showed adenocarcinoma in situ. This occurred despite the fact that the patient had been seen several times in the clinic since the test was done.

E.4.2. Missed Diagnosis

Case 1. In 1993, a 34-year-old woman [30] 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 was diagnosed to have a sebaceous cyst. A year later, the obstetrician sent the woman to a surgeon for removal of the "sebaceous cyst," and pathology revealed a malignancy consistent with ductal carcinoma.

Case 2. In 2003, an undiagnosed SARS case may have infected 25 health care workers and numerous other patients. Another 1,000 people, who may have come into contact with the suspected cases, have been given a 10-day quarantine order [39].

E.4.3. Wrong Diagnosis:

There are also cases where people are told they are afflicted with a disease when that is not the case. According to a study of the biopsy slides of 6,171 patients referred to the John Hopkins Medical Institution for Cancer Care; for eighty-six patients, or 1.4 percent, it was determined that neither a disease or a medical problem was present [31].

The new taxonomy, which is a combination of the IOM, JCAHO and NCC MERP classifications, is presented in Figure 1.

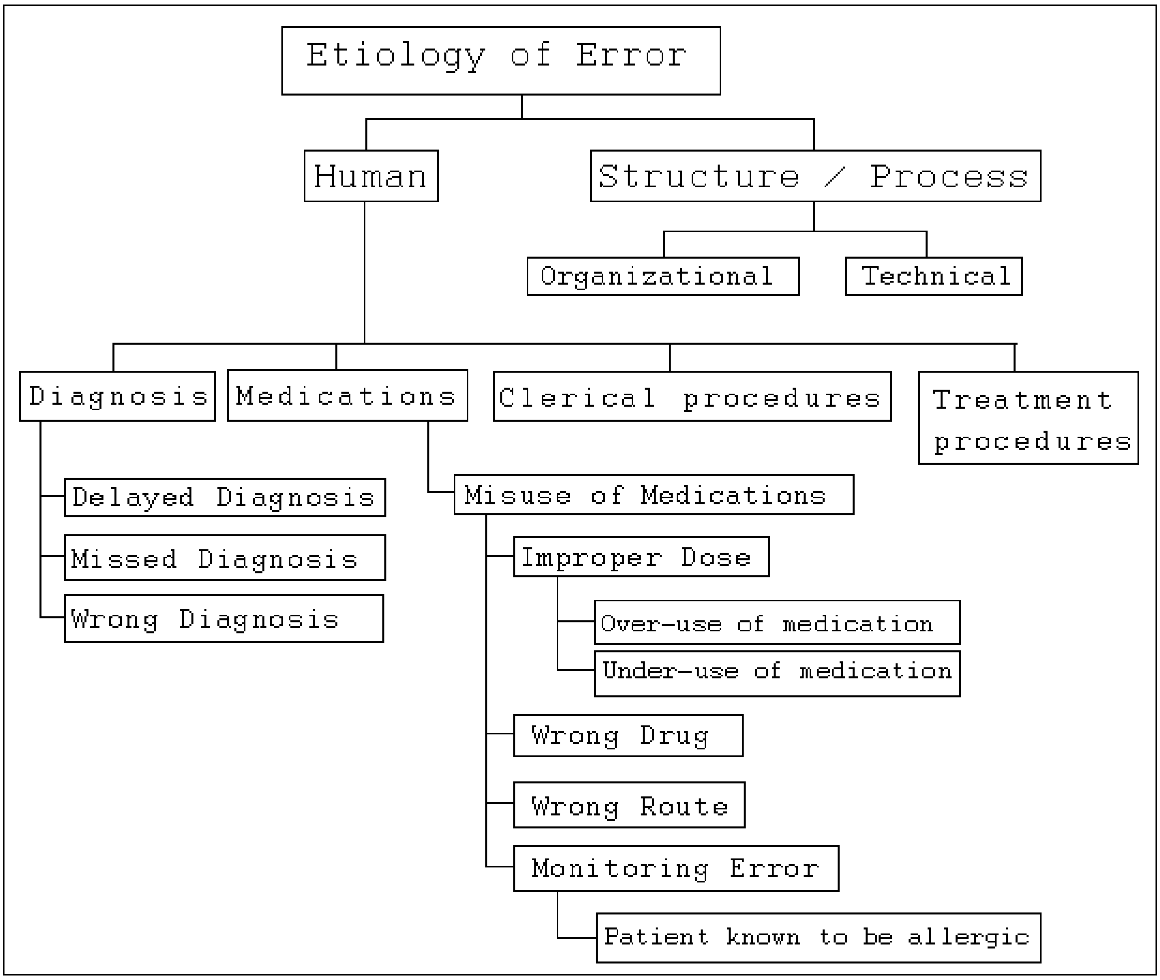

Figure 1. Recommended New Taxonomy of Medical Errors.

3. Taxonomy of Medical Errors and Software Applications to Reduce Them

The process of identifying and classifying errors is a complex one with a huge number of possibilities. The international taxonomy describing errors reported by general practitioners in Australia and five other countries was a five-level system encompassing 171 error types [44]. The NCC MERP classification system consists of more than 500 categories [42]. The International Classification of Diseases, 9th Revision (ICD-9,2004) includes over 10,000 diagnoses and 7,000 procedures [46]. Considering the possibility of one error for each diagnosis and procedure, we estimate that a complete medical error taxonomy would have more than 10,000 error descriptions and codes.

This is strongly suggestive that proper analysis and classification of medical errors would be greatly facilitated by a computer-based system. Through such a system prescriptions could be checked, drug interactions could be determined, alternative drugs can be found, and consequently ADE's would be reduced. X-ray images would be another way of confirming information, illustrating certain errors, and checking factual data. Built-in features (messages, alerts, and reminders) might suggest best practices and could be automatically added to the user’s account; finally, a set of integrated health maintenance and disease management rules will alert physicians about outstanding tests and procedures [48].

4. The Medical Portable On-Drive Record

This is one software-based approach which has been used to manage patient records. This approach has two requirements: 1) it should be housed on a portable device which can hold a substantial amount of information and 2) it has to provide privacy and security according to the Health Insurance and Portability and Accountability Act of 1996 (HIPAA) [49]. One such on drive device is the Smart Card and another, perhaps superior approach, is the use of Flash Memory. Advantages of Flash are: 1) more memory -- the typical Smart Card has a capacity of 64 KB while Flash Memory can store up to hundreds of megabytes of information, enough to hold several X-ray images or electrocardiographs (ECGs or EKGs). 2) portability -- Smart Cards require special terminals while the USB interface used for Flash Memory is available on most PCs. The contemporary USB Flash Memory Pen Drive offered by PINGTEC is a removable hard disk drive with a USB interface that makes transporting data easy. It has the following parameters: 128 MB, data retention time 10 years, dimensions (LWH) 91 mm x 28 mm x 13 mm, weight 22 grams. With continuing technological advances in hardware we can expect that such approaches will become more common and offer more opportunities.

5. Medical Errors Taxonomy and Database

Data related to medical errors articles has been *extracted, transformed and loaded* (ETL) into a MySQL database. This ETL procedure is written in Java. The CGI-bin report application for this database is written in C and is available on the Web. (http://acc4.its.brooklyn.cuny.edu/~gshagas/mederr.html). The prototype of the search engine is based on the use of Red-Black Trees. Red-Black Trees (RBT) are a binary tree-based data structure which enables efficient search/retrieval, insertion, and deletion of information.

The user should be able to search the medical errors database for specific articles, authors and words, which are parts of the article name. We performed a test of two possible search options, including (1) a direct search using database engine and program methods, and (2) using a search engine, based on a tree data structure. The first approach is implemented by a selection of article names and performed a simple substring search on the entire data set.

The second approach requires a tree data structure, which contains a set of keywords with pointers to where they exist in the database. We used the RBT data structure for storing and searching this set.

The number of articles in our database is 143, and the average length of an article title is 6.3 words. We inserted additional artificial data sets, with titles close to existing articles, into the database. We performed a search for a unique word, which existed in only one article. We tested the direct database search and search using the RBT engine for an existing medical errors database, particularly, for the words, which are parts of the article name. The programs for such procedures were written in Java, with an HTML front-end and the middle tier utilized Servlet technology and JDBC.

The results of our research are presented on Figure 2. The x-axis is logarithmic, while the y-axis is linear.

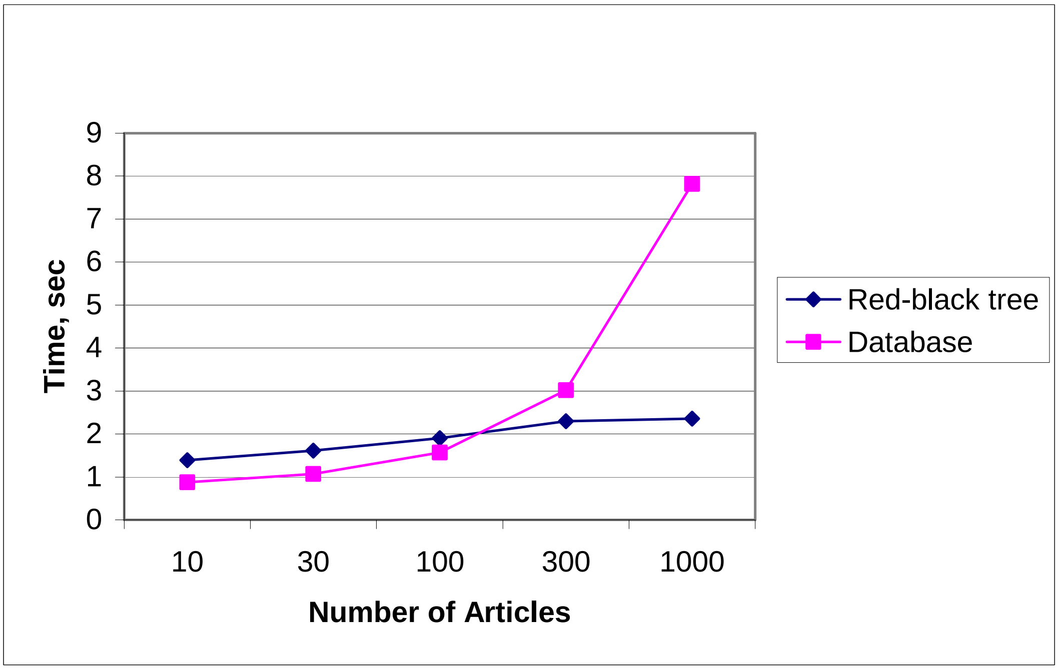

Figure 2. Retrieve Time for Medical Errors Database

Figure 2 shows that for a small number of articles the search time is less than 2 seconds for both the search engine and the direct database search. For a small number (10…30) of articles, the longest part of the procedure is to establish a connection to the database, which takes between 0.4 and 0.6 seconds. The overhead processes make direct database search more efficient for a small number of articles. We should also mention other disadvantages of the RBT search engine, such as space overhead and the costly updates required. Use of the RBT search engine on the database becomes justified when the number of articles is more than 100. In the case where the number of articles is on the order of 1000, the average successful search takes four times longer than when the RBT search engine is used.

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.[50] Regardless, the number of deaths caused by such errors is alarming.

We have analyzed the nature of medical errors, including errors in medications, treatment procedures, diagnosis, and clerical functions, and have developed a new Taxonomy of Medical Errors. We have revised and extended the JCAHO and NCMERP classifications and the IOM classification of medical errors by focusing on four categories of medication misuse. 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.

To facilitate access to medical errors research we have built a web-enabled Medical Errors Database and evaluated the performance of the Red-Black tree engine for our database’s implementation. We have learned that the use of a Red-Black Tree search engine on the database becomes justified when number of articles is greater than 100. If the number of articles reaches 1000 then savings from use of the Red-Black Tree structure will be 400%!

The use of medical on-drive records can be recommended to manage patient records. It could help to reduce the over-prescription for elderly people and practice commonly known as "doctor shopping."

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