Preventing Medication Errors in Hospitals through a Systems Approach and Technological Innovation: A Prescription for 2010

JACQUELYN CRANE and FREDERICK G. CRANE

Abstract. Medication errors in hospital settings are considered both widespread and costly to the American healthcare system; yet, it is tractable to available solutions. This article offers a novel prescription for the problem that could be implemented by 2010. It consists of a systems approach—failure mode effects analysis (FMEA)—in combination with emerging technologies, such as a decision support system (DDS) with integrated real-time medical informatics, electronic medical records (EMR), computer physician order entry (CPOE), bar coding, automated dispensing machines (ADM), and robotics. Cost and benefit analysis reveals that this proposed integrated solution will radically reduce medication errors in hospitals and save the lives of thousands of Americans who frequent such facilities on an annual basis, as well as reduce healthcare costs.

Key words: DDS, EMR, failure mode effects analysis, medication errors, technology

The Scope and Nature of the Problem

The U.S. spends over $1.6 trillion on healthcare. Yet, Americans pay much more for medical treatment than anyone else in the world, and also experience some of the highest medical errors rates of any industrialized nation (Heavey 2005; Schoen et al. 2005). In fact, $300 billion is spent each year on healthcare that does not improve patient outcomes—treatment that is unnecessary, inappropriate, inefficient, or ineffective (Bush 2004). The Institute of Medicine (IOM) estimates that medical errors alone cost the U.S. over $37 billion each year. Furthermore, the IOM suggests that between 44,000 and 98,000 Americans die each year from medical errors. Even the lower estimate is higher than the annual mortality from motor vehicle accidents (43,458), breast cancer (42,297), or AIDS (16,516), making medical errors the eighth leading cause of death in the United States (Institute of Medicine 1999). Yet research shows that most medical errors are largely preventable (Meadows 2003).

The IOM defines medical error as the failure to complete a planned action as intended or the use of a wrong plan to achieve an aim. An adverse event is defined as an injury caused by medical management rather than by a patient's underlying disease or condition (Institute of Medicine 1999). Medical errors fall into four main categories: diagnostic, treatment, preventative, and other (Al-Assaf et al. 2003). Medication errors fall under the rubric of treatment errors. A medication error is any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in control of the healthcare provider or patient. Medication errors have been found to be one of the most

Jacquelyn Crane is a pre-med student at Dartmouth College, Hanover, NH, where she is completing a special major in medical science. She is an Endowed Scholar at Dartmouth, a member of the Global Health Initiative Project, a member of the Nathan Smith Premedical Society, and a member of the Women in Science Program. **Frederick G. Crane**, the author of 11 books and over 100 refereed papers, is an executive professor at Northeastern University, Boston, MA. Formerly the president of the QMA Group, Dr. Crane has completed numerous consulting projects in the healthcare industry. He also sits on the editorial boards of several healthcare journals.

common causes of medical death, costing the lives of over 7,000 patients each year (Meadows 2003). Many more suffer permanent disability because of medication errors. Yet medication errors are considered the most preventable of all medical errors (Oren, Shaffer, and Guglielmo 2003).

Typically, medication errors involve preventable mistakes in prescribing and delivering medication to patients, such as prescribing two or more drugs whose interaction is known to produce adverse side effects, prescribing a drug to which the patient is known to be allergic, or simply prescribing or administering the wrong drug to a patient. The extent of medication errors is considered to be pervasive in hospital settings (Meadows 2003).

Causes of Medication Errors

Contrary to popular belief, medication errors are not typically the result of negligent or incompetent healthcare providers. Instead, experts contend that medication errors are a direct result of how the health system is organized and how care is delivered (Migdail 2000; Leape, Epstein, and Hamel 2002). When a patient enters a hospital for treatment, they are exposed to an outdated, paper-based system that is highly fragmented, highly variable, and error prone (Nielsen et al. 2004; Olsen 2002; Institute of Medicine 2001). Generally, a patient's medical information is scattered across numerous medical records that are kept by different providers in different locations or departments that may even be within the same hospital. Even the patient does not have an up-to-date, comprehensive medical record. Therefore, all relevant medical information is rarely available in one location in real-time when the patient requires care. The result is that patients are seen by doctors who generally do not have access to patient records, including current treatments, medications, and allergies.

Typically, physicians keep information about drugs, drug interactions, managed care formularies, clinical guidelines, and recent research in memory and not in documented form. Medical orders and prescriptions are handwritten and are too often misunderstood or not followed in accordance to physician instructions. Moreover, it has been found that most medication errors occur during drug ordering (Wilson et al. 2005). In short, all of these conditions set the stage for medication errors. Thus, unless there is a new approach to prevent such errors, patients will continue to die or be injured because of medication errors (Meadows 2003; Institute of Medicine 2001). In particular, it appears that the healthcare system itself must change.

Many experts argue that most errors committed in healthcare organizations, especially hospitals, are usually a result of system error, and even the remaining errors can be avoided if the system is organized to prevent errors (Crosby 1984; Deming 1984; Juran 1989; Institute of Medicine 2001; Meadows 2003; Nielsen et al. 2004; Reiling, Knutzen, and Stoecklein 2003). In fact, Crosby has argued that all errors are not inevitable and has pushed the concept of zero defects for many years. Moreover, research indicates that prevention strategies targeting systems rather than individuals have been found to be the most effective in reducing medication errors (Wilson et al. 2005).

Available Solutions to the Problem

There are numerous available solutions to the medication error problem in hospital settings. But often, many of the solutions are being used in isolation rather than through a integrated systems-approach. Some focus on better staff training, while others focus on better error tracking and reporting, adopting the best practices from highly reliable industries, involving system redesign, and involving the use of emerging technologies (Al-Assaf et al. 2003).

One system-based solution is called *failure mode effects analysis* (FMEA). This is a systematic group of activities intended to do three things: (*a*) recognize and evaluate the potential failures of a product or process and the effects of those failures, (*b*) identify actions that could eliminate or reduce the chance of potential failures occuring, and (*c*) document the entire process (Reiling, Knutzen, and Stoecklein 2003). Many industries have successfully used FMEA for systems improvement. In fact, FMEA has been used in healthcare for system improvements in the field of anesthesiology, where mortality resulting from errors has been reduced by 95% over the past 15 years (Orkin 1993). Unfortunately, FMEA is not being used to improve medication safety. Without a systemwide medical informatics program where all patient information is shared and updated across all relevant departments, FMEA is not likely to improve the medication error problem by itself.

Another proposed solution is electronic medical records (EMRs). With EMRs, physicians can easily access a patient's medical records to check any cur-

rent medications the patient is on, and probe for any allergies or adverse drug interactions. A very basic EMR system replaces all paper charts with fully electronic medical records. Moreover, EMRs can be made available to the patient via smart card technology or even by implanting it into the patient and can be electronically scanned and uploaded into a hospital's computer system (Grant 2005). In fact, President Bush (2004) is now advocating an electronic medical records program by 2010 that will put the needs of the patient first and provide all the necessary information required for safe and effective treatment. Experts suggest that electronically entering all medical information, such as admission narratives, laboratory tests, radiology studies, and nurse and physician notes, and storing this information on EMRs can vastly increase the safety of the healthcare encounter. One such study found that compared to paper-based systems, EMRs reduced medical errors by 55% (Wendel 2000). But according to one study, no more than 25% of U.S. hospitals and 20% of doctors' offices have adopted electronic medical records (Hillestad et al. 2005). Further, according to the National Ambulatory Medical Care Survey, only an average of 17.6% of physicians reported use of EMRs in their office-based practices (Burt and Sisk 2005).

Comprehensive decision support systems (DSSs), with real-time medical informatics obtained from a patient's EMRs, is deemed one of the prime strategies for reducing medication errors in the future (Wilson et al. 2005). These systems allow for improved communications with clinicians, access to medical knowledge, technique monitoring (including remote monitoring), automated calculations, patient information sharing, and error tracking and reporting. The Mayo Clinic, for example, has deployed such a system that has not only reduced medication errors, but also reduced medication costs. Current technology allows for even portable, handheld DSSs. Both the American Medical Informatics Association and the Agency for Healthcare Research and Quality suggest that a systems approach using real-time medical informatics within a decision support system is the key to reducing medication errors and improving patient safety (Jacot 2003). Used in conjunction with up-to-date electronic medical records, DSSs are considered essential tools for combatting medication errors.

Another proposed solution is computer physician order entry (CPOE) programs. Clearly, illegible handwritten prescriptions, overlooked allergies and drug interactions, and incorrect dosage often lead to medication errors. CPOEs have been found to be effective in reducing such medication errors (Oren, Shaffer, and Guglielmo 2003). CPOE involves entering medication orders into a computer system rather than verbally or on paper. With CPOE, physicians select the drug they want to prescribe along with the correct dose from a computerized menu. However, a survey of hospitals in 2002 revealed that only 3% of hospitals were using CPOE and only 30% more planned on implementing it in the future (Meadows 2003). Moreover, most CPOE programs are used alone and are not part of a decision support system, nor are they linked to EMRs.

Another solution to reducing medication errors is the use of bar coding technology. Since the FDA advocated the use of bar code on certain drug labels in 2003, healthcare providers now use bar code scanning technology to make sure the right drug in the right dose and route of administration is given to the right patient at the right time. Veteran Affairs (VA) hospitals use bar code technology nationwide and have seen an 86% reduction in medication errors (Meadows 2003). Bar coding technology used in conjunction with EMRs can prevent even more medication errors. For example, once a prescription order is checked against the electronic medical records, it is routed to the hospital pharmacy, where medication is labeled with the patient's name and unique barcode. The nurse scans the barcode on the medication, then scans the bar code on the patient's wrist band, assuring that it is right medication in the right dose for the right patient, virtually eliminating errors (Meadows 2003).

Finally, some other technological solutions involve automated dispensing machines (ADM) and robotic dispensing technology. The University of Pittsburg Hospital, for example, uses robotic dispensing technology—the Robot-Rx system—in its hospital pharmacy. This technology is used in conjunction with bar code technology where robots scan bar-coded medications from inventory and packages them in ADMs for delivery to inpatient units. Once in the patient unit, the automated dispensing machines dispense the medication to ensure patient safety. Order of St. Francis Medical Center, in Bloomington, IL, has also reduced the number of medication errors by 50%, primarily by implementing safety processes through ADMs and robotic drug dispensing (Nielsen et al. 2004).

Cost and Benefit Analysis of the New Technologies

Most experts suggest that adopting new technologies in a hospital setting will improve patient safety and patient care and reduce medical errors (Swartz 2005), while others point to the cost of implementing and maintaining new technology, as well as possible patient privacy concerns as possible resistance factors to adopting the technologies (Podichetty and Penn 2004). However, the RAND Corp. used a statistical model to predict the potential savings and business efficiencies if 90% of hospitals and doctors ultimately adopted the emerging technologies. The model showed $81 billion in annual savings, $77 billion from improved efficiency, and $4 billion from reduced medical errors and side effects (Swartz 2005). The RAND Corp. suggests it might cost $98 billion for hospitals and $17 billion for doctors to put such technologies in place and that it might take as long as 15 years to convert from a paper-based system to an electronic system (Swartz). But the RAND Corp. insists that, over time, the costs of implementation will be recouped and the financial and safety benefits of the system will far outweigh the costs. In fact, RAND Corp. is recommending that the healthcare system move aggressively to embrace such new technologies.

Brigham and Women's and its sister hospital, Massachusetts General, both located in Boston, MA, have demonstrated both the patient safety and financial benefits of the new emerging technologies discussed in this article, including EMRs. These hospitals have cut frequency of serious medication errors by 55% and the number of overall medication errors by 81%. Moreover, these hospitals have saved $10 million a year—a 10 to 1 payback on annual costs (Symonds 2000). Other researchers have also found that the financial benefits of implementing new technologies far outweigh the costs, including the possibility of introducing new errors (Schmitt and Wofford 2002). For example, one study showed that over a five-year period, new technologies provided a net financial benefit of $86,400 per provider in primary care health facilities (Wang et al. 2003).

In terms of patient safety and error reduction, VA hospitals have also demonstrated the effectiveness of the new technologies. Historically, patients entering VA hospitals were unlikely to have their paper record charts found. The goal now is to ensure that records will be available 100% of the time because of new technologies, including EMRs. Importantly, medication errors and medication costs are also down in VA hospitals that have implemented EMRs. (Lehrer 2005).

Still, one of the major concerns about the new technologies, specifically EMRs, is patient privacy. With providers and payers linked electronically and sharing patient records, privacy advocates are concerned about possible misuse of records and resultant patient harm. Privacy advocates argue that stringent security procedures and privacy protocols, including patient consent, must be part of any public policy regarding EMRs. They are also urging new federal laws to guard patient privacy (Goldberg 2000). However, experts suggest that patient privacy can be maintained if EMRs are implemented and maintained properly. Furthermore, they argue that the overall benefits of the new technologies outstrip its costs and other concerns, including patient privacy issues and the introduction of new errors (Brailer 2005; Podichetty and Penn 2004).

The Optimal Solution

To date, no hospital has put together an innovative and integrated solution to the medication error problem. What is proposed here is a novel but optimal solution. It involves the implementation of FMEA as a starting point. FMEA will examine the system to pinpoint failures or potential failures in the process of ordering and dispensing medication, identify actions to reduce the chance of failure, and document the entire process. Leveraging from the experience of using FMEA in the field of anesthesiology, FMEA can be used to make system improvement recommendations in the medication field. However, to be effective, FMEA must be used conjunction with the development and implementation of an innovative system-wide decision suppport system (DDS), which will include real-time medical informatics as well as the integration of EMRs.

Such systems are already in the early commercialization stages. VisualMed, for example, is a robust decision support system that contains real-time medical informatics and provides expert order entry, real-time decision support, integrated clinical reporting, patient safety tracking, and outcomes data generation (Posey 2002). A key component to the solution, however, will be the electronic medical records (EMRs), which both the patient and providers will have ready access to and

which can be updated continuously. As mentioned, the federal government is advocating that all patients have EMRs by 2010.

Additionally, emerging technologies such as CPOE, bar coding, ADMs, and robotics will be part of an integrated, system-wide approach to reducing medical errors and improving patient safety. This proposed solution will be safe, effective, patient-centered, timely, efficient, and equitable (Institute of Medicine 2001).

Envisioning Scenario: The Proposed Solution Is Implemented

The proposed solution, if implemented, would result in the following scenario. A patient will enter a hospital that has already made system improvements through FMEA, including an innovative decision support system capable of using real-time medical informatics. The patient arrives with her EMR card or subdermally imbedded chip. It is read into a scanner and all patient information is uploaded and disseminated to all hospital departments involved in the patient's care. All pertinent drug information (i.e., current medications, allergies) are highlighted and noted. An electronic bar code bracelet is placed on the patient. Any prescription order is checked against the EMR and routed to the hospital pharmacy. In the pharmacy, there will be robotic technology, such as the new Robot-Rx system, that will select the correct medication from stock using bar code technology, thus eliminating a dispensing error. The medication is then labeled with the patient's name and barcode, placed in an automated dispensing machine (ADM), and delivered to the inpatient unit.

The ADM will dispense the medication at that inpatient site. At the bedside, the provider will have a handheld DDS device equipped with a scanner. When the medication is dispensed from the ADM, the scanner is used to scan the patient's bracelet. The bar code provides the identifying information about the drugs to be given and the drugs are cross-checked with the patient information. If there is not a match, a warning pops up on the screen to alert the provider. This ensures the right medication in the right dose for the right patient is given. The DDS will also allow for remote monitoring to ensure another level of safety. Before the patient is discharged, all information about the treatment is updated electronically on all existing records, including the one in the patient's possession. The updated EMR is also sent electronically to the patient's primary care physician.

Conclusions

Medication errors are system problems requiring system-wide responses. A comprehensive support decision driven by real-time medical informatics coupled with the emerging technologies outlined in this article (i.e., CPOE, ADMs, bar coding) is the optimal solution for preventing medication errors in hospitals. This will require changes in both healthcare organizational design and delivery, as well as a time and financial commitment. However, the resources will be well spent if even one life is saved. Moreover, pragmatic cost and benefit analysis demonstrates the use of this proposal.

Experts have urged organizational leaders to commit to quality and a culture of safety, and they have given us the blueprint for achieving these goals (Nielsen et al. 2004; Reiling, Knutzen, and Stoeckein 2003). Furthermore, they urge prevention, not appraisal, and that is what the healthcare system must aspire to. The proposal in this article is consistent with what experts are advocating, and it is both forward-looking and preventative in nature. Clearly, it requires due consideration for implementation. This proposal takes the position that medication errors are not inevitable, but are preventable with proper system redesign and innovative and emerging technologies. Patients deserve to be safe in our healthcare system; this innovative solution will provide that safety.

REFERENCES

Al-Assaf, A., L. Bumpus, D. Carter, and S. Dixon. 2003. Preventing errors in healthcare: A call for action. *Hospital Topics* 81 (3): 5–12.

Brailer, D. J. 2005. Interoperability: The key to the future health care system. *Health Affairs* 24 (1): 19–21.

Burt, C. W., and J. E. Sisk. 2005. Which physicians and practices are using electronic medical records? *Health Affairs* 25 (5): 1334–43.

Bush, G. 2004. *State of the union address.* http://www.whitehouse.gov/news/releases/2006/01/20060131-10.html.

Crosby, P. 1984. *Quality without tears.* Chicago: IL: McGraw-Hill.

Deming, W. E. 1984. *Out of crisis.* Cambridge, MA: MIT Press.

Goldberg, I. 2000. Electronic medical records and patient privacy. *Health Care Manager* 18 (3): 63–69.

Grant, I. 2005. Medicinal compounds. *III-Vs Reviews: The Advanced Semiconductor Magazine.* 18 (1): 34–39.

Heavey, S. 2005. US leads the way in medical errors: Study, *Reuters,* November 3.

Hillestad, R., J. Bigelow, A. Bower, F. Girosi, R. Meili, R. Scoville, and R. Taylor. 2005. Can electronic medical record systems transform health care? Potential health benefits, savings, and costs. *Health Affairs* 24 (5): 1103–17.

Institute of Medicine. 1999. *To Err is Human: Building a safer health system*. Washington, DC: National Academies Press.

———. 2001. *Crossing the quality chasm*. Washington, DC: National Academies Press.

Jacott, W. 2003. Medical errors and patient safety. *Postgraduate Medicine* 114 (3): 1–3.

Juran, J. 1989. *Quality control and planning*. Milwaukee, WI: American Society of Academy Press.

Leape, L., A. Epstein, and M. Hamel. 2002. A series on patient safety. *New England Journal of Medicine* 347 (16):1272–74.

Lehrer, J. 2005. Medical errors. *Jim Lehrer Newshour Online*. http://www.pbs.org/newshour/bb/health/jan-june05/errors_2-7.html (accessed March 5, 2005).

Meadows, M. 2003. Strategies to reduce medical errors. *FDA Consumer* 37 (3): 20–27.

Migdail, K. 2000. Medical errors: The scope of the problem. *Agency for Healthcare Research and Quality* (Publication No. AHRQ 00-P037).

Nielsen, D., M. Merry, P. Schyve, and M. Bisognano. 2004. Can the gurus' concepts cure healthcare? *Quality Progress* September: 25–34.

Olsen, K. 2002. Medication errors: Problems identified, but what is the solution? *Critical Care Medicine* 30 (12): 944–45.

Oren, E., B. Shaffer, and J. Guglielmo. 2003. Impact of emerging technologies on medication errors and adverse drug events. *American Journal of Health System Pharmacy* 60 (14): 1447–58.

Orkin, P. 1993. Patient monitoring during anesthesia as an exercise in technology assessment. In Saidman, L. & N. Smith, eds. *Monitoring in Anesthesia*, 3rd Ed. London, England: Butterworth Publishers.

Podichetty, V., and D. Penn. 2004. The progressive roles of electronic medicine: Benefits, concerns, and costs. *The American Journal of The Medical Sciences* 328 (2): 94–99.

Posey, L. 2002. Medication errors: Technology coming to the rescue. *Pharmacy Today* 8 (2): 1–23.

Reiling, J., B. Knutzen, and M. Stoecklein. 2003. FMEA—the cure for medical errors. *Quality Progress*, August: 67–71.

Schmitt, K. F., and D. A. Wofford. 2002. Financial analysis projects returns from electronic medical records. *Healthcare Financial Management* 56 (1): 52–57.

Schoen, C., R. Osborn, P. Huynh, M. Doty, K. Zapert, J. Peugh, and K. Davis. 2005. Taking the pulse of health care systems: Experiences of patients with health problems in six countries. *Health Affairs* 16: W5-509-W5-525.

Swartz, N. 2005. Electronic health records could save $81 billion. *Information Management Journal* 39 (6): 6.

Symonds, W. 2000. How e-hospitals can save your life. *Business Week* 3711: 70–73.

Wang, S. J., B. Middleton, L. A. Prosser, C. G. Bardon, C. D. Spurr, P. J. Carchidi, A. F. Kittler, R. C. Goldszer, D. G. Fairchild, A. J. Sussman, G. J. Kuperman, and D. W. Bates. 2003. A cost-benefit analysis of electronic medical records in primary care. *The American Journal of Medicine* 114 (5): 397–403.

Wendel, S. 2000. Medical errors. *Healthcare Informatics* 17 (2): 37–40.

Wilson, J., L. Oyen, N. Ou, M. McMahon, R. Thompson, J. Manahan, K. Graner, J. Lovely, and L. Estes. 2005. Hospital rules-based system: The next generation of medical informatics for patient safety. *American Journal of Health System Pharmacy* 62 (5): 499–505.