

Improving Patient Safety through Information Technology

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Abstract

Health information technology (HIT) is generally accepted as the solution for the nation's medical error crisis. Although limited studies suggest the importance of using HIT in the process of medication management, research has failed to adequately describe how HIT actually works in capturing medication error data and improving patient safety within a healthcare system.¹⁻³ The aim of our study is to identify essential elements in the adoption of technology within the broader context of system change and workflow modification. Using the adoption of an electronic reporting system to improve patient safety, we examine the role of this technology within process improvement, culture, and workflow.

Background

Since publication of the landmark Institute of Medicine report *To Err Is Human*, several subsequent studies have documented both the economic cost and patient harm resulting from medication error.⁴⁻¹⁰ Consequently, information technology, such as Web-based reporting, electronic patient records, bar coding, and computerized prescriber order entry, is being implemented nationwide as a means to improve patient safety.¹¹⁻¹² In particular, Web-based reporting systems are used by risk management departments to process medication errors in a timely and cost-effective manner and are becoming increasingly available for healthcare institutions.¹³⁻¹⁴ For example, one recent study showed that the implementation of a computerized reporting system resulted in a decrease of adverse drug events (ADEs) by more than 250 percent, and it also showed that the cost of data collection decreased by \$30,000 annually;¹⁵⁻¹⁷ subsequent studies have shown similar results.¹⁸⁻²¹ The Healthcare Information and Management Systems Society, in a 2003 survey, found that the implementation of patient safety technology was ranked as the number one priority among healthcare executives.²²

While it is important to demonstrate the link between technology and improved patient care, it is equally important to contextualize the adoption of technology as an evolutionary process within broader systemic changes. Technology must be understood as a means to an end rather than an end in itself. In the past, other investigators have focused on the implementation of technology as a change agent,²³⁻²⁶ typically viewing it as a top-down process initiated by management. In contrast, we focus on the adoption of technology as a result of the interplay between top-down support by management and user buy-in as a bottom-up process within the context of workflow improvement. We found that the adoption of technology will fail without broad-based worker buy-in. Sustainability occurred at the intersection of support initiated by administration and buy-in from users who experienced improved workflow. This paper examines how we used our Web-based reporting system as a technological change agent in continuous process improvement of patient safety initiatives at an academic medical center.

Methods

Web-based Method of Occurrence Report Collection

Prior to December 2002, occurrence reports at the University of Mississippi Hospitals and Clinics (UMHC) were collected using a paper-based reporting mechanism. In December 2002, a Web-based system of collecting occurrence reports was introduced campus-wide. Occurrence reports are used to collect information on all medication errors or mistakes regardless of whether or not they resulted in patient harm. An occurrence report icon was placed on all personal computers within the UMHG system including inpatient, ambulatory, and administrative sites (e.g., administrator offices) ([Figure 1](#)). As a result, all providers and staff have easy access for reporting. To ensure confidentiality and anonymity, the reporter has the option of

accessing the Web occurrence report using a universal access code either from clinical workstations or from his or her private office. The occurrence report icon is linked directly to an electronic form with drop-down boxes and text options (Figure 2). This form requires a minimal amount of typing for answers, ensuring both accuracy and consistency of the data, and lessening the time it takes to complete the report.

Figure 1

Novell window with arrow indicating the "Medication Error Report" icon

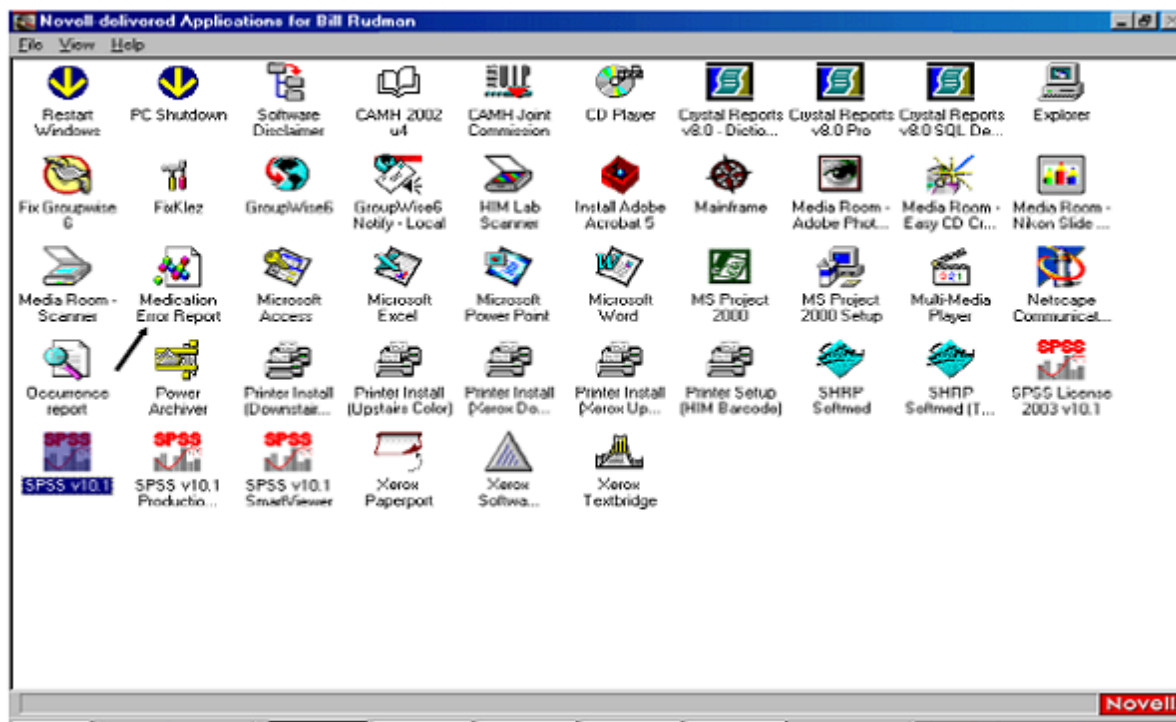


Figure 2

Medication Error Report opening screen with drop-down boxes

1.	Billing number: Medical record number:	<input type="text"/>
2.	What is the patient's name?	<input type="text"/>
	Patient's Date of Birth (mm/dd/yyyy):	<input type="text"/>
	Patient's gender:	<input type="text"/>
	Patient's race:	<input type="text"/>
3.	Date and Time of error:	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>
4.	Location:	<input type="text"/>
	Unit:	<input type="text"/>
	Department:	<input type="text"/>
5.	Where in the process did the initial error:	<input type="text"/>

Unlike most Web-based systems that are self-contained and do not interface with other information systems within the hospital, our occurrence report Web page is linked to the SoftMed ClinTrac data system, containing clinical, financial, and demographic patient data. The ClinTrac system is a comprehensive software tool that combines risk management, quality management, medical record abstracting, clinical data, and financial data. Data are automatically scrubbed to eliminate duplicates and non-patient events before being entered into the system. To further ensure data accuracy, the reported patient's name, medical record number, and billing number on the occurrence report must match data from corresponding administrative records for the Web form to be accepted and stored in the database.

From an operational perspective, data entered into the occurrence report system are sent directly to the risk management department. A clinical nurse coordinator begins the analysis process by e-mailing the occurrence information to appropriate healthcare providers. The nurse manager on the floor investigates the event and sends an e-mail message with additional information to a clinical nurse coordinator for final analysis. The clinical nurse coordinator then completes the report in the ClinTrac system for in-house reports (e.g., to the Patient Safety Council) or for further analysis for quality improvement reports and initiatives. At each stage, automated time logs are processed to improve accountability and to establish work standards for processing medication error occurrence reports. Time logs allow us to determine how long it took to work on each error at a particular stage in the process. For example, we know how long the floor nurses worked on an error before sending the results of their investigation back to risk management.

Data

Primary data from the Web-based reporting system were collected from January 2003 to June 2005. Our analysis focuses on the following monthly patterns: the number of errors reported; who discovered the error; whether or not the error reached the patient; and whether or not those errors that reached the patient resulted in patient harm. Our outcome measure severity is reporter driven; individuals choose from nine options. The options range in hierarchical sequence from having the capacity to cause error to possibly contributing to or resulting in the patient's death. For the purpose of our analysis, reported severity is then grouped into three categories: intercepted, no harm, and patient harm (Table 1).

Table 1: Categorization of Medication Error Severity Levels

Category	Description	Level
A	Circumstances or events that have the capacity to cause error	Intercepted
B	An error occurred that did not reach the patient (An "error of omission" does reach the patient)	
C	An error occurred that reached the patient but did not cause patient harm	No Harm
D	An error occurred that reached the patient and required monitoring to confirm that it resulted in no harm to the patient and/or required intervention to preclude harm	
E	An error occurred that may have resulted in temporary harm to patient and required intervention	Harm
F	An error occurred that may have resulted in temporary harm to patient and required prolonged hospitalization	
G	An error occurred that may have contributed to or resulted in permanent patient harm	
H	An error occurred that required intervention necessary to sustain life	
I	An error occurred that may have contributed to or resulted in the patient's death	

In order to examine the impact of the Web-based system of reporting, data from the former paper-based system (1994-2000; n = 2914 with a mean of 416 per year) were used to establish baseline criteria to measure success. In our analysis, data

collected in 2001 and 2002 were not included. Although the total number of medication errors identified in the occurrence reports during 2001 and 2002 were consistent with the former paper-based system (337 and 394 per year, respectively), these two years represented a transitional period of experimentation with several methods of medication error occurrence report collection. The current Web-based method of collecting medication error occurrence reports was put into production in December 2002 after being tested in UMHC's School of Health Related Professions Health Information Management lab.

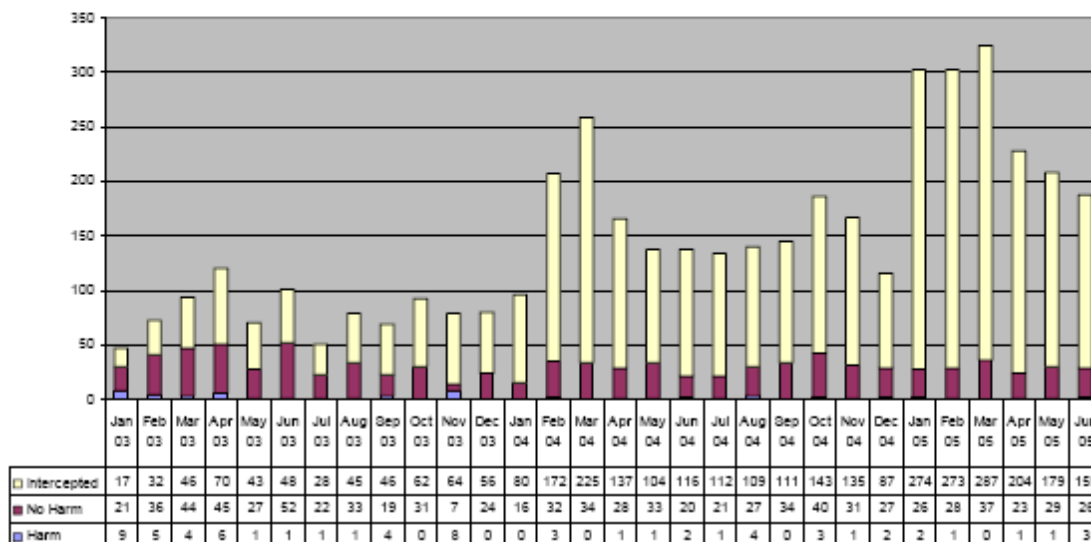
To measure the impact of the Web-based reporting system, the total number of errors per year and the categorization of medication error severity (intercepted, no harm, or patient harm) from the paper-based and Web-based systems were compared. Data on who discovered the error were not collected in the paper-based system. As a result, comparisons between who discovered the error in paper-based and Web-based reporting systems are not possible. However, the Web-based system captured data on who discovered the error from January 2003 through June 2005.

Results

The goals of using a Web-based medication error reporting system were to increase the number of medication errors reported, to increase the number of intercepted errors, and to decrease the number of adverse events. *A priori* expectations were based on prior research that suggests that Web-based reporting tools are correlated with improved outcome measures such as an increase in the number of errors reported and an increase in the number of intercepted errors.²⁷⁻³⁴ Not surprisingly, solely from a numerical standpoint, our most impressive results are an increase in the total number of errors reported, an increase in the number of intercepted errors reported, and a decrease in the number of errors that resulted in patient harm. Prior to the adoption of the Web-based reporting system (1994-2000), the number of medication errors reported averaged 416.3 per year. In 2003, the first full year the Web-based reporting system was operational, the number of medication errors reported increased to 958; it continued to increase to 1,892 in 2004. In the first half of 2005, we have had 1,553 medication errors reported. The number of medication errors by month ranged from a low of 47 in January 2003 to a high of 324 in March 2005 (Figure 3). Although this upward trend is not perfectly linear, each successive high and low period of monthly medication errors exceeds the preceding high and low periods in a stair-step fashion. For example, in the high period between March and June 2003, the average number of errors was 97; the next high period between February and April 2004 averaged 211; and, finally, the high period between January and March 2005 averaged 309. Between each of the high periods, lows increased from an average of 78 between July 2003 and January 2004 to an average of 146 between May 2004 and December 2004 (Figure 3). During this period, there was not a significant increase in either inpatient or outpatient cases, nor was there a significant change in the organization's service line profile.

Figure 3

Monthly Total of Medication Errors by Severity



Of the total number of reported medication errors, the most dramatic change was the complete reversal in the number of errors reaching the patient and the number of errors being intercepted; prior to adoption of the Web-based system, approximately 80 percent of reported errors reached the patient, and, after the adoption of the Web-based system, approximately 86 percent of reported errors were intercepted ([Figure 3](#)). Specifically, with the paper-based system of collecting medication error data, only 18.6 percent of medication errors were intercepted. In comparison, with the Web-based system, 58 percent of the errors were intercepted in 2003, 83 percent were intercepted in 2004, and approximately 88 percent were intercepted in the first half of 2005.

Interestingly, as the number of intercepted medication errors increased, the number of medication errors that resulted in harm decreased. Before implementation of the Web-based system (1994-2000), harm errors per month averaged 11.1. After implementation of the Web-based system, the number of harm errors dropped from the average of 11.1 to an average of 1.0 per month in the first quarter of 2005.

Discussion

Implementation of the Web-based system of collecting medication error data at our institution served as a visible and tangible catalyst for change in the system infrastructure of the inpatient and ambulatory patient safety environments. The new reporting system provides all healthcare employees in our institution a confidential, anonymous means of reporting events. This system provides a safe environment for reporting errors. Healthcare providers can use the system in the privacy of their own offices or even in a busy nurses' station without fear of reprisal. A Web-based system of reporting in and of itself is not entirely novel. However, our system is novel in these three ways: it allows real-time transmission of data to the risk management department; data are automatically cleaned and scrubbed to ensure accuracy and avoid duplication; and data are automatically connected to demographic and clinical information.

As a result of our novel Web-based system of reporting medical errors, healthcare providers experience a significant reduction in the time between reporting a medication error and the resulting investigation by risk management. Closing this time lapse in the feedback loop allows the system to be proactive in processing medication errors and, ultimately, in developing interventions. In addition to providing system process improvements, the site-specific data gathered from the electronic format are also used to develop new educational initiatives.

Findings from this research suggest that adoption of a Web-based system of reporting medication errors served as a catalyst for environmental change that resulted in increased medication error reporting at our institution. Concurrently, as the number of errors reported increased, the number of errors that reached the patient decreased. And, most significantly, this decrease in the number of errors that reached the patient was paralleled by a reduction in the number of events reaching the patient with resultant harm. At a cursory glance, these descriptive data imply that a simple, linear relationship exists between the Web-based reporting system and the reduction of patient harm. But such straightforward relationships rarely occur in highly complex systems, and, thus, they are suspect. By definition, complex organizations such as large medical centers are fragmented into departments and disciplines, each passionately protective of their domain. Creating a common vision that is not viewed as compulsory requires several champions who cut across both managerial and specialty domains within the organization.

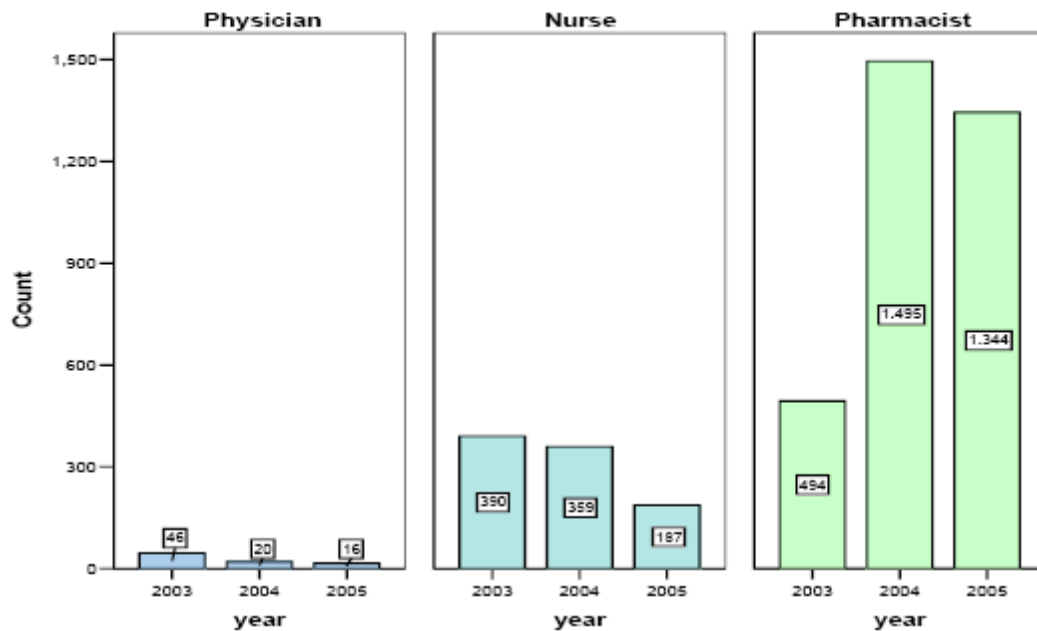
To better define the relationship between the Web-based reporting system and the reduction of patient harm, it is important to drill down in the data and examine significant outcomes in relation to environmental changes over time within the healthcare system. To accomplish this, we will only focus on data trends collected after the adoption of the Web-based reporting system. Specifically, we will examine trends in the number of errors reported and whether or not harm occurred.

Data that report the person who discovered the error between January 2003 and June 2005 are illustrated in [Figure 4](#). Although data show a general linear progression in the number of errors reported, [Figure 3](#) shows that this trend is curvilinear with spikes in April 2003, February and March 2004, and January through March 2005. Based on complexity theory, this pattern of "peaks" and "valleys" (i.e., the pattern of variation in the number of errors reported) is expected.³⁵ We would, therefore, expect that after a "flick" (an event that causes disruption in the system), change occurs in the organization and an immediate positive, sometimes dramatic, response to change will occur. This change will be followed by a drop-off and then gradual improvement, or, at the least, will achieve and maintain a new mean at a level greater than the preceding mean prior to the "flick." In our particular case, increases both in the number of medication errors reported and in the number of intercepted errors correspond to the number of pharmacists reporting or detecting medication errors ([Figure 3](#) and [Figure 4](#)). Specifically, spikes in the data correspond to an increase in errors reported by the pharmacist. The number of errors reported by

pharmacists increased from 494 in 2003 to 1,495 in 2004 to 1,344 in the first half of 2005. During that same period of time, reported medication errors by physicians and nurses remained constant ([Figure 4](#)).

Figure 4

Staff Who Discovered the Reported Medication Error by Year
(January 1, 2003 to June 30, 2005)



At our institution, increased pharmacist involvement in the detection of medication errors is closely related to a significant increase in the number of intercepted errors and a decrease in the number of medication errors that resulted in patient harm. Immediately prior to the first spike in reporting, administrative reorganization, particularly with pharmacy involvement, occurred within the UMHC Safety Council. The first “flick” occurred in early 2003, near the first spike, after the implementation of the Web-based system of reporting medication errors. Adoption of the Web-based system of reporting served as an impetus for reorganization of the former UMHC Safety Council into a formalized, institutional Patient Safety Council. Before reorganization, an incident report team would investigate medication errors and report findings to risk management and, if warranted, to the hospital CEO. After the application of the Web-based reporting system, it quickly became apparent that the old mechanism of investigating events could not process the increased volume and navigation of reports up the administrative chain. This reorganization legitimized patient safety efforts and event reporting as an institution-wide endeavor, if not an institutional mandate.

The second “flick” centered on the CEO’s becoming chair of the Patient Safety Council and a change of the pharmacy department head. Both the CEO and the new pharmacy head were strong supporters of the Web-based application and proactive in their support of our patient safety initiatives. The CEO’s involvement sent a strong signal throughout the organization that patient safety was a growing priority, and as his awareness grew, so did his engagement in hospital safety activities. Action plans identified by the committee now carried the clout of top leadership. In addition, the new head of the pharmacy department not only removed fear of reporting medication errors, but also encouraged reporting as a positive sign of effecting change.

Empowered by the Patient Safety Council’s restructuring, members of the pharmacy department became much more involved in the Patient Safety Council, taking on leadership roles of several subcommittees and making formal reports regarding pharmacy-related issues and events. These subcommittees were transformed from reporting venues to action committees. Although the pharmacy department always supported patient safety initiatives, the new department head was a vocal, enthusiastic supporter of patient safety in general and the Web-based reporting system in particular. This individual actively encouraged and expected the department’s pharmacists to report errors. He also led the development of new educational modules (many using the newly collected data) to be used by all healthcare providers.

The third and final “flick” centered on an increased campus-wide awareness of patient safety initiatives and findings from our analysis. After 18 months of data collection and analysis, there were sufficient data to document trends and patterns in our process and outcome measures, including intercepted errors and harm errors. Findings were then reported in the hospital

newsletter and presented in Grand Rounds. The pharmacy department was acknowledged by the administration for their contributions to improvement in patient safety efforts on the campus.

Conclusions

This is one of the first studies in which the adoption of technology in one part of the system process, in this case the pharmacy, resulted in system-wide culture changes. Although technology from the Web-based reporting system was implemented through efforts of the Patient Safety Center staff (a multidisciplinary group), a culture change within the institution resulted from a culture change within a single department, the pharmacy. Interestingly, among the major reporters (physicians, nurses, and pharmacists), only pharmacists' patterns of reporting increased significantly following the adoption of the Web-based reporting system. Future research needs to explore physician and nurse buy-in and potential changes in patient safety culture resulting from this buy-in.

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