Evaluation of Reported Medication Errors Before and After Implementation of Computerized Practitioner Order Entry

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ABSTRACT

While a major objective of CPOE is to reduce medication errors, its introduction is a major system change that may result in unintended outcomes. Monitoring voluntarily-reported medication errors in a university setting was used to identify the impact of initial CPOE implementation on medical-surgical and intensive care units. A retrospective trend analysis was used to compare errors one year before and six months after implementation. Total error reports increased post-CPOE but the level of patient harm related to those errors decreased. Numerous modifications were made to the system and the implementation process. The study supports the notion that CPOE configuration and implementation influences the risk of medication errors. Implementation teams should incorporate monitoring medication errors into project plans and expect to make ongoing changes to continually support the design of a safer care delivery environment.

KEYWORDS

- Medication error
- Computerized practitioner order entry (CPOE)
- Implementation
- Reporting
- Medication cycle
- Trend analysis

Implementing a computerized practitioner order entry (CPOE) system with clinical decision support has been proposed as an important way to foster the development of a new care delivery process for hospitals to decrease harmful medication errors. Information technology is viewed as a critical component in the development of a healthcare delivery system that prevents errors and incorporates the lessons learned from errors that do occur.1

The Institute of Medicine also recommends that information on adverse events and near misses be captured to design safer care delivery systems. However, the Institute of Medicine also cautions that while technology may solve
some problems, it may generate new forms of error and failure.

Through CPOE, clinicians who have order-writing authority directly enter orders via the computer. It replaces the use of making handwritten orders in a patient chart and the physical delivery of the order to the receiving department or clinician. Clinical decision support refers broadly to giving clinicians clinical knowledge and patient-related information, intelligently filtered or presented at appropriate times, to enhance patient care. CPOE is intended to primarily decrease ordering and transcription errors, while clinical decision support provides additional information to prevent ordering errors related to lack of drug knowledge, rules violations, lack of standardization, lack of patient information, and inadequate monitoring.

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Inpatients face risks of medication errors throughout their hospital stays. In various studies, the risk varies based on how medication errors, adverse drug events, or adverse drug reactions are defined; how data was retrieved; and the populations studied. The studies have illustrated that medication errors are a significant problem in hospitals.

For example, the rate of medication error was reported as 1.4, 5.07%, or 0.19% per admission. Risk of serious harm is less, variable, and unacceptable. Examples of rates are 6.5 per 100 non-obstetrical admissions, 0.25% of admissions, or 14.97 per 100 patient-days in critical care. Numerous studies conclude that many medication errors are preventable.

Most of the studies demonstrating the benefits of CPOE-CDS in reducing medication errors have been conducted at a few sites with home-grown systems. Because there have been few studies of commercially available CPOE applications, the ability to replicate benefits of CPOE across most of the hospitals in the United States is still an unmet challenge. Because implementation of CPOE is recommended as a way to help hospitals decrease medication errors, it is imperative that medication errors be used as a measurement outcome.

An increasing number of studies caution those implementing systems that CPOE can inject new errors into the healthcare delivery system. Different CPOE-CDS systems have different areas of risk for medication errors based on application design, workflow integration, and deployment strategy.

Weiner et al emphasized the need to monitor ordering errors and institute processes to prevent errors resulting from CPOE implementation. Ash, Berg, and Coiera recommended qualitative research to identify why and how the kinds of unintended consequences occur. George and Austin-Bishop identified the need for CPOE optimization, and Hicks et al suggest that design flaws, poor or insufficient decision support rules, inadequate training, and user resistance undermine the promised benefits of CPOE. They encourage enhanced vigilance in error detection and careful pilot testing to ensure that errors are prevented and not perpetuated.

Koppel et al recommend emphasizing workflow, aggressive examination and resolution of technology problems, and diligent investigation of error causes to support resolution. They also suggest the continual evaluation of new risks and support ongoing revisions. Nebeker et al suggest that adverse drug events become more visible as more of the record is computerized, and they theorize that the system does not necessarily induce more of them. They recommend that clinical decision support will be needed to resolve many types of adverse drug events.

Kim et al also recommend ongoing medication error surveillance and guidance by domain and IT experts when CPOE is deployed. Battles and Keys warn that, “While automation holds substantial promise for improved safety, error experts caution that all technology introduces the potential for new and different errors. It is critical that any new automated system be tested in actual operational settings to determine what, if any, unanticipated failures exist. Field-based research is essential in the emerging field of patient safety to create the evidence as to which technologies actually improve patient safety and those that may well increase the potential for harm.”

These studies and the advice from safety experts reinforce the need to incorporate the evaluation of the impact of CPOE-CDS on medication errors as part of the implementation process. The outcome of a CPOE-CDS implementation is not to just successfully install the system from a technical viewpoint, but to reduce harmful medication errors.

While not the most effective method of error identification, using reports of medication errors is a timely, cost-effective way to provide data on the impact of implementing CPOE. Dixon reports that the benefits of electronic reporting via the Web include increased standardized reporting, along with immediate notification and investigation. Rapid communication of errors via e-mail also supports earlier analysis and prevention efforts. Rudman et al found that internet reporting increased the volume and completeness over a paper-based system.

Additionally, Spencer et al used voluntarily reported medication errors to identify CPOE-related errors. Zhan et al reported that a national voluntary medication error-reporting database can be used to identify specific types of errors related to CPOE systems. Miller et al reviewed reports from a voluntary online error-reporting system and
found most reports to be accurate and reflect true errors.

While reported medication errors cannot be used to determine error rates\cite{1,2}, they are valuable for providing information that can be used to improve CPOE-CDS systems and the work processes surrounding their use. This paper reviews changes in reported medication errors before and after CPOE implementation in a university hospital and describes changes made as a result of monitoring errors.

**Methods**

A descriptive study of reported medication errors before and after implementation of CPOE within two groups was conducted at the University of Kentucky Hospital, a 473-bed facility. The study was approved by the University of Kentucky’s institutional review board. The system was the Sunrise Clinical Manager from Eclipsys, version 3.04, and included patient lists, CPOE to 22 departments, and basic CDS, including allergy checking, drug-food, and drug-drug interactions. Interfaces included incoming patient demographics and bidirectional interfaces with laboratory, pathology, and radiology for textual results. A unidirectional orders interface to the pharmacy system (Mediware WORx) was activated four months after the beginning of this study.

The CPOE-CDS system was implemented via an incremental rollout strategy. This represented the first major step toward an electronic medical record at the hospital. Two clusters of units and services were implemented approxi-

<table>
<thead>
<tr>
<th>Error Category</th>
<th>Result of Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Error</td>
<td></td>
</tr>
<tr>
<td>Category A</td>
<td>Circumstances or events that have the capacity to cause error</td>
</tr>
<tr>
<td>Error, No Harm</td>
<td>An error occurred but the error did not reach the patient</td>
</tr>
<tr>
<td>Category C</td>
<td>An error occurred that reached the patient but did not cause patient harm</td>
</tr>
<tr>
<td>Category D</td>
<td>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</td>
</tr>
<tr>
<td>Error, Harm</td>
<td>An error occurred that may result in temporary harm to the patient and required intervention</td>
</tr>
<tr>
<td>Category E</td>
<td>An error occurred that may have contributed to or result in temporary harm to the patient and required initial or prolonged hospitalization</td>
</tr>
<tr>
<td>Category F</td>
<td>An error occurred that resulted in permanent patient harm</td>
</tr>
<tr>
<td>Category H</td>
<td>An error occurred that required intervention necessary to sustain life</td>
</tr>
<tr>
<td>Error, Death</td>
<td>An error occurred that may have contributed so or resulted in the patient’s death</td>
</tr>
</tbody>
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mately one month apart in September and October of 2004. Six acute care and three intensive care units were included, incorporating the services of neurosurgery, neurology, urology, nephrology, solid organ transplant, cardiology, and cardiothoracic surgery.

Data for the study was obtained from the hospital’s voluntary Web-based reporting system for medication errors. The system is a combination of incident reports via the Web and solicited reports as pharmacists interact with direct patient care providers. The report includes incident date and time, report date, location, medical service, gender, type of error, medication(s) involved, severity (level of harm), who was notified of the error, reporting person, and a free-text field for a description of the incident.

Clinicians are encouraged to report medication errors in a non-punitive environment. The hospital uses the following definition for a medication error and harm by the National Coordinating Council for Medication Error Reporting and Prevention: "A medication error is any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the healthcare professional, patient, or consumer. Such events may be related to professional practice, healthcare products, procedures, and systems, including prescribing; order communication; product labeling, packaging, and nomenclature; compounding; dispensing; distribution; administration; education; monitoring, and use."

"By detecting errors or potential errors, prevention strategies can be developed."

Harm is a term used to describe the impact of the medication error on the patient. Harm is defined as, "Impairment of the physical, emotional, or psychological function or structure of the body or pain resulting there from." The Medication Error Category Index\cite{3} that categorizes errors based on severity of patient outcome is part of the error report form. It contains nine categories, A through I, ranging from identification of medication errors that had the potential for harm, to errors that may have resulted in
the patient’s death (see Figure 1).

At the University of Kentucky Hospital, after a clinician submitted an error, an Access database received the error and automatically routed an e-mail of the information to the pharmacy director, associate director of pharmacy, nurse manager of the unit where the event occurred, and nursing services quality care coordinator. After implementation of CPOE, the project leader was added to the recipient list to participate in this concurrent review.

The project leader and pharmacy directors closely reviewed each error to confirm severity coding and to identify errors that could potentially be related to CPOE implementation. Virtual e-mail discussions were used between pharmacy, nursing, physicians, and project team members to discuss, recommend, and confirm actions taken.

In addition to the concurrent review, a retrospective review was conducted to identify changes and trends. Pre-activation data was collected for twelve months preceding each area’s activation date. Post-activation medication error data was collected for six months from those units and services, beginning in October and November 2004. Because of the comparison of twelve months pre-data to six months post-data, percentages are reported. Data on the number of patients and doses was obtained from the pharmacy system.

The project director removed any data from the database that fell outside of the study parameters. For medication errors occurring after implementation of CPOE, additional fields were added to the database—CPOE-related error, potential cause of error associated with CPOE, and actions taken. For example, if an error was related to a nurse selecting the wrong drug from the medication administration cabinet or a nurse giving a medication to the wrong patient, it was not coded as a CPOE-related error. If the error was, for example, the physician selecting the wrong patient in the computer or pharmacists entering wrong frequency into the pharmacy system, it was coded as CPOE-related. All coding was confirmed by the associate director of pharmacy.

Results

For the twelve months prior to CPOE implementation, 135 errors were reported in the sample population and 164 for the six months post-CPOE. To account for variations in patient volume and the number of prescribed medication doses, rates were determined for both study phases. The reported error rate per patient pre-CPOE was 5 percent (.0551) and per prescribed dose 0.12 percent (.0012). For the six months immediately after CPOE implementation, the reported error rate per patient was 10.75 percent (.1075) and 0.25 percent (.0025) per dose.

The NCC MERF index was used to determine any change in levels of harm. For the one year pre-CPOE implementation, 19.3 percent were “no error” reports, 73.3 percent were “error, no harm” reports, and 7.4 percent were “error, harm” reports. For the first six months post-CPOE, “no errors” were 25.6 percent, “error, no harm” represented 73.8 percent and “error, harm” was 0.6 percent. Figure 2 shows the rates based on patient volume, errors per 100 patients. Thus, data indicated that reporting of errors increased post-CPOE and the level of patient harm decreased.

CPOE-related errors. During the post-activation period, 164 errors were reported from the study areas. Of these, 117, or 71 percent, were considered CPOE-related. By level of harm, the percentage of CPOE-related errors to the total reported post-activation errors were 62 percent of the “no error,” 74 percent of the “error, no harm,” and 100 percent of the “error, harm.”

The majority (79 percent) of the errors related to CPOE did not reach the patient (categories A and B). Less than one-fourth (21 percent) reached the patient (category C, D and E). There was only one reported error in category E and it was CPOE-related.

Within the medication administration cycle, there were more transcribing mistakes and fewer errors related to dispensing and administration (see Figure 3). The most common CPOE-related errors were related to transcribing, followed by prescribing and administration. In prescribing, the most common error was inappropriate medication, followed by duplicate orders, wrong patient, and wrong dose. Errors of illegibility were eliminated. For transcription, the most common error was order not entered by pharmacy, followed by entry of wrong dose, wrong medication, and wrong patient into the pharmacy system.

In administration, unauthorized dose (for example, order discontinued but medication still given) and omissions were the most common errors. The most prevalent non-CPOE related error was in the administration process. Frequently, errors reflect multiple slips within the medication cycle.

Contributing causes. To assist in the development of safety interventions, contributing causes were identified for reported errors. The most common contributing cause was noncompliance to policy and procedure, identified in 40 percent of errors. For example, a previous order may not have been discontinued when a new dose change was entered, resulting in two active orders for the same medication with different dosages.

The next most common contributing cause was computer entry errors, seen in 25 percent of mistakes. One example
was if a medication order was placed on the wrong patient. The next most common error was initial load errors (19 percent). During entry of all current medications on the day of activation, multiple category B errors were made. An example was a written order for sliding scale calcium gluconate “PRN,” which was entered into the CPOE system as “scheduled.”

There were also computer design issues that contributed to 10 percent of errors. An example was when the pharmacist received two printouts for methylprednisolone 500 mg

IV. He assumed it was a duplicate order, but when he reviewed the CPOE system, he saw that one order was for today and the other was for tomorrow. The dates for these orders were not visible on the order printout from the CPOE system.

Concurrent and retrospective review of reported errors post-CPOE provided input into system changes and alterations to CPOE-CDS deployment plans. The most significant was the decision to implement the interface between the CPOE system and the pharmacy system before CPOE was deployed to any additional areas.

System safety interventions were classified into the following seven categories:

- **Force**—eliminate options or force required actions.
- **Simplify**—reduce steps and the number of options.
- **Differentiate**—enhance the differences between items.
- **Standardize**—set up systems to guide practitioners for consistent communication and decision-making.
- **Redundancy**—provide check systems and backups.
- **Educate**—provide information to the practitioner at the point of decision-making.
- **Notify**—tell the practitioner of an event when certain conditions are met.

Figure 4 contains examples of system safety interventions that have been implemented between go live and the present. Other common actions initiated in the initial six months related to changes and clarification in workflow, such as what should be done when a patient is transferred from a unit running on CPOE to a non-CPOE unit or visa versa. Many hours were spent re-educating through 24-hour clinician support, and educational materials were provided in newsletters, unit notebooks, and on the Web. Monitoring reported medication errors continues, along with system revisions and development of future recommendations.

**Comments**

In this review, the number of reported medication errors increased
in the first six months following CPOE implementation. Battles and Lilford\textsuperscript{1} state that one of the goals of a patient safety program is to increase reporting rates to decrease the risk of harm. By detecting errors or potential errors, prevention strategies can be developed.

While we would like to think that education efforts contributed to the increased number of error reports, there are several reasons that may have influenced this change. For example clinicians may be more likely to report an error that they believe is aimed at a computer system vs. an individual practitioner. Clinicians are increasingly using the computer and may have easier access to the online reporting form. The increased reports did provide valuable feedback to the implementation team.

As cautioned by others\textsuperscript{2,3} when CPOE is implemented, new errors were uncovered in the review of the reported medication errors. As reported by Spencer et al.,\textsuperscript{1} a separate pharmacy system requiring pharmacists to re-enter the order into the pharmacy system resulted in transcription errors. Errors resulted from some fields not being visible on the printout or typing errors. Most of these errors were resolved when orders were interfaced between the two systems. Another transcription error occurred between CPOE and the paper medication administration record. Because CPOE does not generate the administration record, nurses must transcribe the order onto it. If this does not occur, delays in implementation of the order result. An electronic medication administration record is planned to eliminate the need for this manual process.

Many error reports were related to duplicate order entries. In the paper world, if duplicate therapy was ordered, the pharmacist clarified the duplication and entered the appropriate order into the pharmacy system. The current CPOE design does not prevent duplicate therapy, resulting in errors of duplication. Training prescribers to remember to discontinue orders when a new dose was entered was not effective. An exact match drug-dose duplicate alert was implemented. In the next upgrade, additional duplicate checking functionality will be added.

Selection errors also were identified. Wrong chart selection in the paper process translated into wrong patient selection in CPOE. Illegible writing was eliminated but was replaced with selection errors from drop down lists. The use of a mouse with a scroll wheel can inadvertently change the item selected in CPOE. A replacement mouse was distributed to all clinical areas. Application changes and recommendations to the vendor have been made to minimize user-selection errors.

Another contributor to errors was the incremental rollout of CPOE. Patients were transferred from active CPOE areas to areas not using CPOE and visa versa. Errors arose over the confusion about which process to use when a patient’s destination was unknown. Nursing leadership strongly recommended increasing the pace of CPOE deployment.

Additional activation support resources were obtained so more units could be activated simultaneously. The procedure for how to handle orders upon patient transfer were revised and widely communicated. There was much less confusion with patient transfers after all inpatient units were live with CPOE.

As the types of errors have changed, there is a need to update the medication error report form to keep the process user-friendly and reflective of the CPOE process. Converting choices to reflect “wrong chart” to “wrong chart-patient” and adding a mechanism to enable the reporter to indicate CPOE contributed to the error are some examples. Efforts will continue to promote reporting of errors, unsafe situations, and potential solutions.

Ongoing monitoring of medication errors requires significant resources. Having a pharmacist as part of the implementation team is critical. Adding time for medication error evaluation and implementation of recommended changes needs to be included in project resource planning. There are more opportunities for medication error prevention with implementation of CPOE and CDS. Additional studies are planned to include all activated inpatient CPOE areas and lengthen the review period to one year post-activation.

This study had several limitations. First, this study was not designed to measure the effectiveness of CPOE in decreasing medication errors. A basic assumption is that the universe of medication errors is currently unknown. Any conclusion that medication errors have been reduced is an error in and of itself. The trending of data is meant to be only informational. Also, six months is too short of an interval to determine the long-term effects of this major change. There was no attempt to control for any variables such as incremental deployment of units and services, various levels of staff CPOE competency, the influence of frequent policy-procedure and system changes, the impact of 80-hour resident work weeks, staffing levels-workload or seasonal fluctuations. Because of numerous differences in the site, system, and implementation strategy, these results are not generalizable.

In conclusion, implementation of CPOE is a major institutional change fraught with variability. Monitoring reported medication errors is a strategy that can be successfully employed to provide constructive feedback for the never-ending evolution of a safer care-delivery system for hospitalized patients.

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