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An Evaluation of the Impact of Computerized Physician Order Entry on Medical Errors

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AN EVALUATION OF THE IMPACT OF COMPUTERIZED PHYSICIAN ORDER
ENTRY ON MEDICAL ERRORS

by

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AN EVALUATION OF THE IMPACT OF COMPUTERIZED PHYSICIAN ORDER ENTRY ON MEDICAL ERRORS

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The purpose of the present study was to examine the effects of a computerized physician order entry (CPOE) system on medication error. The study took place in a 343-bed hospital in the pediatrics inpatient unit. During baseline, participants placed medication orders in the same manner that they always had, handwriting them on a specific form and handing the form to the unit clerk who then faxed the order to the pharmacy. In the CPOE phase, participants used the computerized system to place orders, which were electronically sent to the pharmacy. The primary dependent variable was errors made during physician medication ordering, as recorded by pharmacy residents using a detailed check sheet. Several secondary dependent variables were also measured and reported. The CPOE system appeared to have some effect on the quality of patient care. The implementation of the system was associated with decreased variability and more order sets being completed 100% correctly. The order processing time was drastically reduced with the use of the CPOE system. The increase in orders completed 100% accurately, and the decrease in the length of time it takes for an order to reach the pharmacy could both make a significant impact on the quality of patient care.

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INTRODUCTION

The Institute of Medicine (IOM) reported that 44,000 to 98,000 people die annually of an iatrogenic injury (i.e., an injury caused by a medical procedure) and 1.3 million people are injured by faulty medical treatment each year (Institute of Medicine, 1999). Surveys suggest that 42% of Americans reported that they, their family, or a friend has experienced a medical error in the past five years, suggesting that medical errors affect roughly 100 million Americans (AHRQ, 2005). Lost and significantly altered lives are the most important result of these medical errors, however, medical errors also cost healthcare organizations enormous sums of money. The malpractice payout from insurance companies for medical error is estimated to be $4.5 billion annually (National Practitioner Data Bank, 2006). These statistics highlight the importance of finding techniques to lower the rate of errors committed during medical procedures.

Potential adverse drug effects (ADEs) occur at a rate of 6.5 per 100 admissions (AHRQ, 2005). Adverse Drug Events (ADEs), by definition, are injuries that result from the use of a drug (Kaushal, Barker, & Bates, 2001). Data published by the Agency for Healthcare Research and Quality (AHRQ, 2005) suggest that one-third of ADEs are preventable. The typical ADE results in an extended hospital stay (by an average of two days), costs approximately $2,400, and increases the chances of mortality by three times (Classen, Pestotnik, Evans, Lloyd, & Burke, 1997). Although errors can occur at many stages throughout the process of medication ordering and administration (e.g. during pharmacy processing or medication administration to patient), they are most likely to

occur at the stage of physician ordering (Classen et al.). The AHRQ also reports that ADEs are three times as likely to occur in pediatric cases, and 45% of errors can be prevented by using computerized order entry. Medication errors are the most common way that pediatric patients can be harmed, and when these errors do occur, pediatric patients have a much higher chance of being harmed than do adults (Hughes & Edgerton, 1998).

Physician ordering errors are not only made by doctors, however. One study showed that over one-third of nurses in a specific hospital reported making a medication-related error in the previous month (Balas, Scott, & Rogers, 2004). The study analyzed reports taken from a daily log that the nurses kept, and errors ranged from relatively innocuous mishaps to life-threatening mistakes. The majority of these errors were related to medication administration, including: giving the wrong drug (17%), omitting a medication (15%), giving medication at the wrong time (34%), giving the wrong dose (24%), administering medication to the wrong patient (8%), or administering medication via the wrong route (2%).

Initial methods used for reducing error rates were somewhat successful, but often flawed. AHRQ reported that a study conducted in 1998 decreased serious medication errors by 55%, and all medication errors by 81% (AHRQ, 2005). However, this system (a combination of physician order entry with integrated checks and a rounding pharmacist on the floor) was very costly (over $2 million), and therefore, not practical. Recent studies have suggested that computerized systems of prescription order entry (CPOE) may be effective in reducing certain types of medication errors, such as issues with

legibility of written orders or omitting important drug information. However, the technique is new and the research that has been conducted to demonstrate its effects or to determine its optimal parameters is conflicting. Many studies show beneficial effects of CPOE on error rates, however, some newer studies suggest that CPOE may cause as many errors as it alleviates. Computerized Physician Order Entry is defined as "a process which allows a physician to use a computer to directly enter medical orders" (p. 235, Ash, Gorman, & Hersh, 1998). The CPOE system essentially eliminates the need for any written or verbal communication regarding medication administration, which eliminates many opportunities for error.

There is an overwhelming amount of empirical support claiming that the use of a CPOE significantly decreases the rate of error (e.g., Bates, Cohen, Leape, Overhage, Shabot, & Sheridan, 2001; Bates, Cullen, Laird, et al. 1995; Bates & Gawande, 2003; Bates, Kuperman, & Teich, 1994; Bates, Leape, Cullen, et al. 1998; Institute of Medicine, 1999; Kaushal, Shojania, & Bates, 2003; Schiff & Rucher, 1998; Teich, Merchia, Schmiz, Kuperman, Spurr, & Bates, 2000). One example is a study that showed a reduction in actual ADEs by 17% and potential ADEs by 88% by using computerized order entry (Bates et al. 1998). The main outcome measure for this study was nonintercepted serious medication errors, those that were not intercepted and therefore reached the patient.

Although there are numerous studies reporting positive effects of CPOE, many of these studies have significant methodological shortcomings. Most hospitals use self-report data collection methods to report errors (the primary dependent variable in the

majority of CPOE studies), and the underreporting percentage is estimated to be 50%-96% (Barach & Small, 2000). These error data collection methods require healthcare providers to report their own errors or errors committed by coworkers, which research has shown they are highly unlikely to do (Stanhope et al., 1999).

In a field that is becoming more and more inundated with litigation each day, the culture of hospitals is becoming one of keeping medical errors secret, for fear that reporting them may cause a myriad of problems for the individual, the organization, and the field in general (Force, Deering, Hubbe, Andersen, Hagemann, Cooper-Hahn, & Peters, 2006). It is safe to assume that the number of errors, or potential errors (i.e., errors that are caught and corrected and therefore do not actually "occur"), that are self-reported, and consequently documented by the hospital, is a gross underestimation of the events that truly occur. For these reasons, using self-reported error as a primary measurement technique is methodologically problematic.

A study conducted by Bates, Teich, et al. (1999), showed a drastic decrease in the amount of error after the implementation of CPOE. Overall, the study reported that error rate decreased 81% from the initial baseline phase to the final phase, which involved a combination of CPOE and decision support. The researchers defined medication error, their main outcome measure, as "errors in the process of ordering, dispensing, or administering a medication, regardless of whether an injury occurred or whether the potential for injury was present" (p. 315). They measured errors in three ways: 1) pharmacists reported any prescribing errors, potential ADEs, or ADEs that they identified during the dispensing process, and verbal reports were also solicited from nurses through

daily visits by the study investigator; 2) a trained reviewer evaluated all medication sheets received by the pharmacy; and 3) the study case investigator reviewed all charts daily on weekdays for evidence of medication errors or ADEs. This is not a consistent method for detecting errors, as "reviewing charts for evidence of medication error" without the use of a standardized check sheet or equivalent aid is quite subjective. The first method, pharmacist reporting, could vary in rigor each day. Although this study represents a beginning in examining a highly complex and important problem, it appears that the data collection procedures on error rates involved some degree of judgment, leaving the reader unsure as to their accuracy.

The authors tested for reliability of error classification and severity, but their procedures did not allow them to determine what percentage of total errors were reported (all error data were initially collected through self-reports and through individuals examining charts). Once a potential incident was identified, it was classified by type. The classifications were: dose error, route error, frequency error, substitution, drug-drug interaction, inappropriate drug, illegible order, known allergy to drug, drug not available, avoidable delay in treatment, and preparation error. Then, incidents suspected of being ADEs or potential ADEs were evaluated by two independent reviewers, who classified each incident into categories. The possible categories were: ADE, potential ADE, medication order with little potential for harm, and no error or ADE. All incidents classified as ADEs or potential ADEs were then given a classification of severity. Reliability between reviewers was taken for these classifications, but not the initial reviews. Therefore, it is not possible to ascertain that individual researchers were in

agreement on whether an event qualified as an ADE or potential ADE. Kappa statistics were used to report reliability and ranged from .81-.98 for whether an event was an ADE; .92 for preventability; and .32-.37 for severity. This classification system appears to be more useful and reliable, however, the error reporting rate could have changed over the course of the study, making the extent of error reduction unclear.

A later study investigated the effects of CPOE implementation on turn-around times and error rates for only specific drug and test orders in a newborn intensive care unit (Cordero, Kuehn, Kumar, & Mekhjian, 2004). This study collected data for orders of the caffeine and gentamicin and the radiology procedures of the first chest and abdominal x-rays taken following endotracheal intubation and/or umbilical catheter placement. The researchers measured medication error rates and the time required from initiation to completion for these orders. They showed an increase in the percentage of correct orders from 87% during baseline to 100% after implementing CPOE. They also reported a statistically significant reduction in the medication turn-around time for the loading dose of caffeine. All data were collected retrospectively from records (written during baseline and computerized after CPOE implementation). The only type of medication error data that were collected was for dosing error. These data were collected by examining the chart to determine the dose given to the patient and comparing it to the dose that should have been given. The study was limited in that 1) it focused on only one type of medication error, and 2) the computer system had decision supports that forced physicians to order the correct dose. This made it impossible for dosing errors to occur for the targeted drug and it explains the 100% correct ordering observed after the

implementation of the system. Therefore, this system appears to have been extremely effective at reducing error, but it is unclear whether errors were reduced by decision support systems preventing the errors, physician behavior change, or some combination of these. Some healthcare professionals fear that decision support can produce an over reliance on support systems, and negatively affect physicians' technical skills due a lack of practice. Researchers are currently examining how much decision support is ideal in order to help prevent error and not allow for physicians to become completely dependent on the CPOE system.

Despite the overwhelming empirical support for CPOE systems, only slightly over 32% of hospitals use one, according to a survey conducted by Ash et al., (1998). In those hospitals reported to use CPOE, fewer than 10% of physicians are estimated to use the system and an estimated fewer than 10% of orders are entered electronically. A possible reason for this resistance is that using CPOE can take up to twice as long as other ordering methods (Ash et al.). Many hospital administrators are finding it difficult to motivate the already overly busy doctors and interns to take the extra time to use the CPOE.

Although the use of CPOE has been widely shown to reduce error, more recent research has suggested that it may also facilitate error (Ash, Berg, & Coiera, 2004; Ash, Gorman, Seshadri, & Hersh, 2004; Berger & Kichak, 2004; Bobb, Gleason, Husch, Feinglass, Yarnold, & Noshkin, 2004; Cook, Render, & Woods, 2000; Ferner, 2004; Kaushal, Kaveh, & Bates, 2003; Patterson, Cook, & Render, 2002; Shane, 2002; Woods & Cook, 2002). A recent study found that a CPOE system facilitated 22 types of

medication error risks (Koppel, Metlay, Cohen, Abaluck, Localio, Kimmel, & Strom 2005). In this study, *medication error risks* were opportunities for errors to occur; they were occasions that could have, but did not, result in errors. The authors classified the error risks as either *information error risks* generated by fragmentation of data and failure to integrate the hospital's several computer and information systems, or *human-machine interface flaws* reflecting machine rules (the way the machine is programmed to operate) that do not correspond to work organization or usual behaviors. The first category included errors such as: assumed dose information, medication discontinuation flaws, antibiotic renewal flaws, allergy information delay, etc. The second category included errors such as: patient selection, wrong medication selection, unclear log on/log off, inflexible order screen/incorrect medications, etc. The study was primarily qualitative in nature, wherein researchers employed surveys, structured interviews, focus groups, and direct observation. The publication of this article in the *Journal of the American Medical Association* (*JAMA*) spurred much debate. Comment papers were published criticizing this study on several different grounds, including a lack of control group or baseline data, and the use of an older model of the CPOE software that could have resulted in more errors than the more modern systems in use today. The commentaries on this study made it clear that more research is needed to quantify the effects that CPOE technology has on healthcare quality.

As stated above, ADEs are more likely to occur in pediatrics units, errors that are committed in pediatrics are more likely to have more severe effects on the patients, and most prescription errors are thought to occur during physician ordering. Given the

relative lack of empirically sound research on the effects of CPOE on medication errors, the current study sought to contribute to the literature through examining the effects of CPOE implementation on physician prescription ordering errors and timeliness in a pediatrics unit. The current study is unique in that targeted potential ADEs caused by physician ordering in a pediatrics unit using a detailed order scoring check-sheet, and utilized a repeated-measures, time-series style, methodology.

METHOD

Participants and Setting

Six board-certified pediatricians in the Pediatric Intensive Care Unit (PICU) served as participants for the study. Due to the fact that the majority of medication administration errors occur when the physician orders the medication, these personnel were the primary targets of the study. More specifically, pediatricians served as participants due to the increased risks associated with medication administration errors in children. All participants were employed by the hospital where the study was conducted, and these participants made up the entire pediatric intensive care unit (PICU). The study took place in a hospital in a medium-sized hospital with 343 beds and over 4,000 employees in the mid-western United States.

Apparatus

A computerized physician order entry (CPOE) system, purchased from McKesson (product number HCI 7.6 SP2), was used. Each of the participants had a user name that he or she was required to use to login to the system prior to using it. The system was customized for use in this specific setting, and it tracked every medication-related interaction. Therefore, it could produce all reports related to medication use (individual, whole group, small groups) that were needed for the study. These reports were printed from the system for coding by the researchers. The technological staff at the hospital had the ability to determine the level of decision support that was used in the system. This hospital chose not to use the decision support available due to recent research showing that too much decision support (in the form of pop-up windows) can become an

"annoyance" to users. The users often combat this "annoyance" by overriding the decision support warnings, rendering them useless. To use the system to place an order, a physician must login with his or her individual username and password. The physician would then progress through a number of pre-set screens that prompt him or her for all necessary information (e.g. name, date, patient information, drug name, dosage, etc.). Once the physician submits the order, it is immediately available for the pharmacy to view and begin processing.

Dependent Variables and Inter-observer Agreement

Order Correctness

The primary dependent variable was percentage of correct elements in each order set scored. Pharmacy residents viewed each order set (whether hand-written or entered electronically) on an individual computer screen. During the baseline phase, hand-written order sets were sent to the pharmacy via a fax machine, which sent them directly into the computer. Therefore, the actual handwriting of the physician appeared on the computer screen, as if it were scanned in. Each component of the order set was recorded using a scoring check-sheet (see Appendix A) that was devised by a team of experts, including physicians and pharmacists, who met with the researchers to determine what constitutes a "perfect" order for this particular hospital. The check-sheet was intended to provide the elements that would be necessary for an order set to be "perfect." Any element from the check-sheet that was omitted or completed incorrectly on an order set could cause a potential error in patient care. The check-sheet was completed by first entering some descriptive data at the top and then assessing the order set for each of the criteria listed and determining whether each of these criteria was completed correctly

(indicated by circling "Y" for "yes") or if an error was made for that criteria (indicated by circling "N" for "no"). Certain criteria (pertaining to specific drugs) may have multiple errors in one order set, as multiple drugs can be ordered on one order set. For these criteria (drug name, dosage, drug route, frequency of administration, and no abbreviations) the number of errors made out of the total number of drugs placed was recorded. Collecting these data allowed for an assessment of whether ordering multiple drugs at one time increased the occurrence of errors. For criteria that were not subject to multiple errors in one order set, "N/A" was listed in this column. After this, scorers would estimate what the probable severity of the error was, using an A-I scale, with "A" being the least severe and "I" being the most severe. This column was only completed for instances in which errors occurred. The total criteria correct were then recorded out of 13 total criteria to form a total percentage of criteria correct. Calculating the percentage correct using this check-sheet provided an extremely accurate and sensitive measure of error through which error rates among handwritten orders could be compared to those found in CPOE orders.

Order Processing Time

The time elapsed from when a physician placed an order to when it was received by the pharmacy was noted on the check-sheet. The time the order was written was required to be entered on the order sheet when orders were placed using pen and paper. However, this is one of the elements that is often left off of handwritten orders, so this variable could not be collected for all order sets used in the study. This measure was available to be collected for 75% of the order sets scored during the baseline phase and 50% of the order sets scored during the withdrawal phase. The time the order was placed

during intervention phases was electronically placed on the order, and therefore, was always available. The time the order was received by pharmacy was electronically noted on the file during all phases. The processing time was then calculated by subtracting the time the order was placed from the time it was received by the pharmacy.

Error Severity

Severity of errors was recorded using the check-sheet, according to a nationally recognized A-I scale (see Appendix B) for rating the severity of an error (National Coordinating Council for Medication Error Reporting and Prevention, 2001). Any time an error was observed in the order, using the check-sheet, the scorer assessed the probable severity of this error using the A-I scale. This allowed for the assessment of any differences that occurred in the severity of errors prior to and after the implementation of CPOE.

Necessary Rework

If rework was necessary, and an estimate of how much time the rework required, was recorded on the check-sheet by the pharmacy residents that were scoring the order sets. Rework refers to a situation in which there was an error on the order that required pharmacy to take extra time processing this order. For example, if the handwriting on the order could not be read and the pharmacist had to call the unit for clarification or send the order back to be rewritten, this extra time would be the rework time. Obviously, this slowed the processing time of the order and also cost the organization money. Using this information the percentage of orders requiring rework was calculated, and also the cost of this rework to the organization was estimated.

Physician Co-signature

For each order delivered verbally, data collectors recorded if a physician co-signature was completed. A verbal order occurred when a physician dictated an order to a nurse or other provider in person or via telephone. This person then placed the order and the physician was required to review this order for correctness and co-sign by the next business day.

Self-reported Errors

At the time of the study, the organization had a system through which they measured errors as reported by staff. Employees are encouraged to report any errors, or near errors, that they are involved in and/or witness. They must voluntarily fill out a report listing all of the descriptive details of the error or near error and submit this to the hospital staff. These data are tracked by the hospital by department, type of error, and outcome of the error. Although these data could not be checked for reliability, they could provide some useful information. From these data the cost of errors to the organization could be calculated using a standard dollar amount ($2400) as a multiplier. This is the standard dollar amount that the hospital estimates they spend on each error. This measure provided an estimate as to whether the CPOE system had an effect on the cost of errors to the organization.

Physician Compliance

Descriptive reports of number of orders placed using CPOE per day per doctor were provided from the electronic system. These were tracked automatically by the system and printed out. During the intervention phase, physicians still had access to paper ordering forms, for "extreme backup only" according to the organization. Any

time these paper order forms were used they were collected and counted. A percentage of physician compliance with CPOE was calculated by dividing the number of orders placed via CPOE by the total number of orders placed (via CPOE and paper).

Length of Patient Stay

Data showing the average length of patient stay were collected, by department. This information was gathered from the hospital's automatically collected records. This measure allowed for assessment of whether there was a change in length of patient stay with the implementation of CPOE. Hospital staff hoped that the use of CPOE might have some impact on LOS due to patient's receiving medication faster and, hopefully, curing them faster. If LOS was impacted by the use of CPOE, this would greatly benefit patients and the hospital by decreasing costs for all and, likely, increasing patient satisfaction with their care.

Social Validity

Social validity was assessed using a satisfaction survey (see Appendix C) administered prior to and after the implementation of CPOE. This survey was administered to all participants (physicians). The survey included questions regarding the social validity of goals, treatments, and outcomes. Measuring the physician's satisfaction with the system was consistent with the stated "Measures of Success" of the hospital's implementation team.

Inter-observer Agreement

Two independent observers scored 30% of all orders scored for the study in order to assess inter-observer reliability. Each line of the scoring check-sheet was scored as either "Agree" or "Disagree" and the total agreements were divided by the total

agreements plus disagreements to form a percentage. Inter-observer agreement

percentages were collected for all variables that were recorded on the check-sheet. Data

gathered from automatically generated CPOE reports does not have IOA calculations.

<div align="center">Procedures</div>

The current study utilized an ABAB withdrawal design. Baseline data (phase A)

were collected over one-month period prior to the initiation of CPOE to assess the current

performance of all participants on each of the dependent variables. All admission order

sets placed during this time were scored. During this time orders were placed via written

order sheets that the physician completed and then handed to the unit clerk who faxed

them to the pharmacy. This was the process that was in place when the researchers

entered the research site, and has been the process in place for years. The participants

(N=6) were exposed to the CPOE system intervention (phase B) for approximately five

months, with at least three admission order sets being scored by the pharmacy residents

each week during this phase. All admission order sets placed during this time were not

score, because the length of this phase was inadvertently extended due to circumstances

present in the research setting, and the resources necessary to score all admission order

sets placed for five months were not available. The CPOE system was not functioning

for a period of approximately 24 hours, creating a natural withdrawal (second A phase).

During this withdrawal of the intervention, physicians reverted to the traditional method

of placing orders using pen and paper. All order sets (admission and other) placed during

this time period were scored in order to provide the most data for analysis. After this

period, the CPOE system was functioning again and was re-introduced and remained in

place for the remainder of the study (second B phase). All order sets placed for two

weeks following the re-implementation of the system were scored in order to obtain enough data to complete the study.

In order to participate in the study, all participants voluntarily signed a consent form approved by the Human Subjects Institutional Review Boards for the university and the hospital (Appendix D). Prior to the beginning of data collection, all participants completed a social validity survey to assess their opinions and beliefs concerning CPOE and error.

Prior to the implementation of CPOE, the physicians received extensive training from the hospital's IT department on how to use the system. Once the intervention was implemented, scoring continued as it had in baseline, however, the file that the observers reviewed appeared in a slightly different format. All of the same information was available, however, it was in an electronic format. Due to this, it was not possible for the observers to be blind to which ordering process the participants were using, however, the observers did not have any knowledge of the study or its purpose. They were only trained, by the experimenters, as to how to accurately use the check-sheet. Data collection continued, with no more than a five-day gap, for a five-month period in total.

At the conclusion of the study, all participants were asked to complete the social validity survey again and provided with the debriefing document (see Appendix E). This document was distributed to all participants of the study by the hospital's coordinator for this project. They were informed that they may view the performance data, as scored and graphed according to the study's dependent variables, if they wished by contacting the experimenter and setting up an individual meeting.

HSIRB Approval

Strict confidentiality of participant information was observed. This study was approved by the Western Michigan University Human Subjects Institutional Review Board and the Institutional Review Board of the hospital (see Appendix F for approval letters). Informed consent was obtained from each of the participants. All participants were informed that their participation was completely voluntary, and if they wished to terminate participation at any time, they would not suffer any adverse consequences from the experimenters or from the hospital administration. They were also informed that the risks associated with participation were minimal, if any, as participants were only observed doing their normal work tasks. The benefits of participation included possibly reducing medication error, and in turn, improving patient care, as well as contributing to the scientific community of both behavioral psychology and medicine. The participants of the study were required to use the CPOE system by the hospital. By agreeing to participate in the study, they were consenting to the use of their data for scientific research.

RESULTS

Order Correctness

As mentioned previously, the site of this study was an extremely high-functioning hospital that won awards, around the time of the study, based on the quality of their patient care. Due to this, high levels of errors were not expected, even during the baseline phase. The order correctness percentage was 96.05% during baseline. A small improvement was observed after the implementation of the CPOE system and the order

correctness percentage increased to 99.14%. When the CPOE system was withdrawn the order correctness percentage decreased to 87.43%, and a distinct downtrend can be observed at the end of this phase. It increased with the re-implementation of the system to 96.45%.

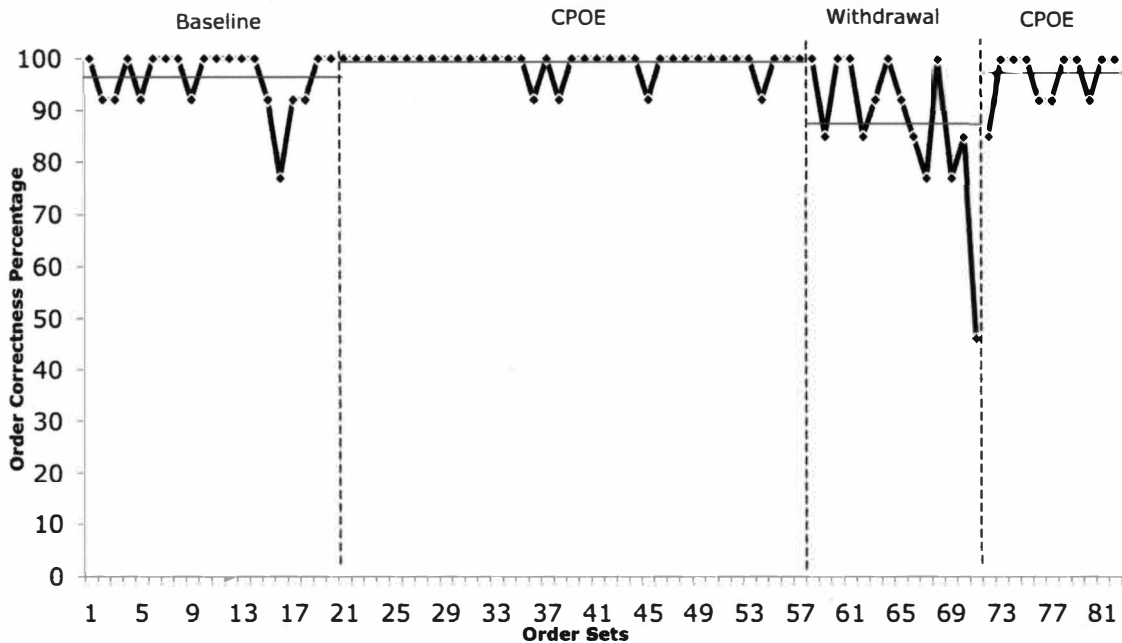Figure 1. Order Correctness Percentage

As seen in Figure 1, the CPOE system onset was associated with decreased variability and more order sets being completed 100% correctly. For example, during the two phases in which the CPOE system was not in place, 53% of orders were completed 100% correctly. During the two phases in which the CPOE system was in place, 83% of orders were completed 100% correctly.

Order Processing Time

The time it took for an order to reach the pharmacy after being placed by a physician was highly variable during baseline. Many factors can affect how long this process takes, including the volume of patients currently being cared for in the unit, the immediacy of the order, staffing conditions on the unit, etc. The average order processing time during baseline was 45.6 minutes. This average was based only on order sets in which both the time the order was written and the time the order was received by pharmacy was recorded, which was 75% of all order sets scored. When the CPOE system was in place, the order was automatically sent to pharmacy the instant it was placed; therefore, the average order processing time during the CPOE phase was zero minutes. During the withdrawal phase, variability increased and the average order processing time was 35.43 minutes. This average was based only on order sets in which both the time the order was written and the time the order was received by pharmacy was recorded, which was 50% of all order sets scored. When the CPOE system was re-introduced the average order processing time returned to zero minutes.

Figure 2. Order Processing Time

Error Severity

During baseline, the errors committed by participants were given a severity score

of "B" 100% of the time. According to the nationally recognized A-I scale used at this

hospital, this score indicates "an error that did not reach the patient." Once the

intervention was implemented, 100% of the errors were given a rating of "A," which

indicates "circumstances or events that have the capacity to cause error." During the

withdrawal phase, 62% of committed errors were given a severity rating of "A" and 38%

of errors made were given a severity rating of "B". Once the intervention was re-

implemented, 100% of the errors were rated as "A."

Necessary Rework

Rework was necessary for two order sets placed during the baseline phase. It was estimated that each of these order sets required five additional minutes to process. Therefore, the average rework time needed during this phase was .5 minutes per order. Rework was necessary for three order sets during the first CPOE phase, and the average rework time needed during this phase was .54 minutes per order. The estimated time necessary for each of these orders requiring rework ranged from 5-10 minutes. Rework was necessary for seven of the order sets placed during the withdrawal phase, which constituted half of all order sets placed during this phase. The estimated time necessary for each of these orders requiring rework ranged from 2-15 minutes. An average of 3.5 additional minutes was necessary to process each order set placed during this phase. Only one order set placed during the second CPOE phase required rework, estimated to take an additional five minutes. Therefore, the average rework time needed per order set in this phase was .45 minutes.

Figure 3. Average Rework Time Per Order Set

Physician Co-signature

Only one order set completed throughout the entire study was a verbal order that required a physician co-signature, so this measure could not be evaluated. This single verbal order did not receive a physician co-signature in the allotted time according to the hospital's protocol, which is 24 hours.

Self-reported Errors

The monthly average for 2006 (baseline) was 2.1 errors, reported by employees using the hospital's reporting system. This includes any and all errors reported for that unit, so it is not specific to errors that are made during medication ordering. Intervention data were collected for the months of February, March, April, and May. In the month of February, 2 errors were reported. An increase occurred in March, with 9 errors reported. The number of errors reported during April and May decreased to 4 and 3, respectively. These data do not account for the withdrawal and reinstatement of the intervention, as these phases occurred in June 2007 and July 2007 and the errors data were only available through May 2007.

Figure 4. Self-reported Errors

Physician Compliance

The participating physicians complied with the administration's request to use the CPOE system 100% of the time when the system was in place. This greatly exceeded the goal, set by hospital administration, which was 70%.

Length of Patient Stay

The average length of patient stay in the Pediatric Intensive Care Unit during January (baseline) was 5 days. This decreased slightly during the months in which the CPOE system was in place; 4 days in February, 4.4 days in March, 4.2 days in April, and 4 days in May. These data do not account for the withdrawal and reinstatement of the intervention, as these phases occurred in June 2007 and July 2007 and patient stay data were only available through May 2007.
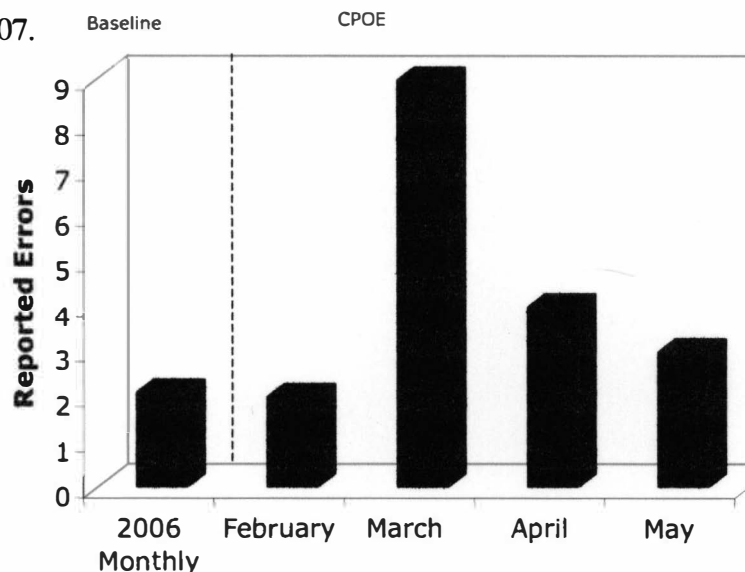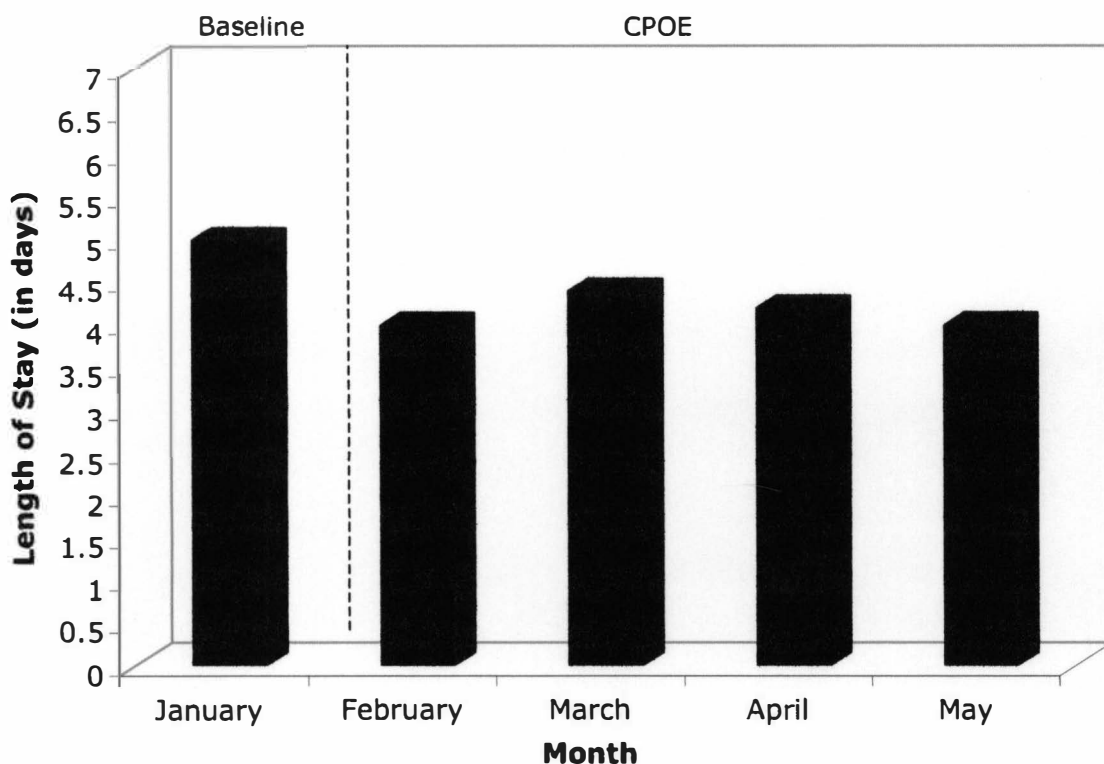

Figure 5. Average Length of Patient Stay (LOS)

Social Validity

Social validity data were collected via a survey administered to all participants (N=6) using the hospital's electronic system for survey administration. A number of positive statements about CPOE and the physicians' opinions of CPOE were evaluated using a 5-point Likert scale. A score of 1 indicated "strongly agree" with the positive statement and a score of 5 indicated "strongly disagree" with the positive statement, with a score of 3 being "neutral." Table 1 summarizes the average scores for each item on the survey.

Question	Pre-CPOE Average	Post-CPOE Average
I believe that CPOE can significantly reduce errors associated with medication ordering.	2.2	3.5
I believe that CPOE will make my job more efficient.	3	3.5
I believe that CPOE will decrease order-processing time.	2.4	4.5
I believe that CPOE will make patients' overall healthcare experience at Bronson better.	2.6	3.5
My overall opinion of CPOE is positive.	2.2	3.5
I believe that switching from paper to CPOE will go smoothly.	3.6	3
I believe that CPOE will decrease the severity of errors that are committed.	2.4	4
I believe CPOE will decrease the amount of rework necessary.	3.4	3
I believe that CPOE will save Bronson money, by decreasing the amount spent on errors and rework.	2.4	3.5
I am confident that I will be able to work with the computer to place orders successfully.	1.6	3.5
I feel that the training I have received on CPOE has sufficiently prepared me for placing orders this way.	1.8	3
I believe that, after an initial learning period, CPOE will not significantly affect the time it takes me to place an order.	2.8	3
I am satisfied with Bronson's decision to switch to CPOE.	2.2	3.5
I am satisfied with the process Bronson has gone through to develop and launch CPOE.	1.8	4

Table 1: Average Social Validity Scores

Inter-observer Agreement

Two independent observers scored 30% of all orders scored for the study in order to assess inter-observer reliability. Each line of the scoring check-sheet was scored as either "Agree" or "Disagree" and the total agreements were divided by the total agreements plus disagreements to form a percentage. Inter-observer agreement percentages were collected for all variables that were recorded on the check-sheet. The average percentage of agreement was 89% and individual agreement calculations ranged from 83%-96%. These agreement calculations included all measures on the check-sheet, including subjective measures such as the probable severity of errors and the estimated time that rework would take to complete. Including these variables in the calculations made it more difficult to achieve perfect agreement.

Effect Sizes

The overall effect sizes for the dependent variables of order correctness, order processing time, and average rework time when comparing the combined baseline phases to the combined CPOE phases can be seen in Table 2.

Variable	Combined Baseline Mean	Combined CPOE Mean	Effect Size (d)
Order Correctness	92.5% correct	98.02% correct	.73
Order Processing Time	42.36 minutes	0 minutes	-1.76
Average Rework Time	1.74 minutes	.54 minutes	-.45

Table 2: Cohen's d Effect Sizes

DISCUSSION

The implementation of a CPOE system in a hospital's Pediatric Intensive Care

Unit appeared to affect the functioning of the unit in several aspects. The percentage of

orders completed 100% correctly did increase when the CPOE system was in place. The

order processing time (from when a physician places an order until it is received by the

pharmacy) decreased drastically when the intervention was implemented. The impact

that the system had on the amount of rework necessary was unclear. Very little change

was seen with the first implementation of the system; however, a large increase in

necessary rework was observed when the intervention was withdrawn. The intervention

did not seem to have any systematic effects on self-reported errors, although some

interesting variability was observed. The length of patient stay decreased slightly when

the CPOE system was in use, but the change was not large enough to warrant firm

conclusions. The physicians' satisfaction with the intervention varied. Changes in some

of the dependent variables in the study were evaluated using an experimental design,

whereas other dependent variables were naturally occurring and therefore, not evaluated

using an experimental design.

The primary dependent variable, order correctness, was empirically evaluated

using a naturally occurring ABAB reversal design. During this naturally occurring

reversal, the CPOE system was not functioning properly for a period of approximately 24

hours, and therefore, physicians had to return to the traditional pen-and-paper method of

ordering. Once the system was functioning properly again, it was re-implemented.

A small mean change in order correctness was observed soon after the initial

implementation of the CPOE system, with an increase from 96.05% to 98.49% over a

period of approximately 4 months. The baseline level of errors was very low for this measure, and did not allow for much room for improvement. This suggests that a ceiling effect was present for this measure. The mean decreased to 87.43% correct when the CPOE system was withdrawn, and then increased again with re-implementation of the intervention to 96.54%. During the two phases in which the intervention was not in place, 53% of orders were placed 100% correctly. During the two phases in which the intervention was in place, 77% of orders were placed 100% correctly. In an industry where one, seemingly insignificant, error can cost a human life, perfection is the standard for healthcare professionals. The order correctness results from this study suggest that electronic prescribing helps to move individuals closer to this goal.

Another, somewhat automatic, impact that the CPOE system had on the quality of service provided was to decrease order processing time. Using the traditional ordering method, with pen and paper, required a long process from the time that a physician wrote an order until the time the reached the pharmacy to begin filling. In this case, once a physician wrote an order, it was then handed off to a unit clerk. The unit clerk subsequently faxed it to the pharmacy. There are several opportunities in this process for time to be wasted. The unit clerk may have a large volume of orders to process at once, which would be time consuming. Alternatively, the clerk could have other pressing job responsibilities, the order sheet could be misplaced, or the fax lines could be busy. Consequently, the baseline mean time required for an order to reach the pharmacy, once written by a physician, was 45.6 minutes. In this study, baseline data ranged from zero minutes to 156 minutes. The latter figure represents a long time for a newly admitted

patient to wait for medication that may be needed to stabilize his or her condition. Once the CPOE system was implemented, the processing time (i.e., the time between physician order completion and pharmacy receipt of the order) immediately dropped to zero minutes. This is because, when using the electronic system, the order was automatically sent to pharmacy immediately upon the physician's completion of the order. This drastically decreases a primary contributing factor to medication wait time. It was not possible to collect data on the actual time patients received medication orders in this study, due to the hospital's recording systems. If such data were available in future studies, this would be an important variable to evaluate. When the intervention was withdrawn, the average processing time increased to 35.43 minutes, and then dropped to zero minutes again when the intervention was re-implemented.

The "rework" necessary for orders with errors in them also seemed to be affected by the implementation of the electronic prescribing system. Rework refers to a situation in which an error is committed in an order that prevents the order from being processed and requires the pharmacist to spend some amount of time to verify information or otherwise correct the error in order to proceed with processing the order. Sometimes this only necessitates a phone call to the unit from which the order was received, however, on other occasions the order must be returned to the sender and re-processed. This, of course, adds to the time required for the medication to reach the patient, and also costs the hospital money. The average additional time necessary for rework during baseline was .5 minutes. This increased slightly to .54 when the CPOE system was implemented. Virtually no change was observed with the first implementation of the CPOE system,

which indicates that errors requiring rework were still occurring. It is possible that errors continued to occur due to unfamiliarity with the CPOE system. Also, this measure is a highly subjective estimate of whether rework would be necessary, and if so, how long it would take. Therefore, these data should be interpreted with caution. A large increase in the average rework time necessary was observed in the withdrawal phase to 3.5 minutes per order. It is possible that this increase was due to an increased stress level in the unit during this phase. The CPOE system was unexpectedly not usable for a short period of time due to technical difficulties, which may have created a frantic and urgent environment. This could have created more opportunities for error. This average decreased to the earlier levels at .45 minutes when the system was re-implemented. The estimated cost of rework is $300 per hour. Using this number as a multiplier, the hospital would have spent $245 on rework alone (49 total minutes of rework during this phase multiplied by $5.00 per minute) for only the order sets that were scored for this study during the withdrawal phase. Only $25 would have been spent (5 total minutes of rework during this phase multiplied by $5.00 per minute) on rework for the order sets scored during the final phase when the CPOE system was re-implemented. When the baseline and withdrawal phases are combined and compared to the CPOE implementation phases, it appears that some savings for the hospital may occur. However, these results should be viewed with caution, as the withdrawal phase lasted only 24 hours and may not be representative of normal hospital functioning.

Physician compliance, which is mentioned in the literature as one of the primary struggles when implementing electronic prescribing, did not appear to be much of an

issue in the setting of this study (Ash et al., 1998; Bates et al., 1994). This may be because the physicians were highly involved in the process of implementing the current system from the beginning. The implementation was planned by the hospital over several years, all along keeping physicians involved to gain their input and to create a sense of ownership and buy-in. The physicians were told that paper ordering would be available for "emergencies only" to alleviate concerns they had of high volumes or orders needing to be placed and the electronic prescribing requiring more time during the initial learning stages. The hospital tracked the percentage of total orders that were placed electronically. The hospital set a goal of 70% of orders to be placed electronically, which was exceeded in all five months of implementation investigated in this study. Orders were placed electronically 100% of the time when the system was in use. A more thorough investigation of this hospital's implementation plan might be beneficial to other healthcare organizations that are experiencing problems with physician compliance. Although it appears that physicians were not satisfied with the system, they did continue to use it to place orders.

The hospital had a system already in place within the hospital for employees to report errors that were committed and "good catches." A "good catch" is an instance in which an error could have been made, but was caught and prevented. The hospital attempts to create a positive and supportive environment for reporting such instances, as they can be used for education and improvement. As this is a self-reporting system, it is likely not an accurate account of the errors actually committed. Usually such systems tend to report underestimates of the true error, as individuals are hesitant to "turn

themselves in" (Barach & Small, 2000). Although this is a flawed measure and was not empirically evaluated during this study, it is still of interest. The number that the hospital uses to track these errors is obtained by dividing the number of errors (from self-reported records) divided by 1000 patient days. The monthly average for 2006 (baseline) was 2.1 errors reported in the Pediatric Intensive Care Unit. This decreased slightly in the month of February (the first month that electronic ordering was in place) to 2 errors. An increase in reported errors was seen in the month of March, with 9 errors reported. Many factors could be responsible for this increase, none of which could be controlled for in this study. Employees might have felt more comfortable reporting errors for any number of reasons. Slightly higher patient volumes were experienced in the pediatrics unit that month. Higher patient volumes not only create more opportunities for error, but they also create a sense of urgency and a lack of time, which causes healthcare professionals to be more likely to commit errors. Reported errors decreased in April to 4 errors, and in May to 3 errors reported. It is important to keep in mind that these numbers include any errors that were reported involving this particular unit. These numbers include errors committed in activities other than medication ordering, such as errors in surgery or admissions protocol, etc. This particular unit has more errors reported than a comparison unit, the Medical Intensive Care Unit (MICU). The MICU unit has higher patient volumes than PICU, but had zero errors reported from February-May. Once again, these data have questionable reliability, and it is possible that the MICU did have errors occur that were not reported. It is also possible that more errors truly did occur in PICU. Much more research is needed in the area of error reporting within healthcare organizations.

More accurate means of tracking errors and "good catches" are needed, as well as more research on ways of increasing the accuracy with which employees report such incidences.

Using the self-reported error rates collected by the hospital and the standard dollar amount that they associate with each error ($2400), a gross estimate of the amount the hospital is spending on errors can be calculated. From January 2006 through December 2006, approximately $5,040 was spent per month on errors in the Pediatric Intensive Care Unit. The CPOE system was implemented on January 31, 2007. The estimated amount spent on reported errors decreased slightly in February (after CPOE implementation) to $4,800. The amount spent on errors increased dramatically in the month of March to $21,600. These amounts decreased in the months of April and May to $9,600 and $7,200, respectively. As you can see the amount spent on the preventable problem of errors can vary greatly. These are unnecessary costs that hospitals would like to keep as low as possible, in addition to the primary concern of quality of care provided to the patient.

The average length of patient stay (LOS) decreased slightly during the months after the implementation of the CPOE system, however, not substantially enough to make any conclusions on the system's impact on this variable. The average length of patient stay in the month of January (baseline) was 5 days. This decreased slightly after the system was implemented to 4 days in February, 4.4 days in March, 4.2 days in April, and 4 days in May. The average LOS did decrease after the system was adopted and it remained at this decreased level for four months. The LOS in PICU is slightly higher

than in MICU, a comparison unit. In MICU, the average LOS each month ranged from 3-3.6 days. More data are needed to make any firm of conclusions on the impact of electronic prescribing on the length of patient stay. However, the data collected in the study suggest that electronic prescribing may decrease the average LOS, which would have substantial benefits for patients and healthcare organizations. Patients tend to dislike being in a hospital and away from the comforts of their own homes. It is generally seen as an aversive experience, and therefore, patients would likely be more satisfied with their care if it were shortened as much as possible. It also decreases the cost for the patient and the hospital, and frees up resources at the hospital, which tend to be in constant demand.

Mixed results were observed regarding the social validity of electronic prescribing. These data were collected via pre-intervention and post-intervention surveys, and therefore, they should be viewed with caution. The method of administering the survey pre-intervention and post-intervention was used in order to assess the change in beliefs/opinions about CPOE once the participants actually used the system. With the exception of a few questions, participating physicians' overall confidence in the CPOE system and its impact on the quality of patient care decreased with the implementation of the CPOE system. The average scores for most questions, seen in Table 1, increased (signaling a decrease in confidence) approximately 1 point on a 5-point Likert scale. Prior to the intervention, participants scored most questions approximately a "2," whereas after the intervention, they scored questions more neutrally, approximately a "3" or "3.5." This decrease in confidence could be due to any number of factors external to this

study, however, it could also signal a decrease in the physicians' confidence in e-prescribing. Some physicians reported experiencing frustrations with the electronic system. Some of these issues reportedly caused the physicians to take longer when placing orders. Unfortunately, this variable (order entry time) could not be evaluated in this study. This is an oft-cited factor for physician resistance to electronic ordering systems (Ash et al., 1998; Bates et al., 1994). Hospital administrators informally reported a belief that, over time, these problems with the system will be alleviated and the physicians will become more comfortable and satisfied with the system. The hospital plans to continue to evaluate the physicians' opinions of electronic ordering and the quality of care being provided throughout this process.

In order to facilitate a closer examination, the effect sizes observed for the dependent variables of order correctness, order processing time, and average rework time were provided, using the *d* statistic as calculated by Cohen (1988). The effect size observed for each of the above-stated variables is represented in comparison to the combined baseline performance for that variable in Table 1. Therefore, all data from the phases in which the intervention was not present were compared to all data from the phases in which the intervention was present. Effect size calculations in the current study were performed using the equation presented by McConville, Hantula, and Axelrod (1998). As a reference for interpreting effect sizes, Cohen suggested that effect sizes of .2-.49 should be considered small; from .5-.79 should be considered medium, and effect sizes of .8 or greater should be considered large. By these standards, the effect size of .73, which was calculated for the variable of order correctness, would be considered

medium. A large effect can be seen for the variable of order processing time ($d = -1.76$), and a small effect was observed for the variable of average rework time ($d = -.45$).

The current study contributed to a gap in the literature of systematically evaluating the effects of e-prescribing on the correctness of each element of an order set, along with several secondary variables. The study was conducted in an actual hospital setting that encountered many issues while attempting to implement the system. This study attempted to capture actual errors made by physicians while placing orders, and did not rely on self-reported error reports for data. However, there are some limitations to the study. Order sets were scored during a "review" and not during the actual processing of the order, which some may view as a limitation. Scoring order sets while they were actually being processed would be very difficult to do, as it would require time to score the order set, which would take away from time that a pharmacist would need to process the order quickly and get medications to the patient. Only one group of physicians could be observed in this study, due to constraints present in the study's setting. Comparing performance across physician groups would be ideal. Also, data on the time it takes physicians to place orders was not available for collection. These data would be useful, as physicians' concerns with e-prescribing often include the worry that placing orders via computer will take longer until they become fluent with the software. Data collection had to be terminated; therefore, more data during the final phase of the study could not be collected. Having more data in this phase would be optimal to allow for better comparisons. The natural withdrawal phase only lasted 24 hours, and therefore, data had to be collected in a shorter time frame than would be ideal. Instead of continuing to score

only admission order sets, all order sets during this phase were scored in order to collect

enough data for analysis. This presents a limitation, in that the change in the data during

that phase may be exaggerated due to the collection method changing.

An error analysis was conducted to see if the type of errors varied across the

different phases. Certain types of errors (e.g., legibility, physician signature, time of

order placement) were not possible once the Computerized Physician Order Entry system

was implemented as they were automatically included on electronic orders. The

breakdown of types of errors that occurred in each phase can be seen in Figure 6.

Figure 6: Error Analysis

Overall, electronic ordering seemed to have several positive effects on the quality of care being provided to patients. More research is needed in this area to further investigate these effects and the exact impacts they have on patient care. Studies are needed on the impact of CPOE systems on errors in ordering in settings that have a higher baseline level of errors. This study could not provide a clear evaluation of this relationship due to ceiling effects. Also, research in the area of best practices for implementing such systems would be beneficial to the healthcare community. A majority of hospitals experience physician resistance to the use of electronic ordering systems; so more research on increasing physician compliance and/or improving the usability of the CPOE software would be beneficial. Electronic ordering could provide great benefits to the healthcare industry, however, more empirically sound research is needed to identify the specific benefits and the best method for implementation to maximize these benefits.

APPENDIX A

Scoring Check-sheet

Medication Order Scoring Check-sheet

Rater name: _____   Date: _____

Department (circle): PICU   Peds   Order #: _____

Criteria	Y or N		# of Errors	Probable Severity of Error
Legibility	Y	N	N/A	A B C D E F G H I
Physician Name	Y	N	N/A	A B C D E F G H I
Patient Name	Y	N	N/A	A B C D E F G H I
Date	Y	N	N/A	A B C D E F G H I
Signature	Y	N	N/A	A B C D E F G H I
Drug Name	Y	N	____/____	A B C D E F G H I
Dosage	Y	N	____/	A B C D E F G H I
Drug Route	Y	N	____/____	A B C D E F G H I
Frequency of admin.	Y	N	____/	A B C D E F G H I
No Abbreviations	Y	N	____/____	A B C D E F G H I
Time order was written	Y	N	N/A	A B C D E F G H I
Drug to drug interaction	Y	N	N/A	A B C D E F G H I
Patient allergy	Y	N	N/A	A B C D E F G H I

Total items of criteria correct   _____/13

Total percentage of criteria correct   _____ %

How many medications were ordered during this ordering session? ___ medications

Rework		
Will rework be required for this order?	Y	N
If yes, approximately how long will the rework take?	_____	minutes

Physician Co-signature		
Was this a verbal order?	Y	N
If yes, was it co-signed by a physician by the next day of business	Y	N

Order Processing Time		
What time was the order written or entered by the physician?	___:___	M
What time was the order received by the pharmacy	___:___	M
What time was the order clerked	___:___	M
What time was the order noted	___:___	M
What time was the order redlined	___:___	M

APPENDIX B

Severity Categorization

Categorization for Severity of Adverse Drug Events

Category A: Circumstances or events that have the capacity to cause error

Category B: An error that did not reach the patient

Category C: An error that reached the patient but did not cause harm

Category D: An error that reached the patient and required monitoring or intervention to confirm that it resulted in no harm to the patient

Category E: Temporary harm to the patient and required intervention

Category F: Temporary harm to the patient and required initial or prolonged hospitalization

Category G: Permanent patient harm

Category H: Intervention required to sustain life

Category I: Patient death

APPENDIX C

Social Validity Survey

Social Validity Survey

Please circle the number that corresponds to your opinion for each item, according to the scale below.

1 – strongly agree
2 – agree
3 – neutral
4 – disagree
5 – strongly disagree

1. I believe that HEO can significantly reduce errors associated with medication ordering.

   1   2   3   4   5

2. I believe that HEO will make my job more efficient.

   1   2   3   4   5

3. I believe that HEO will decrease order processing time.

   1   2   3   4   5

4. I believe that HEO will make patients' overall healthcare experience at Bronson better.

   1   2   3   4   5

5. My overall opinion of HEO is positive.

   1   2   3   4   5

6. I believe that switching from paper to HEO will go smoothly.

   1   2   3   4   5

7. I believe that HEO will decrease the severity of errors that occur.

   1   2   3   4   5

8. I believe that HEO will decrease the amount of rework necessary.

   1   2   3   4   5

9. I believe that HEO will save Bronson money by decreasing the amount spent on errors and rework.

   1   2   3   4   5

10. I am confident that I will be able to work with the computer to place orders successfully.

   1   2   3   4   5

11. I feel that the training I have received on HEO has sufficiently prepared me for placing orders this way.

1   2   3   4   5

12. I believe that, after an initial learning period, HEO will not significantly affect the time it takes me to place an order.

1   2   3   4   5

13. I am satisfied with Bronson's decision to switch to HEO.

1   2   3   4   5

14. I am satisfied with the process Bronson has gone through to develop and launch HEO.

1   2   3   4   5

APPENDIX D

Informed Consent

WESTERN MICHIGAN UNIVERSITY and BRONSON METHODIST HOSPITAL
Department of Psychology

An Evaluation of the Impact of Computerized Physician Order Entry on Medical Errors

John Austin (PI)
Shannon Loewy (SI)
WESTERN MICHIGAN UNIVERSITY

Jane Janssen (co PI)
Aaron Lane-Davies (co PI)
BRONSON METHODIST HOSPITAL

<u>Purpose.</u> You are invited to participate in a research study that will evaluate the impact that Computerized Physician Order Entry (CPOE) has on medical errors. The intent of this study is to determine how the use of such a system impacts the quality of healthcare provided.

<u>Duration.</u> Data will be collected on your ordering behavior over the course of 2-5 months. During this time, nothing will differ from your normal work activity. The approximate end date for the study is June 1, 2007.

<u>Explanation of Study Procedures.</u> As stated above, data will be collected on your ordering behavior for a short period of time prior to the implementation of CPOE and a short period of time after. Also, during this time period an observer may be present in your work environment to observe your behavior. No data on your individual behavior will be presented (i.e. no name is included on the observation form). All information gathered during the study will be presented in a group format.

<u>Compensation.</u> You will not be compensated beyond your normal work compensation, as you are only performing your every-day work tasks.

<u>Benefits.</u> You will not receive any direct benefits from this study, however, data gained from your participation in the study may benefit the general scientific community by providing information on the effects of CPOE on the quality of healthcare.

<u>Risks and Protections.</u> You will not be subject to any risks above and beyond what you are subject to as part of your work environment. You may have some anxiety or fear pertaining to data being collected on your performance. As stated above, no physician name is written on the observation form and no individual data will be available from this study. All data will be presented in a group format. Therefore, there will be no risk to your employment status. No negative consequences will occur should you chose to participate or not participate in this study.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency procedures will be taken; however, no compensation or additional treatment will be made available to you except otherwise stated in this consent form.

Confidentiality. All of the information collected from you and about your performance is confidential. That means that your name and other identifying information will not appear in any publications or presentations of the data collected. Only group data will appear in publications and presentations of this research. Should you choose not to participate in this study, no data will be collected on your performance.

The experimenters are prepared to meet personally with any participant who wishes to discuss any aspect of this research project and answer questions about the way data may be or are presented. As mentioned above, any information that could identify individuals will be removed from the data used in any publications or presentations.

Voluntary Participation. Your participation in the study is completely voluntary. You are free to withdraw at any time without penalty. No negative consequences will occur should you choose to participate or not participate in this study. At the end of the study, the experimenter will answer any questions you have and explain how your data helped us learn more about the impact of CPOE.

Who to Contact with Questions. If you have any questions about this study you may call Shannon Loewy at 269/930-0726. In Addition, Dr. John Austin, my faculty advisor can be reached at 387-4495 or the Vice President for Research, 387-8298 if questions or problems arise during the course of the study. For questions specifically pertaining to Bronson Methodist Hospital and their involvement in this study, please contact Dr. Carter, Chair of the Institutional Review Board at (269)341-7898.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate if the stamped date is more than one year old.

Your signature below indicates that you read the above information and agree to participate in the study.

_____   _____
Participant Signature   Date

Please keep the attached copy of this form for your records.

APPENDIX E

Debriefing Document

PARTICIPANT DEBRIEFING DOCUMENT

This document will provide you with a brief explanation of the purpose of the study. Please feel free to contact the researchers with any further questions you may have.

The purpose of this study was to determine the effects of a Computerized Physician Order Entry (CPOE) system on the quality of healthcare. Several studies have shown that such systems decrease medication error. However, more recent research has questioned this claim and provided evidence that the use of computer technology may create different types of errors association with medication ordering. This study seeks to objectively and accurately measure errors in medication ordering prior to and after the implementation of CPOE.

Decreasing errors in healthcare is obviously of immense importance and is currently receiving large amounts of attention. Additionally, electronic ordering systems are quite expensive and healthcare organizations want to ensure that the technology and effort to utilize it produces valuable results.

In order to evaluate the error associated with both handwritten and electronic ordering, we evaluated all orders that you placed for a short time prior to and after the implementation of CPOE. This evaluation was conducted by having pharmacy residents review the orders retrospectively using a scoring check-sheet. The check-sheet included 13 elements that experts suggested were necessary in order for an order to be considered "perfect." This yielded a "percent correct" for each order and we will be able to compare this percentage for the stage before CPOE was in place to the percentage for the stage after CPOE was in place. We believe this will help us to adequately evaluate the effects of the CPOE system.

We also collected and/or estimated many secondary measures to assess the impact that CPOE had on these measures. The secondary measures included: order processing time, patient length of stay, number of orders placed, severity of errors, amount of rework necessary, cost of necessary rework, percentage of correct physician co-signature, self-reported errors, and cost of self-reported errors. Comparing these measures prior to the use of CPOE to the measures after the implementation of CPOE will give us a better picture of how the electronic system effects the patients' experience overall.

You are free to view our records of your performance and we invite you to do so. If you choose to do so, you may make arrangements with Shannon Loewy. The data gathered during this study will, hopefully, contribute to the body of scientific research about the effects of CPOE, and ultimately, to improve the

quality of healthcare. Thank you for participating in this study. Your help is greatly appreciated.

Please feel free to contact the researcher, Shannon Loewy, with any concerns you may have or if you wish to discuss the study or the results from the study in more detail. Shannon Loewy can be contacted via email at shannon.m.loewy@wmich.edu or by phone (269)830-0726.

APPENDIX F

Human Subjects Institutional Review Boards Approval Letter

Date: March 26, 2007

To: John Austin, Principal Investigator
       Shannon Loewy, Student Investigator for thesis

From: Amy Naugle, Ph.D., Chair *Amy Naugle*

Re: HSIRB Project Number: 06-12-22

This letter will serve as confirmation that the changes to your research project "An Evaluation of Computerized Physician Order Entry on Medical Errors" requested on March 23, 2007 (elaboration of risks and benefits as requested by the Bronson IRB) have been approved by the Human Subjects Institutional Review Board.

The conditions and the duration of this approval are specified in the Policies of Western Michigan University.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: January 26, 2008

BIBLIOGRAPHY

Agency for Healthcare Research and Quality (2005). Error rates and error prevention. Retrieved October 31, 2005, from http://www.ahrq.gov/

Ash, J. S., Berg, M., & Coiera, E. (2004). Some unintended consequences of information technology in health care: The nature of patient care information system-related errors. *Journal of the American Medical Informatics Association, 11*, 104-112.

Ash, J. S., Gorman, P. N., & Hersh, W. R. (1998). Physician order entry in U.S. hospitals. *Proc. AMIA Symposium*, 235-239.

Ash, J. S., Gorman, P. N., Seshadri, V., & Hersh, W. R. (2004). Perspectives on CPOE and patient care. *Journal of the Medical Informatics Association, 11*, 207-216.

Balas, M. C., Scott, L. D., & Rogers, D. (2004). The prevalence and nature of errors and near errors reported by hospital staff nurses. *Applied Nursing Research 17*, 224-230.

Barach, P., & Small, S. D., (2000). Reporting and preventing medical mishaps: Lessons from non-medical near miss reporting systems. *British Medical Journal, 320,* 759-763.

Bates, D. W., Cohen, M., Leape, L. L., Overhage, J. M., Shabot, M. M., & Sheridan, T. (2001). Reducing the frequency of errors in medicine using information technology. *Journal of the American Medical Informatics Association, 8*, 299-308.

Bates, D. W., Cullen D., Laird, N., et al. (1995). Incidence of adverse drug events and potential adverse drug events: Implications for prevention. *Journal of the American Medical Association, 274*, 29-34.

Bates, D. W., & Gawande, A. A. (2003). Patient safety: Improving safety with

    information technology. *New England Journal of Medicine, 348*, 2326-2534.

Bates, D. W., Kuperman, G., & Teich, J. M. (1994). Computerized physician order entry

    and quality of care. *Quality Management in Health Care, 2*, 18-27.

Bates, D. W., Leape, L. L., Cullen, D. J., Laird, N., Peterson, L. A.,

    Teich, J. M., Burdick, E., Hickey, M., Kleefield, S.,

    Shea, B., Vliet, M. V., & Seger, D. L. (1998). The effect of

    computerized physician order entry and a team intervention on prevention of

    serious medication errors. *Journal of the American Medical Association, 280,*

    1311-1316.

Bates, D. W., Teich, J. M., Lee, J., Seger, D., Kuperman, G. J., Ma'Luf, N., Boyle, D., &

    Leape, L. (1999). The impact of computerized physician order entry on

    medication error prevention. *Journal of the American Medical Informatics*

    Association, 6(4), 313-321.

Berger, R. G., & Kichak, J. P. (2004). Computerized physician order entry: Helpful or

    harmful? *Journal of the American Medical Informatics Association, 11*, 100-103.

Bobb, A., Gleason, K., Husch, M., Feinglass, J., Yarnold, P., & Noshkin, G. (2004). The

    epidemiology of prescribing errors. *Archives of Internal Medicine, 164*, 785-792.

Classen, D.C., Pestotnik, S. L., Evans, R. S., Lloyd, J. F., & Burke, J. P. (1997).

    Adverse drug events in hospitalized patients: Excess length of stay, extra

    costs, and attributable mortality. *Journal of the American Medical Association,*

    277, 301-306.

Cohen, J. (1988). *Statistical power analyses for the behavioral sciences* (2nd ed.).

Hillsdale, NJ: L. Erlbaum Associates.

Cook, R., Render, M., & Woods, D. D. (2000). Gaps: learning how practitioners create

safety. *British Medical Journal, 320*, 791-794.

Cordero, L., Kuehn, L., Kumar, R. R., & Mekhjian, H. S. (2004). Impact of

computerized physician order entry on clinical practice in a newborn intensive

care unit. *Journal of Perinatology, 24*, 88-93.

Ferner, R. (2004). Computer aided prescribing leaves holes in the safety net.

British Medical Journal, 328, 1172-1173.

Force, M. V., Deering, L., Hubbe, J., Andersen, M., Hagemann, B., Cooper-Hahn, M.,

& Peters, W. (2006). Effective strategies to increase reporting of medication

errors in hospitals. *The Journal of Nursing Administration, 36*(1), 34-41.

Hughes, R. G., & Edgerton, E. A. (1998). Reducing pediatric medication errors.

American Journal of Nursing, 105(5), 79-84.

Institute of Medicine (1999). *To err is human: Building a safer health system.*

Washington, DC: National Academy Press.

Kaushal, R., Barker, K., & Bates D. W. (2001). How can information technology

improve patient safety and reduce medication errors in children's health care?

Archives of Pediatric & Adolescent Medicine, 155, 1002-1007.

Kaushal, R., Kaveh, S., & Bates, D. W. (2003). Effects of computerized physician order

entry and clinical decision support systems on medication safety: A systematic

review. *Archives of Internal Medicine, 163*, 1409-1416.

Kaushal, R., Shojania, K. G., & Bates, D. W. (2003). Effects of computerized physician order entry and clinical decision support systems on medication safety: A systematic review. *Archives of Internal Medicine, 163*(12), 1409-1416.

Koppel, R., Metlay, J. P., Cohen, A., Abaluck, B., Localio, A. R., Kimmel, S. E., & Strom, B. L. (2005). Role of computerized physician order entry systems in facilitating medication errors. *Journal of the American Medical Association, 293*(10), 1197-1203.

McConville, M. L., Hantula, D. A., & Axelrod, S. (1998). Matching training procedures to outcomes: A behavioral and quantitative analysis. *Behavior Modification, 22*(3), 391-414.

National Coordinating Council for Medication Error Reporting and Prevention (2001). Index for Categorizing Medication Errors. Retrieved August 26, 2006, from http://www.nccmerp.org/medErrorCatIndex.html

National Practitioner Data Bank (2006). Medication Error Statistics. Retrieved May 20, 2006, from http://www.npdb-hipdb.com/index.html

Patterson, E. S., Cook, R. I., & Render, M. L. (2002). Improving patient safety by identifying side effects from introducing bar coding in medication administration. *Journal of the American Medical Informatics Association, 9,* 540-553.

Schiff, G., & Rucher D. T. (1998). Computerized prescribing: Building the electronic infrastructure for better medication usage. *Journal of the American Medical Association, 279,* 1024-1029.

Shane, R. (2002). Computerized physician order entry: Challenges and opportunities.

American Journal of Health-System Pharmacy, 59, 286-288.

Stanhope, N., Crowley-Murphy, M., Vincent, C., O'Connor, A. M., & Taylor-Adams, S.
E. (1999). An evaluation of adverse incident reporting. *Journal of Evaluation in
Clinical Practice, 5*(1), 1-4.

Teich, J. M., Merchia, P. R., Schmiz, J. L., Kuperman, G. J., Spurr, C., & Bates, D. W.
(2000). Effects of computerized physician order entry on prescribing practices.
Archives of Internal Medicine, 160, 2741-2747.

Woods, D. D., & Cook, R. I. (2002). Nine steps to move forward from error. *Cognition,
Technology & Work, 4,* 137-144.