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The Impact of Computerized Provider Order Entry (CPOE) on Medication Order Processing and Workflow Efficiency by Pharmacists: A Time and Motion Study

by

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Dedicated to Catherine,

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&

Leah

Abstract

The Impact of Computerized Provider Order Entry (CPOE) on Medication Order Processing and Workflow Efficiency by Pharmacists:
A Time and Motion Study

Introduction: Recently, there has been a tremendous increase in the preparation on the part of US hospitals to implement CPOE. Employer groups, the federal government, and others have been advocating its implementation since the early 2000s, yet the number of hospitals which have met meaningful use criteria for CPOE is still less than 15%. This number is projected to increase exponentially in a very short time, spurred by incentives from the Centers for Medicare and Medicaid (CMS). With such a large amount of hospitals preparing for CPOE implementation, there is still much to learn about the impact of these systems. The objective of this study is to quantify the change in pharmacist workflow after CPOE is implemented.

Methods: An experimental, enhanced pretest-posttest, prospective, time and motion study was conducted in four inpatient pharmacies within the same hospital system. Order entry pharmacists were observed for two separate time periods. The intervention pharmacy was observed first as a non-CPOE pharmacy and then later, after CPOE had been implemented. There was a control pharmacy which was non-CPOE for both time periods. There were two treatment control pharmacies, both of which had CPOE for both time periods.

A database instrument recorded 37 different pharmacist tasks, which were grouped into four activities: clinical, distributive, administrative, and miscellaneous.

Comparisons of the amount of time spent by the order entry pharmacist in each of the four different activities were conducted. SAS® version 9.3 was used to analyze the data, with statistical significance set at 0.05.

Results: A total of 114 hours at the non-CPOE site and 197 hours at the CPOE site met the inclusion criteria. Non-parametric linear regressions were modeled and the predicted values were analyzed. The predicted mean number of minutes for each recorded hour were, by activity (predicted mean ± SD for non-CPOE versus CPOE, *p*-value): clinical (5.10 ± 2.24 versus 3.83 ± 1.34, $p<0.05$); distributive (44.55 ± 1.07 versus 47.61 ± 1.43, $p<0.05$); administrative (7.25 ± 2.34 versus 6.67 ± 1.28, $p<0.05$); and miscellaneous (3.11 ± 0.77 versus 1.89 ± 0.68, $p<0.05$).

Conclusions: Less time was spent in the clinical, administrative, and miscellaneous activities, while more time was spent in the distributive activity after CPOE implementation. These findings were statistically significant.

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Chapter 1

Introduction

This chapter will serve as an introduction to computerized provider order entry (CPOE), including a history of CPOE and its future. The purpose and objectives of the study will be outlined at the end of the chapter.

Technological Advances in the Inpatient Pharmacy

Over the years, there have been many technological advances in the inpatient pharmacy. Following are a few examples of some of the recent technologies which have been introduced to the inpatient pharmacy: automated dispensing cabinets, carousel drug storage units, high speed barcode packaging devices, robotic dispensing devices, robotic IV preparation devices, barcode medication administration (BCMA) systems, and intelligent IV infusion pump technology (Brookins, Burnette, De la Torre et al. 2011). All of these technologies aim to ultimately improve the outcome of the patient, either directly or indirectly. They also serve an added benefit of reducing the workload on the pharmacist by improving productivity through automated technology.

With the advent of electronic medical records (EMR), the pharmacist is able to easily view a patient's chart without having to leave the central pharmacy or make a call to the nurse station. Having a single record for a patient which can be modified by those who are qualified and have access is a powerful tool. For the pharmacist, it means having almost immediate access to information which will lead to more informed decisions.

Computerized provider order entry (CPOE) is yet another technology which holds a lot of promise in terms of improving patient safety. It may also help with improving the productivity of the pharmacist.

CPOE Defined

CPOE has been defined as "computerized provider order entry", "computerized prescriber order entry", "computerized physician order entry", and "computerized pharmacist order entry". This study uses the definition used by meaningful use terminology when referring to CPOE, which is "computerized provider order entry".

CPOE is the electronic entry of orders by an authorized provider, such as the physician or a nurse on behalf of the physician (Young 2003). These orders were traditionally handwritten and communicated to the pharmacy by one of many methods for dispensing. With the advent of a CPOE system, a provider will directly enter the orders into the computer. These orders are typically available to the pharmacist for verification virtually immediately upon completion by the provider.

At the very least, CPOE eliminates the need for a pharmacist to interpret the provider's handwriting and subsequently enter the order into the computer. Indeed, this is a tremendous benefit to the pharmacist who has traditionally been on the receiving end of some orders which are very difficult to interpret. Such was the case in the unfortunate demise of a cardiac patient in a Texas hospital due directly to the understandable misinterpretation of a physician's handwritten order on the part of the pharmacist (Glabman 2005). The physician was found liable in the court system.

Indeed, as of 2005, six states had passed laws requiring physicians to write orders which are legible (Glabman 2005).

More than just a tool used to eliminate the potentially devastating effect of cacography, or illegibility of poor handwriting, CPOE improves safety in other ways, depending on the level of sophistication of the system. The first is that the orders are structured, meaning the provider typically must include the dose, route, and frequency. The second is that the provider can be easily identified, which allows for easy follow-up, if necessary. Third, the provider has information readily available throughout the prescribing process. This can include patient medical records, lab results, allergy information, customized order sets, and clinical decision support systems (CDSS) (Bates 2000).

Order sets are defined as standardized medication and procedure orders (Hoey, Nichol, and Silverman 2009). They are designed to facilitate the entry of multiple orders for standardized purposes. They are the electronic version of the pre-printed paper order forms.

As defined in an article by Ash, McCormack, Sittig et al, clinical decision support (CDS) refers to "passive and active referential information as well as computer-based order sets, reminders, alerts, and condition (-specific) or patient-specific data displays that are accessible at the point of care" (Ash, McCormack, Sittig et al. 2012). Among other things, CDS provides guidelines for Best Practices to the provider as the order is entered.

Additionally, CPOE is integrated with the electronic medication administration record (E-MAR) and the electronic health record (EHR), allowing for real-time information availability to the provider. Patient scheduling, billing, and hospital inventory are also integrated with the system.

CPOE systems vary greatly in capability and cost, depending on the capability of the system. In 2003, First Consulting Group, in a report for the American Hospital Association and the Federation of American Hospitals, performed a case study of five hospitals (Young 2003). They found that the total one-time capital and operating costs for the implementation of CPOE averaged $12 million, with a range between $6.3 million and $27.3 million.

Why CPOE

CPOE has become the goal of many entities. The federal government, specifically the Centers for Medicare and Medicaid (CMS) and the Agency for Healthcare Research and Quality (AHRQ), the Leapfrog Group, and hospitals all across the country have listed the implementation of CPOE as one of their top priorities. This is due to many factors, but chiefly patient safety.

In 1999, the Institute of Medicine released the landmark publication *To Err is Human: Building a Safer Health System* (Kohn, Corrigan, and Donaldson 1999). This writing shed light on the severity of the problem facing the nation's healthcare system. It was found that of the 33.6 million hospital admissions in 1997, there were 98,000 deaths, of which 7,000 were due to medication errors.

Moreover, on average, each hospital patient was exposed to one medication error per day (Young 2006). The widespread effect of this data energized the combined efforts of those in both the public and private sectors to find solutions to the alarming problem. For reasons which will be outlined in subsequent sections, CPOE became a large part of the multi-faceting approach targeting the source of the safety issue.

Another secondary factor which pointed to CPOE as a possible solution dealt with the economic concerns of the nation. The CMS budget for the year 2019 was estimated to increase to 6% of the national gross domestic product (GDP) (IOM 2010). By the year 2050, that figure was projected to double.

Preventable adverse drug events (ADEs) were found to cost between $17 to $19 billion in 1999 (Kohn, Corrigan, and Donaldson 1999). This translated to approximately $4,700 added to the cost of each hospital admission.

Studies had shown the potential for CPOE to reduce these medication errors, thereby bettering patient outcomes and consequently lowering healthcare costs. Even as far back as the 1960's, it had been advocated to have the physician enter an order directly into the computer, in order to ensure quality outcomes (Sittig and Stead 1994). One of the first hospitals to implement a version of CPOE was the El Camino Hospital in Mountain View, CA. After implementation, omission errors in medication orders were significantly decreased (Sittig and Stead 1994). Similar findings have been discovered since the El Camino Hospital study, and will be discussed in the *Medication Safety* section.

History of CPOE

Early Beginnings

CPOE was born from the idea that patient safety could be improved if the interpretation of a physician's handwriting could be minimized or eliminated. To that end, it was developed and has been around in one form or another since the late 1960s. El Camino Hospital is credited with implementing one of the first CPOE systems (Sittig and Stead 1994). The National Center for Health Services research selected El Camino Hospital to test the recently-developed Tehnicon Medical Information Management System. The results were positive. Prescription omission errors of site and route of medication administration fell from 7.9% to less than 0.5% ($p<0.01$) as well as dosage scheduling errors were reduced from 1.3% to less than 0.5% ($p<0.01$).

Time passed and improvements were made, but it wouldn't be until the end of the last century that CPOE would really begin to accelerate in terms of widespread implementation and acceptance.

CPOE Takes Off

To Err is Human truly brought to the fore the challenges facing the U.S. healthcare system for both those in the health care profession as well as the layperson (Kohn, Corrigan, and Donaldson 1999). These statistics became a real signal to the profession that systematic change needed to take place. In *To Err is Human*, the Institute of Medicine emphasized that whenever humans are involved, processes are

subject to failure. However, changes to the processes themselves can alleviate the effect of potential errors.

In 1995, the Leape study was published (Leape, Bates, Cullen et al. 1995), focusing on 5 distinct errors of the medication use process. CPOE would prove to address each of these, either directly or indirectly:

1. Prescribing. Numerous features would become available to the provider, including: prescribing error prevention capabilities, clinical decision support with alerts, and guidelines for best practices.
2. Transcribing and Documentation. Inherent to CPOE, the pharmacist will no longer have to interpret handwriting. Additionally, the order would automatically become part of the electronic health record (EHR).
3. Dispensing. The act of ensuring that the correct medication is pulled from inventory, aided by CPOE in that the medication which was prescribed by the physician and verified by the pharmacist is the one which is automatically made available to the technician or nurse for delivery to the patient.
4. Administration. The actual administration of the medication, typically by the nurse, is verified through the CPOE system through the scanning of the medication barcode and the scanning of the patient's identification wristband barcode.

5. Monitoring. The CPOE system is integrated with the EHR which allows for real time monitoring of the patient by the clinicians involved with the patient.

The Leapfrog Group was, and continues to be, an instrumental player in advocating for the implementation of CPOE (Kilbridge, Welebob, and Classen 2006). It was created in response to the research in *To Err is Human* in November 1999. The group started as a consortium of large healthcare purchasers charged with the mission of making "great leaps forward" in the safety and quality of the nation's healthcare. At the top of the group's list of goals was the recommendation of the implementation of CPOE, specifically to address the improvement of patient safety by reducing the potential for harm in medication use. Since then, the group has added another 27 safe practice objectives.

Direction of CPOE

Since 2000, there have been concerted efforts to assess the progress of hospitals all across the nation with regards to the implementation of CPOE. The question has arisen as to what constitutes acceptable CPOE, since there are a wide range of criteria. The Leapfrog Group proposed a set of criteria and in 2002, assessed that 2% of US hospitals had implemented qualified CPOE systems (Leapfrog Group 2012). By 2008, the group found that 8% of US hospitals had implemented qualified CPOE systems.

More recently, the Health Information Technology for Economic and Clinical Health Act (HITECH) of 2009 was passed as a part of the American Recovery and

Reinvestment Act of 2009 in an effort to aid with improving patient outcomes and ultimately reducing healthcare costs with the implementation of technological efficiencies (ARRA 2009). A key feature of the act was that it brought about incentives for hospitals to implement electronic health records (EHR) with "meaningful use" through CMS (CMS 2012).

Despite this trend, according to the HIMSS Analytics™ Database, as of the third quarter of 2012, there are still only 14.2% of US hospitals which were compliant with Stage 4 (part of a separate rating scale for EHR and CPOE implementation which is now the industry accepted criteria), which includes the implementation of a CPOE system with meaningful use (HIMSS Analytics 2012). This implies that there are still many hospitals that have not yet transitioned fully into CPOE systems. *Table 1* displays the progress which has been made on behalf of the US, according to the current EMR Adoption Model, relating to the metrics of "meaningful use".

Table 1. US EMR Adoption (HIMSS Analytics 2012)

Stage	Cumulative Capabilities	2012 Q2 (N=5303)	2012 Q3 (N=5303)
7	Complete EMR; CCD transactions to share data; Data warehousing; Data continuity with ED, ambulatory, OP	1.7%	1.8%
6	Physician documentation (structured templates), full CDSS (variance & compliance), full R-PACS	6.5%	7.3%
5	Closed loop medication administration	11.5%	12.0%
4	CPOE, Clinical Decision Support (clinical protocols)	13.3%	14.2%
3	Nursing/clinical documentation (flow sheets), CDSS (error checking), PACS available outside radiology	42.4%	41.3%
2	CDR, Controlled Medical Vocabulary, CDS, may have Document Imaging; HIE capable	11.7%	11.2%
1	Ancillaries – Lab, Rad, Pharmacy – All installed	5.1%	4.8%
0	All Three Ancillaries Not Installed	7.9%	7.4%

With hospitals and pharmacies implementing CPOE at such a rapid rate, pharmacy leadership will be forced to reexamine pharmacy workflow in order to remain productive.

Study Purpose & Significance

The purpose of this study is to assess the impact of a technological intervention (namely CPOE) on the workflow processes of pharmacists. The significance of this study is aimed at helping the pharmacist and pharmacy management better understand the impact of the implementation of a CPOE system on pharmacist workflow.

Study Objective

The objective of this research is to perform a time and motion study to quantify the amount of time which an inpatient order entry pharmacist spends on various activities in a non-CPOE versus a CPOE implementation setting.

Chapter 2

Literature Review and Theory

This chapter will explore the background of where CPOE has come from and its future direction. Following is an extensive review of the current literature on CPOE, by major category, specifically: 1) Clinical decision support and Order sets; 2) Meaningful Use; 3) Medication Safety; 4) Unintended Consequences; 5) Order Turn-Around-Time; and 6) Time and Motion Comparisons. Past studies will be referenced which have relevance to this study. The chapter will end with the theory used as a guideline and its application to this study.

CPOE Literature

Much has been written about CPOE, particularly in the last decade. The systems have evolved, but in the light of all medical technological interventions, are still very much in the infant stage. The following literature review is intended to provide an overview of the broad topics regarding CPOE and its implementation.

Clinical Decision Support and Order Sets

As mentioned earlier, clinical decision support (CDS) refers to "passive and active referential information as well as reminders, alerts, and guidelines" (Ash, Sittig, Campbell et al. 2007). Among other things, CDS provides guidelines for best practices to the provider as the order is entered. The complexity of these systems is quite impressive. Such systems can provide alerts and warnings in the event that a potential

drug allergy is detected, if a dose is out of range of the accepted clinical guidelines, if a drug-drug interaction is possible, or if a patient's vital statistics needs to be updated, just to name a few examples. Considering the sheer number of different factors which can play a role in the ultimate decision by the clinician, a CDS system needs to account for any amount of variation from patient to patient. All this needs to be done in the context of giving relevant information, without deluging the provider with too much information. This is a daunting task.

In 2004, an expert panel conference was held to identify the unintended consequences of clinical decision support coupled with CPOE (Ash, Sittig, Campbell et al. 2007). While acknowledging the need and overall benefits of CDS, they found that there were three major themes which still need to be addressed regarding CDS:

1. Elimination or shifting of human roles. For example, the CDS required the physicians to enter a dose, yet the CDS was sometimes found to be inadequate. As advances are made with CDS, less involvement of the pharmacist could arise regarding dosing inquires.
2. Currency of CDS content. In the effort to maintain compliance with CMS or JCAHO, some of these hospitals struggled to update their CDS content.
3. Wrong or misleading CDS content. When some new CDS module updates are incorporated with existing systems, some orders are generated for items which are not in the inventory. There are cases when alerts are inappropriate, or other cases when information cannot be trusted.

In summary, the authors concluded, “While these unintended consequences could be avoided completely if no CDS is implemented, CPOE cannot offer the benefits that can lead to safety improvements” (Ash, Sittig, Campbell et al. 2007).

Order sets are defined as standardized medication and procedure orders. They are designed to facilitate the entry of multiple orders for standardized purposes (Hoey, Nichol, and Silverman 2009). They are the electronic version of the pre-printed paper order forms.

In a recent article, an experimental project was conducted using order sets in a pediatric surgery setting (Avansino and Leu 2012). The purpose was to determine if a systematically developed order set provides better usability or decreased cognitive workload on the part of the provider over an ad hoc developed order set. It was found that among the seven surgeons who participated, they unanimously preferred the systematically developed order sets, by reducing the cognitive workload on the part of the provider and reducing the order variation. This finding is important in view of findings by AHRQ that there can be a reluctance on the part of the provider in changing from paper-based prescribing to CPOE, which has led to low usage rates of CPOE (McDonnell, Werner, and Wendel 2010).

Meaningful Use

In 2009, the American Recovery and Reinvestment Act was passed by Congress (ARRA 2009). This act included the Health Information Technology for Economic and Clinical Health (HITECH) act as well. The HITECH act was a tremendous commitment on

the part of the government to advance health care technology. It allowed for CMS to pay incentives to hospitals for proven "meaningful use" with regard to their information systems.

Currently, there are two stages, each having 16 objectives, which have been clearly defined by CMS, with a third stage still to be defined (HealthIT 2012). Note that this CMS stage system is a different stage system than that of HIMSS Analytics outlined earlier. Stage 1 (termed "Data capture and sharing") requires that more than 30% of all patients have at least one medication order entered with CPOE, among other items. A Stage 2 (termed "Advance clinical processes") requirement is for over 60% of all medication orders to be entered with CPOE. Another Stage 2 requirement is for the implementation of five clinical decision support interventions related to four or more clinical quality measures, in addition to drug-drug and drug-allergy alerts. Stage 3 is termed "Improved outcomes" and will be ratified in the near future.

If a hospital can prove meaningful use for these stages by the timeline specified, then they will receive incentives which can translate to millions of dollars for those years (Laegeler 2012).

Medication Safety

In 2000, an article by Bates related some of the staggering statistics for the time (Bates 2000). The article established that there was an overall incidence of 6.7% for serious adverse drug reactions in hospitals. It was estimated that between 28% and 56% of adverse drug reactions are preventable. The article further lists many of the

technological interventions as having the potential to greatly reduce these statistics. At the top of the list was CPOE, namely for the cited findings of another study, which stated that even a simple CPOE system was found to reduce medication errors by 64%.

A study performed at St. Luke's Episcopal Hospital in 2006 explored whether there was a difference between the number of medication errors in using a non-CPOE versus a CPOE system (Abbass, Mhatre, Sansgiry et al. 2011). The findings were clear. Of the 1,110 orders reviewed, there were a total of 135 medication errors. The non-CPOE system rendered 117 errors versus 18 for the CPOE system.

The Leapfrog Group estimated in 2008 that CPOE systems could reduce the number of ADEs in the US alone by up to 88% (Leapfrog Group 2008). This translated to an estimated prevention of three million serious medication errors each year.

It is clear that CPOE has the potential to prevent many medication errors. These references echo many other similar studies focused on the benefits of implementing CPOE in terms of patient outcomes alone.

Unintended Consequences

As with any medical technological intervention, there are cautionary results as well. Many researchers have warned that CPOE is still far from being fully developed. Unintended consequences of the implementation of CPOE are also documented.

One of the most comprehensive studies into this phenomenon was published in 2009 (Ash, Sittig, Dykstra et al. 2009). This project involved four years of research specifically into the unintended consequences of CPOE. There were 380 examples of

unintended consequences which were analyzed and grouped into the following nine categories:

1. More / New work issues
2. Workflow issues
3. Never ending demands
4. Paper persistence
5. Communication issues
6. Emotions
7. New kinds of errors
8. Changes in the power structure
9. Overdependence on technology

There was a case which unexpectedly found an alarming outcome in Children's Hospital of Pittsburgh (CHP), a tertiary care pediatric facility (Han, Carcillo, Venkataraman et al. 2005). The study population included 1,942 children who were referred and admitted to CHP over an 18 month period, from October 2001 to March 2003. Of those patients, 75 died, which was an overall mortality rate of 3.86%. The mortality rate was found to have increased from 2.80% pre-CPOE to 6.57% post-CPOE implementation. Even after multivariate analysis, CPOE remained independently associated with increased mortality, after adjusting for other mortality covariates. The authors warned of the possibility that even though ADEs at their facility were reduced, this cannot directly translate into reduced mortality.

A recent article in the New England Journal of Medicine portrays a growing concern about electronic health records (EHR) as a whole (Sittig and Singh, 2012). Since 2008, the number of certified EHR vendors in the US has increased by over 16 times (60 companies as of 2008 to over 1000 as of 2012). The authors proceed to offer a three-phase model to encourage the development of EHR-specific patient safety goals (e-PSGs): 1) Address safety concerns unique to EHR technology; 2) Mitigate safety concerns arising from failure to use EHR's appropriately; and 3) Use EHR's to monitor and improve patient safety. This proposal creates a strategy aimed at addressing patient safety issues specifically regarding EHR.

These systems are as sophisticated and complex as they come, both in the medical field or elsewhere, and they require a certain amount of resources to implement and maintain. Indeed, one estimate of maintaining a CPOE system at a 500 bed hospital was $1.35 million annually (Wietholter 2009).

Certainly, in the wake of such a rapid adoption of CPOE by such a large number of hospitals in a relatively short amount of time, experts caution of the importance of constant vigilance to protect the safety of the patient. Indeed, just because a process is automated does not, by itself, make it necessarily safer than the original process (CPOE 2003).

Order Turn-Around Time

In the pharmacy, medication order turn-around time (TAT) is the amount of time from when the order is received in the pharmacy to the time that the order is verified by the pharmacist.

At the Pitt County Memorial Hospital in Greenville, NC, TAT was reduced by 90% after the implementation of CPOE (Wietholter, Sitterson, and Allison 2009). Similarly, TAT was reduced by: 83.4% at Denver Health Medical Center in Denver, CO (Steele and DeBrow 2008); and 71% at Providence Portland Medical Center in Portland, OR (Jensen 2006).

However, at St. Luke's Episcopal Hospital in Houston, TX, TAT was found to have increased by 50% (Abbass, Mhatre, Sansgiry et al. 2011). It should be noted that these results should be tempered by the fact that this study was conducted during the pilot phase of CPOE implementation at the hospital and the CPOE orders were rarely seen by the pharmacists (1% of the total orders). Further, the CPOE orders at the time may not have been as evident as the scanned orders in the presentation on the pharmacists' monitors.

Due to the efficiencies stated previously, medication turn-around time has been found to be significantly reduced after the implementation of a CPOE system.

Time and Motion Comparisons

A systematic review of the literature was performed spanning 1966 to 2004 regarding the time efficiency of physicians and nurses using electronic health records

(EHR) (Poissant, Pereira, Tamblyn et al. 2005). Three of the articles reviewed included comparisons of CPOE and non-CPOE time. Among their findings, the amount of time which physicians spent on prescribing in a CPOE setting versus a non-CPOE setting averaged an increase of 98.1% to 328.6% per shift. The weighted average for these three studies yielded a 238.4% increase. The CPOE system was inefficient for the physicians compared to not using CPOE.

In a thesis from 2011, a time and motion study similar to this study was conducted regarding pharmacist workflow (Cox 2011). The amount of time spent by pharmacists in a CPOE versus a non-CPOE hospital pharmacy was observed. Twenty-four hours were observed in each setting. In terms of the average amount of time spent for each observed hour in percent, by activity, (non-CPOE vs. CPOE, respectively) was as follows: clinical (7% vs. 12%); distributive (81% vs. 72%); administrative (10% vs. 14%); and miscellaneous (3% vs. 2%).

To our knowledge, no study has been published in a peer-reviewed article regarding the impact of time spent by pharmacists in a non-CPOE versus a CPOE setting.

Time and Motion Studies

The modern version of the time and motion study began with the industrial organization wherein management would conduct studies to assess the productivity and efficiency of its workforce (De Cock 2012). The direct measurement of the time taken for observed tasks was aimed at increasing production and efficiency by optimizing an organization's workflow.

Relatively recently, time and motion studies have been used in the healthcare industry. There are two general methods of observation for time and motion studies: 1) self-reporting; and 2) continuous observation. In a study performed in 2000, continuous observation (which is the method used in this study) was found to be more accurate than self-reporting (Burke, Wilson, Donahue et al. 2000). In 2004, a continuous observation time and motion study was conducted comparing the amount of time taken by physicians reviewing patient records before and after implementation of electronic health records (EHR) (Pizziferri, Kittler, Volk et al. 2004). This study also used an Access® (Microsoft Corp., Redmond, WA) database similar to the instrument used in this study. This helps to strengthen the validation of the instrument used in this study.

At St. Luke's Episcopal Hospital in Houston, TX, a time and motion study was performed, comparing the amount of time taken by nurses for the medication administration process before and after bedside barcode administration system (BCMA) (Dwibedi, Sansgiry, Frost et al. 2012). That study revealed the effect of the implementation of a technological intervention in a healthcare setting.

A time and motion study can be a valuable tool for evaluating the effect of the implementation of an intervention in the healthcare field. Very little research has been done regarding pharmacist workflow following the implementation of a technological intervention using a time and motion study, which is the objective of this study.

Theoretical Model

The theoretical model used was based on the model proposed by Avedis Donabedian (Donabedian 1988) and is outlined below.

Theory of the Model

Donabedian's theory related to healthcare quality and its measurement. At its core, the model offers three categories of healthcare quality:

1) Structure. This category encompasses the material resources, human resources, and organizational structure used to perform any process.
2) Process. The process includes all of the tasks involved for the work of interest.
3) Outcome. The outcome of the process being investigated.

The theory states that the structure influences the process, which, in turn, influences the outcome. If either the structure or the process is improved, the outcome has an increased likelihood of improving. Refer to *Figure 1* for a graphical representation of the Donabedian model.

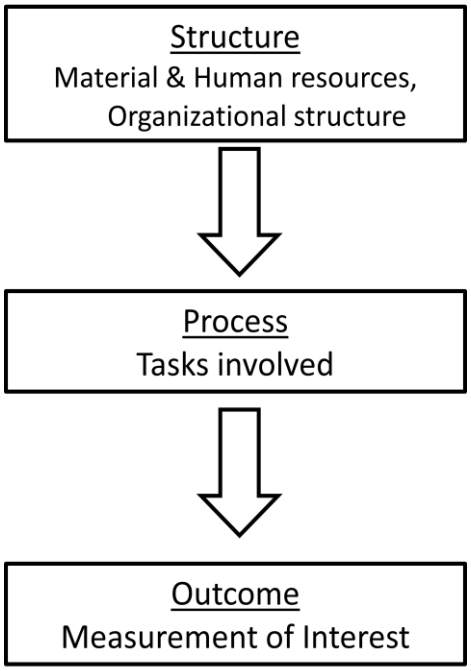

Figure 1. The Donabedian Model

Application of the Model

For this study, the structure category is the technological intervention, namely CPOE. The process includes all of the tasks performed by the pharmacists of interest. The outcome is the amount of time spent on each activity by the pharmacists. Refer to *Figure 2* for a graphical representation of the application of the model.

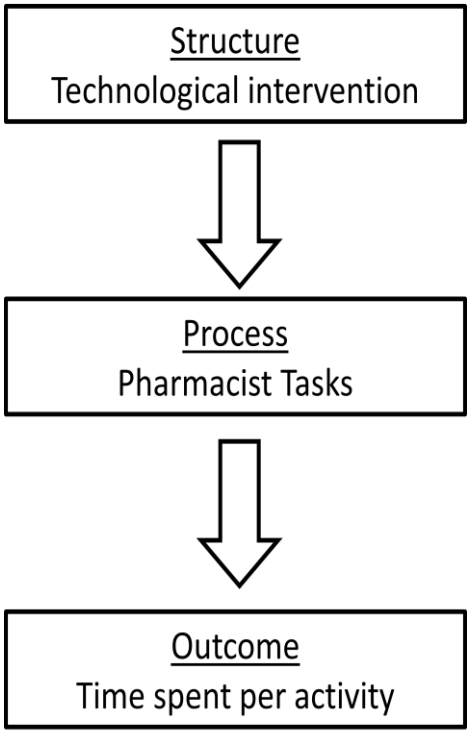

Figure 2. Application of the Model

Operationalization of the Model

The final model of interest in this study involves the measurement of the effect of the technological intervention (CPOE) on the amount of time spent on each activity by the order entry pharmacist. The "process" category was deleted in order to identify the effect of the technological intervention on the outcome. The hypothesis (**H**) is that the implementation of CPOE could have an effect on the amount of time spent by the pharmacist for each of the four activities, comprised of 37 tasks. The independent variable is either non-CPOE or CPOE. The covariates are the four different hospital pharmacies and the two time periods. The dependent variables are the amount of time

spent by the pharmacist for the four activities and the 37 tasks. Refer to *Figure 3* for a graphical representation of the operationalization of the model.

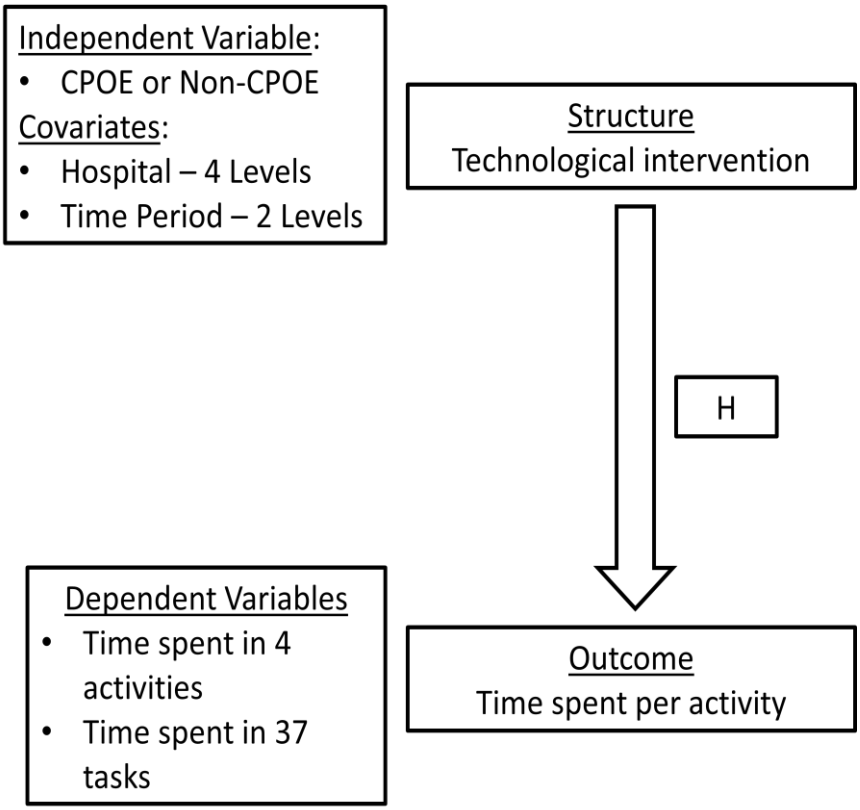

Figure 3. Operationalization of the Model

Hypothesis

Based on the theoretical model and previous literature, the following hypothesis is proposed:

H: There is a difference in pharmacist time spent across four activities in a CPOE versus a non-CPOE setting:

1) Clinical;
2) Distributive;
3) Administrative; and
4) Miscellaneous.

Chapter 3

Methods

This chapter relates the methods of the study. An overview of the design will be followed by an in-depth explanation of the specific methods used. The preparation for the study will be described, followed by the data collection process, statistical hypothesis, and analysis.

Study Design

A representation of the study design outline is in *Figure 4*. Ultimately, the difference in time spent in the four activities will be compared for non-CPOE and CPOE.

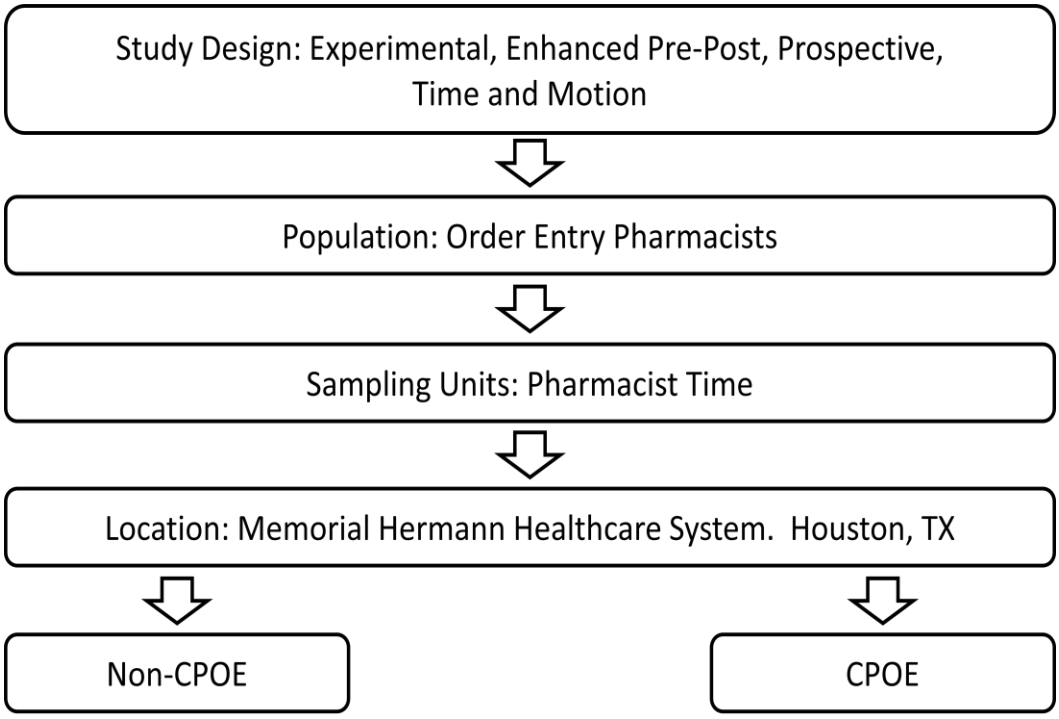

Figure 4. Study Design Outline

Setting

Memorial Hermann Healthcare System was the hospital system wherein this study was conducted. As of 2012, Memorial Hermann Healthcare System (MHHS) was the largest not-for-profit healthcare system in Texas (Memorial Hermann Healthcare System 2012). It consisted of twelve hospitals (among other facilities) which served in and around the Houston area. Six of these hospitals were named among the Nation's 100 Top Hospitals list by Thomson Reuters in 2012. Three of these award-winning hospitals were included in this study: Memorial Hermann Memorial City Medical Center, Memorial Hermann The Woodlands Hospital, and Memorial Hermann Southeast Hospital. Memorial Hermann Katy Hospital had been named to the same list in 2011. Refer to *Table 2* for the number of beds by department by hospital and case mix indexes by hospital.

Table 2. Hospital Summary: Number of Beds by Department and Case Mix Indexes

	MC †	TW †	K †	SE †
Medical/Surgery	330	144	90	221
ICU / CCU	-	24	12	32
Intermediate Care	-	36	-	-
Labor & Delivery	-	34	-	-
Ante partum	16	-	4	-
Post partum	37	-	27	-
Neonatal ICU	24	14	-	7
Continuing Care Nursery	1	-	9	-
Pediatric	18	-	-	-
Comp. Medical Rehab.	-	-	-	14
Total Beds	426	252	142	274
Case Mix Index	1.6276	1.6852 ‡	1.5289	1.6852 ‡

† MC = Memorial City; TW = The Woodlands; K = Katy; SE = Southeast.
‡ Shared CMI between 3 MHHS hospitals (The Woodlands, Southeast, and Northwest)

The four hospital pharmacies involved in the study are further described as follows. The first, Memorial Hermann Memorial City Medical Center, was the site of the intervention of interest. For the first time period, Memorial City was considered to be non-CPOE. CPOE was implemented after the completion of the first set of observations at that site, and over five months prior to the start of the second time period observations for that pharmacy. For the purposes of this study, it will be referred to as the intervention site.

Memorial Hermann The Woodlands Hospital was the control site. It was non-CPOE for both time periods of observation.

There were two treatment control sites for this study, both of which had implemented CPOE previously. Memorial Hermann Katy Hospital was treatment control 1. It had used CPOE for over 5 years before the first time period observations started. Memorial Hermann Southeast Hospital was treatment control 2. It had used CPOE for over 19 months prior to the first time period observations started. A schematic representation is shown in *Figure 5* of the experimental design.

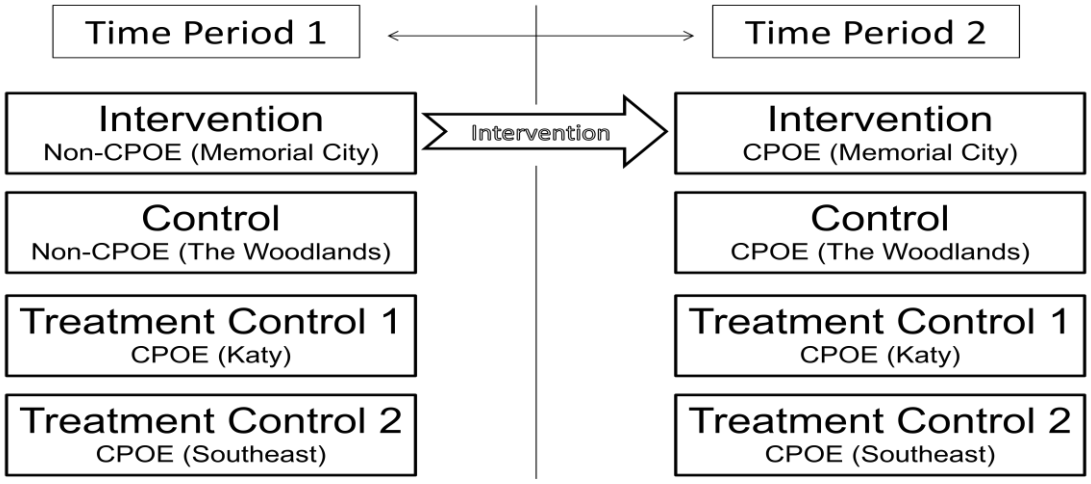

Figure 5. Schematic Diagram of the Enhanced Pretest-Posttest Control Group Experimental Design

Intervention Defined

The intervention for this study was the implementation of CPOE. The Memorial Hermann Healthcare System (MHHS) information technology structure was the same for all of its hospitals. Cerner Millenium® (Cerner Corp., Kansas City, MO) was the hospital-wide information system. All pharmacy orders (either CPOE or non-CPOE) went through

PharmNet®, which was a Cerner application. If an order was a handwritten non-CPOE order, it was first scanned by nursing through Pyxis® Connect (CareFusion Corp., San Diego, CA) and then entered manually into PharmNet® by the pharmacist. If an order was a CPOE order, the order was entered directly by the provider and transmitted in real time through the PharmNet® system for pharmacist verification. The system is summarized graphically in *Figure 6*.

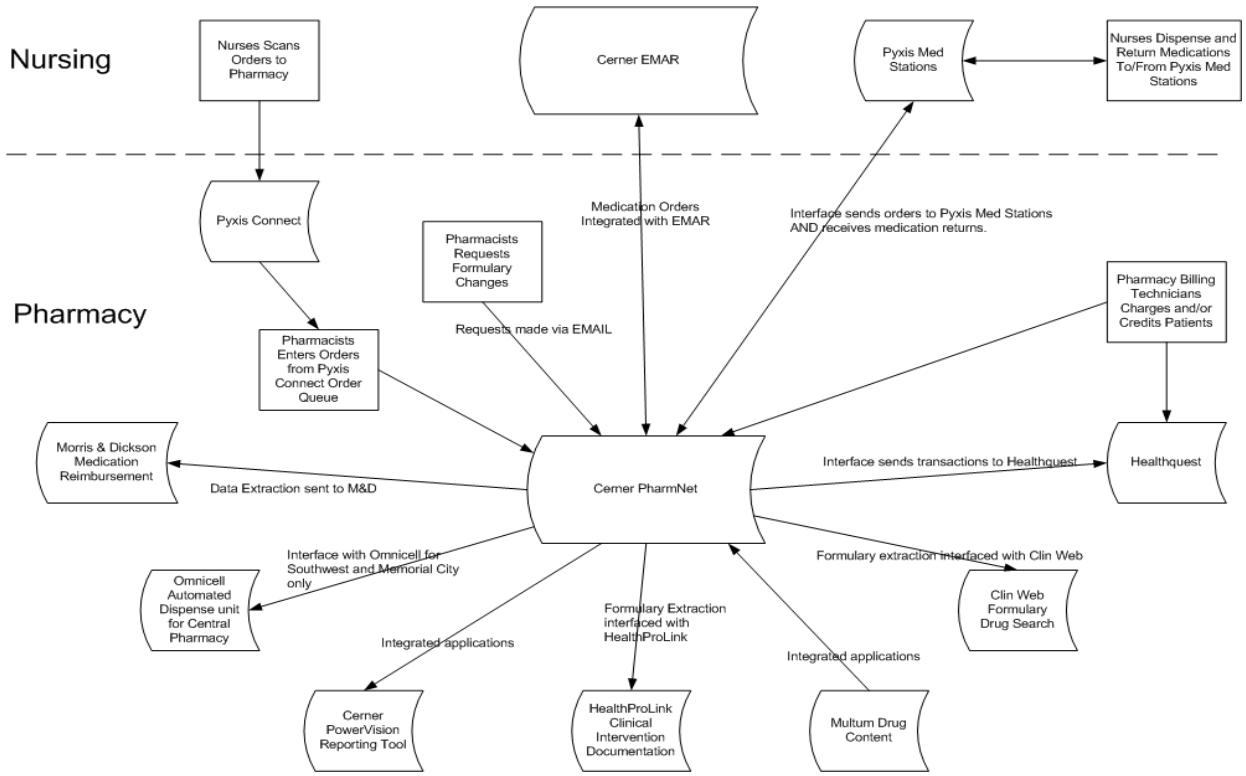

Figure 6. Memorial Hermann Healthcare System Pharmacy Information Technology Structure

Within the Cerner Millenium® system, the basic difference in processing the non-CPOE orders and the CPOE orders by the pharmacist is the transcription of the orders

required for those which are non-CPOE. Both kinds of orders are still processed within the PharmNet® application by the pharmacist.

The implementation of CPOE at a site involved no additional training on the part of the pharmacists since they already used the PharmNet® system. The implementation of CPOE rather had to do with the tremendous preparation and training by hospital and pharmacy management, physicians, nursing, and the information technology department for a concerted effort to switch from the traditional handwritten orders to the direct entry of orders on the part of the providers.

Each pharmacy observed could not be considered entirely non-CPOE nor considered entirely CPOE. Even at a non-CPOE site, some CPOE orders were processed, and the opposite was also true. For instance, at the non-CPOE control site, the Emergency Department was already using CPOE. Similarly, at all of the CPOE sites, the Total Parenteral Nutrition orders (TPNs) were scanned to the pharmacy and then entered by the pharmacist into PharmNet®. For the purposes of this study, a non-CPOE site and a CPOE site were defined by which system was used predominantly.

Human Subject Research

In order to comply with the rules and regulations required for studies involving human subjects, the following process was involved prior to the commencement of data collection. An Institutional Review Board (IRB) was applied for and granted through the University of Houston's Division of Research Committee for the Protection of Human

Subjects. Written approval was also granted by an authorized Systems Executive representing the Memorial Hermann Healthcare System.

The data collection assistant completed the Health Insurance Portability and Accountability Act (HIPAA) Privacy Rule training through the Memorial Hermann system prior to any data collection. All data collection was conducted and recorded in compliance to the HIPAA Privacy Rule, protecting all patients and subjects privacy. No patient information was used or recorded as a part of this study, nor was there any interaction of the researcher and any patient.

A letter of consent to participate in research was given to each pharmacist prior to formally requesting permission for that pharmacist to be included in the study. Refer to *Appendix A* for a copy of the letter of consent to participate in research. All collected data was stored in a password protected file in a password protected laptop computer, with access reserved only for the data collection assistant.

Sample Size Determination

The software G*Power® was used to determine the sample size *a priori* (Faul, Erdfelder, Lang et al. 2007). The calculations for each specific test factors in the following variables in order to calculate the required sample size:

1) The effect size: small, medium, or large;
2) The probability of Type I error: α;
3) The power required.

For the purposes of this study: a medium effect size was used; an α of 0.05 was used, and the power was 0.95. The results of these calculations as well as the actual effect of a previous study similar to this are found below (Cox 2011). The results are found in *Table 3*.

Table 3. Sample Size Calculation Results Performed a priori

	Parametric Tests		Non-Parametric tests		Prior study– Post Hoc ‡
	MANCOVA	t-test	Regression	Wilcoxon †	
Effect Size	0.25	0.5	0.15	0.5	0.408
α	0.05	0.05	0.05	0.05	0.05
Power	0.95	0.95	0.95	0.95	0.95
Calculated Sample Size	279	224	119	260	47

† Wilcoxon rank-sum test.
‡ Cox 2011.

As a conservative measure, a sample size of 300 was used to ensure adequate power.

Inclusion and Exclusion Criteria

The subjects who were included in the study were order entry pharmacists who worked in the central pharmacy for each particular hospital. Only one pharmacist was observed for each one hour period, beginning at the start of each clock hour.

Excluded subjects were clinical pharmacists and pharmacists who had been employed by Memorial Hermann for less than 30 days. A one-hour time period of data

collected was not included in the observations if there was greater than 25% (15 minutes for each one-hour period) of combined time in the miscellaneous activity for each one-hour period. This was determined on an *a priori* basis, in order to gather as much data as possible for value-added activities (clinical, distributive, and administrative), while minimizing the amount of non-value-added activity (defined by the miscellaneous activity).

Activities and Tasks Defined

In an article published in 2006 regarding pharmacist workflow and productivity, four major activities performed by hospital pharmacists were listed (Gupta, Wojtynek, Walton et al. 2006). The four activities were as follows: clinical, drug dispensing, management, and other. In another study, after consultation with pharmacy management and clinical pharmacists, the four activities were similarly defined as: clinical, distributive, administrative, and miscellaneous (Cox 2011). It is the latter list of activities into which all pharmacist tasks were grouped for this study. Similarly, the list of tasks defining each of these activities for the Cox study was used as a benchmark for the pilot study performed with this research. While remaining predominantly intact, this task list was modified to capture some different tasks observed in this study's four pharmacies. Refer to *Appendix B* for the definition for each task.

There are some tasks which could not be observed, such as: personal judgment, decision-making, and other similar tasks. As an example, if a pharmacist was typing a work-related email, it could have been possible that he or she was also internally

evaluating a clinical intervention. Since there was no outwardly observed action which would indicate this internal thought process, this particular task would have been recorded as the email task. Therefore, collected data was recorded based on observable actions.

Following is a discussion of each activity.

Clinical Activity

This activity was designed to capture all tasks which were clinical in nature. While the tasks composing this activity are relatively unambiguous, one could argue that there are many more tasks performed by the order entry pharmacist which could also qualify as being clinical in nature, such as the review of a particular chemotherapy order or consulting with a nurse about a particular patient's medications. However, for this study, the more conservative definition of clinical work was used. Refer to *Table 4* for the list of clinical activity tasks.

Table 4. Clinical Activity Task list

Activity	Task
Clinical	1. Clinical Intervention
	2. Direct Patient Care
	3. Drug Information
	4. E-Mar / Lab Review
	5. Consult Pharmacist – Clinical
	6. Patient Consult – Discharge
	7. Patient Consult – Warfarin
	8. Rounds
	9. Physician Order Form
	10. Other – Clinical

Distributive Activity

This activity was designed to capture all tasks which were distributive in nature. This is the activity where the majority of the order entry pharmacist's time is spent. It includes all tasks associated with: order entry and order verification; discussions with nurses, physicians, technicians, and other pharmacists regarding the distribution of medications to the hospital floors; checking of orders prior to distribution to the floors; and similar tasks relating to the distribution of medications to the floors. Refer to *Table 5* for the list of distributive activity tasks.

Activity	Task
Distributive	1. Order Entry (non-CPOE orders)
	2. Order Verification (CPOE orders)
	3. Clarification – Nurse
	4. Clarification – Physician
	5. Technician Check – non-IV room
	6. Technician Check – IV room
	7. Medication Prep / Delivery
	8. IT Support
	9. Consult Pharmacist – Distributive
	10. Consult Technician
	11. Chemo Order Review
	12. Chemo Mixing Check
	13. TPN Order Review
	14. TPN Mixing Check
	15. Pyxis Cart Fill Check
	16. SCIP / HOP Review
	17. Other – Distributive

Table 5. Distributive Activity Task List

Administrative Activity

This activity was designed to capture all tasks which were administrative in nature. The administrative activity was essentially all of the other tasks which were neither clinical nor distributive in nature, but still value-added tasks. The largest percentage of time in this activity was spent performing the following tasks: work-

related emails; discussions with pharmacy management; other administrative tasks; and documentation duties. Refer to *Table 6* for the list of administrative activity tasks.

Table 6. Administrative Activity Task list

Activity	Task
Administrative	1. Meeting
	2. Huddle
	3. Shift Report
	4. Scheduling
	5. Emails
	6. Q & A – Management
	7. Teaching / Mentoring
	8. Documentation
	9. Other – Administration

Miscellaneous Activity

This activity was designed to capture all non-value-added tasks. This included only personal time. Refer to *Table 7* for the miscellaneous activity task.

Table 7. Miscellaneous Activity Task List

Activity	Task
Miscellaneous	1. Personal Time

Data Collection

All data collection was performed by a single individual – the data collection assistant. Prior to including any pharmacist as a subject for the study, the data

collection assistant handed a copy of the letter of consent to participate in research to the pharmacist. The data collection assistant reiterated that there would be no consequence (positive or negative) for either participating or not participating in the research and that each subject's identity would be kept confidential should the subject choose to participate. Additionally, the subject would not be required to do anything outside of the scope of their normal workload to be included in the study. The data collection assistant answered all questions posed by the pharmacists regarding the study. Once permission was granted, that pharmacist was considered to be included in the study sample. Each pharmacist was assigned a number known only to the data collection assistant. This number was the unique identifier used in data collection.

Data was collected regarding the observed pharmacists involved in the study. Pharmacist's unique identifier, gender, and amount of experience within the Memorial Hermann system as a pharmacist were all recorded.

Data was collected regarding the characteristics of each hospital involved in the study. The number of beds, case mix indexes, and general information about the hospitals were recorded.

The list of data collected from the observations for each individual task were as follows: unique identification number for each observation (created by the original database); task identification number; start time for each task (the end time for each task was established by the start time for the subsequent task); date of each task; and comments associated with that task (if applicable). All of these variables were collected in real time.

The following variables remained constant for each individual hour, and were assigned to each individual observation following the completion of all data gathering. At the beginning of each hour, the pharmacist identification number and pharmacist assignment were recorded in the comment section of the instrument. Each pharmacist was given an assignment at the beginning of his or her shift. At the intervention site, for example, pharmacist "A" was assigned to primarily cover the patients in certain departments and floors, while pharmacist "B" was assigned to different departments and floors. These assignments remained the same for the entire shift. Assignments could change from day to day for each pharmacist.

The following variables remained constant for each individual day: the day number; the pharmacy identification number; the designation of whether the pharmacy was considered CPOE or non-CPOE; and the time period. These variables were assigned to each individual observation following the completion of all data gathering.

Extrapolated variables from the original data included: minutes per task (by finding the difference between the start time for the task and the start time for the subsequent task); activity (depending on the task); hour of the day; hour number; day number; and number of task changes per hour (determined by subtracting the observation number of the first task for that hour from the number of the last task for that hour).

Every different task was recorded in the instrument. In the case where multiple tasks were being performed by the pharmacist at one time, the data collection assistant would have to make a judgment as to which task was receiving more attention by the

pharmacist and record that task. An example of this would be a case where the pharmacist was talking on the phone with a nurse and then put on hold, at which time the pharmacist would return to the order verification task.

Queues were taken from the computer screens used by the pharmacist, actions of the pharmacist, nature of the conversations, and similar indicators. In the rare instance where the data collection assistant was not able to determine which task a pharmacist was conducting, that entire hour was not used in the analysis.

A further discussion on the techniques used to record the observations is in the *Instrument* section.

All observations were recorded by the data collection assistant on a MSI™ (Micro-Star International Company, Ltd., New Taipei City, Taiwan) laptop computer Model number MS-N014. All collected data was stored in a password protected file in the password protected computer, with access reserved only for the data collection assistant.

The Hawthorne Effect

As it applies to this study, the Hawthorne effect essentially states that any subject who is knowingly under observation will perform tasks differently than one who is not under observation. In order to minimize this effect, several measures were taken. The data collection assistant was seated behind two or more order-entry pharmacists whenever possible, at a distance ranging from three to ten feet, depending on the layout of the pharmacy and the existing seating arrangements. In doing so, subjects

could not easily determine which subject was being observed at any given time. Every effort was taken by the data collection assistant to be as unobtrusive as possible once observations commenced. An important aspect of reducing the Hawthorne effect was to have the data collection assistant be as pleasant and accommodating as possible to everyone in the pharmacy, especially the pharmacists. In general, the more at ease that a subject is with the data collection assistant, the more a subject can concentrate on his or her work, thereby minimizing any additional stress or distraction of having a researcher recording observations. This, in turn, allows for a more accurate recording of the order entry pharmacist's actions by the data collection assistant.

It should also be noted that each of these four pharmacies host multiple 3rd and 4th year pharmacy students from local colleges, pharmacy residents, junior college students, volunteer pharmacy technicians in training, and high school students on a regular basis. Several of each of these types of individuals were seen by the data collection assistant regularly at each of these pharmacies throughout the data collection process. The order entry pharmacists at each of these hospitals were already accustomed to being observed and having multiple students learning the profession as visitors in their pharmacies. This helped to minimize the Hawthorne effect by conditioning the pharmacists to being observed even before this study began.

Data Collection Schedule

The central pharmacy at each site was in continual operation (24 hours a day, seven days a week, and 365 days a year). Data collection was performed from 7:00 am

to 5:00 pm on weekdays, in one-hour periods. This data collection schedule was determined based on four criteria.

The first criterion was that the schedule had to capture a block of time during which a large volume of orders would be processed by the order entry pharmacists. This period of time was selected in part because many order entry pharmacists and pharmacy directors stated that this time would capture a great amount of data which was relevant to the study. These statements were later confirmed, according to data presented to the data collection assistant from treatment control 2, for time period 1. This ten hour period of time was consistently among the top third of ten hour periods of time in terms of order actions processed by the entire pharmacy.

The second criterion was that multiple pharmacists could be observed during this time period, in order to sample as many different pharmacists as possible. This time period was chosen to have at least as many opportunities for observations of multiple pharmacists as any other ten hour time period.

The third criterion was that the time period had to be a minimum span of four hours and a maximum span of ten hours, with more hours being preferable. This would help to ensure the broadest coverage of the entire 24 hour day as possible. Ten hours was chosen to be the maximum amount of time that could be accurately captured by the data collection assistant without any breaks.

The fourth criterion was that at least three observations needed to be conducted from any one hour time period, in order to ensure a representative sampling for each of the ten hours during the day for each time period. In other words, a minimum of three

observations were required each from 7:00 am to 8:00 am, 8:00 am to 9:00 am, and so on, for each of the two time periods for each site. Since four days were observed for each time period, this criterion was met.

The resulting schedule was to include four ten-hour days (40 hours) per site per time period. Since there were four sites and two time periods, a total of 320 hours would be gathered before deletion of any hours in order to comply with the minimum sample size determined to be 300.

After the go-live of CPOE at a pharmacy, it has been estimated to take one to three months for the providers to become familiar enough with it to become comfortable. Also, during this time, the pharmacists can be subject to more questions on the part of the providers as to specific questions regarding the CPOE system. It is for this reason that the lag in time from the go-live date at the intervention facility to the second set of observations during time period 2 at that site was over five months. This was the largest time lag between any of facilities from time period 1 to time period 2 observations, so as to allow as much time as possible to pass, thereby capturing more accurate “pre” and “post” measurements at this site. Since all of the other facilities had no changes to either their CPOE or non-CPOE status, shorter lags between their respective Time Period 1 and Time Period 2 observations were allowed, the shortest of which was two and a half months.

Sample Selection

Pharmacists were randomly selected to be observed for each hour of the day prior to arrival of the data collection assistant. Other considerations were taken into account when selecting which pharmacist was to be observed for a particular hour: shift schedules for different pharmacists; lunch schedules for different pharmacists; other pharmacist responsibilities (extended meetings or special projects which were not typical duties of the order entry pharmacist); and the location of the pharmacist relative to the data collection assistant. All of these factors were subject to change at any time, so the data collection assistant had to adapt throughout the day as conditions changed.

Instrument

The instrument used was originally developed by Partners® Healthcare System for the Agency for Healthcare Research and Quality (AHRQ) and was designed to capture and store time and motion data (AHRQ 2012). The instrument is an Access® (Microsoft Corp., Redmond, WA) database. It was modified from its original version to the current version to accommodate this study's tasks and activities by an independent consultant. Refer to *Figure 7* for the screenshot of the modified instrument.

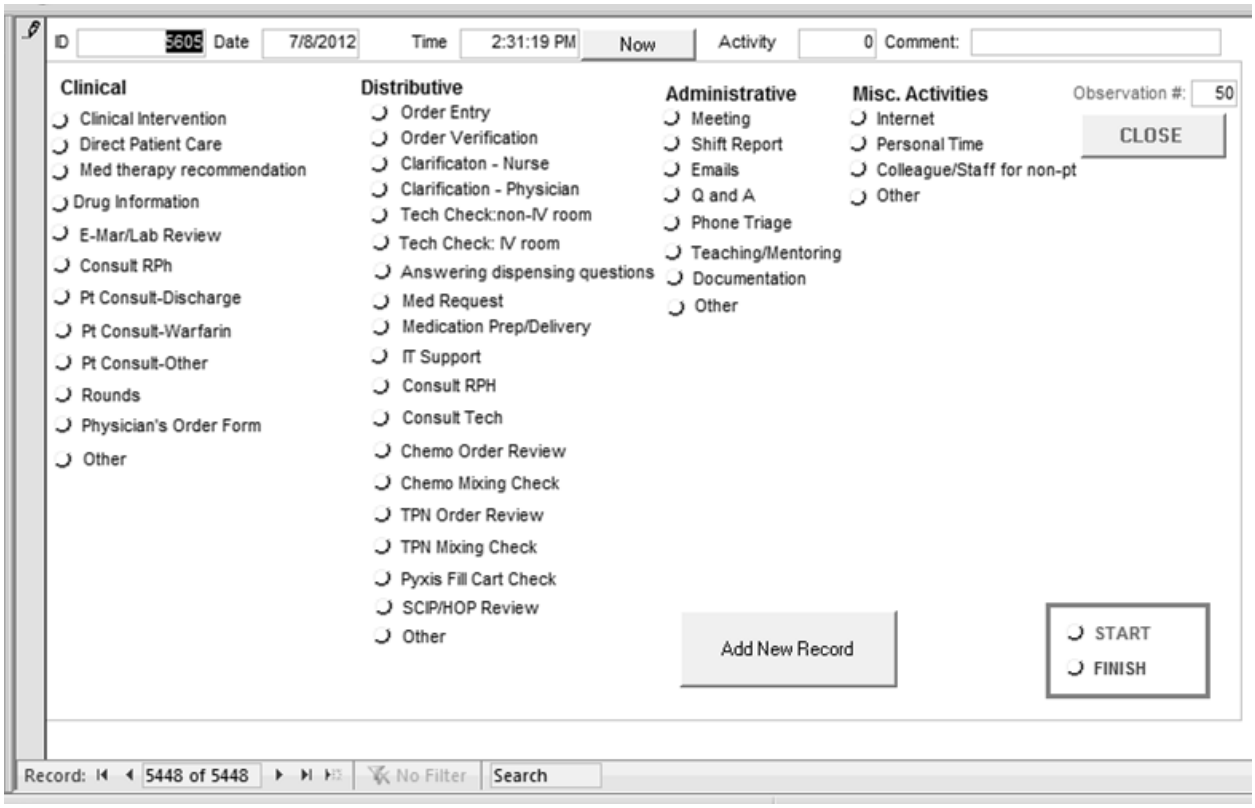

Figure 7. Screenshot of the Instrument

At the beginning of each day of observations, the data collection assistant would arrive approximately five to ten minutes early to prepare for the data collection. The data collection assistant turned the laptop on and the laptop time was synchronized with the pharmacy computer time (if necessary). Then the instrument was opened. The data collection assistant clicked the "Now" button to update the instrument time (based on the laptop time), followed by clicking on the "Start" button, and followed by clicking on the "Add New Record" button. By clicking on the "Add New Record" button, the original observation was added to the record (with its start time which was updated with the "Now" button) and the end time was defined as the start time of the new

observation, which was updated with the "Add New Record" button. This new observation was ready to have a task assigned, so the data collection assistant clicked on that task – "Order Entry", for example. An additional comment could be typed in the comment box at this time. As soon as a new task began, the "Add New Record" was clicked and the new task was selected.

A silent alarm on the data collection assistant's phone was set for the 59th minute of every hour of the daily observations to prompt the data collection assistant to complete that hour's observations in approximately one minute and begin the next hour's observations at the exact second of the start of the new hour.

At the end of a day of observations, the data collection assistant clicked the "Finish" button, then clicked the "Add New Record" button, then exported the database to a secure Excel® (Microsoft Corp., Redmond, WA) spreadsheet. The data collection assistant would then click the "Close" button in the instrument. The same database was used for the entirety of the study. Exporting the data to an Excel® spreadsheet daily served as a backup of the data and after the final export, the data was expanded to include the complete set of variables listed in the *Data Collection* section, prior to the statistical analysis, which was performed using SAS® version 9.3 (SAS Institute Inc., Cary, NC).

Pilot Study

Subsequent to the required permissions by the university and the hospital administration, a pilot study was conducted. The data collection assistant spent the first

day with a Memorial Hermann pharmacy Operations Manager who was an expert with both the Memorial Hermann pharmacy system and the instrument. This training was sufficient for the data collection assistant to become familiar with pharmacist workflow and the instrument. The final hour of the first day was spent having the expert validate the data collection assistant's data collection of an order entry pharmacist as a simulation of all subsequent data collection. This process allowed many of the order entry pharmacists to become familiar with the data collection assistant and the research being conducted. It also allowed for the data collection assistant to not only become more familiar with the data collection process and the order entry pharmacists, but to have the study's data collection process validity tested by an expert.

As a part of the pilot study, the data collection assistant visited each of the four pharmacies over multiple days. Observations were conducted and recorded at this time as a part of the pilot study. These observations were not included with the study observations.

Statistical Analysis

The measured variables used in the analysis are listed in *Table 8*. Analyses would be conducted separately for the activity and task dependent variables. The activity dependent variables will be analyzed using adjusted values (controlling for the independent variables and the covariates), since there is sufficient data to have sufficient non-zero values representing each of the four activities. The task dependent variables will not be adjusted, as there would be too many tasks with zero values. In

other words, not every hour had values for each of the 37 tasks. It is for this reason, that unadjusted means would be used for the task analysis.

Table 8. Measured Variables

Type of Variable	Measurement	Levels	Units or List
Dependent	4 Activities	1. Clinical	Mean minutes / hour
		2. Distributive	
		3. Administrative	
		4. Miscellaneous	
	37 Tasks	See *Tables 3-6*	Mean minutes / hour
Independent	CPOE status	2 levels	0 – non-CPOE
			1 – CPOE
Covariates	Hospital	4 sites	Intervention
			Control
			Treatment Control 1
			Treatment Control 2
	Time Period	2 levels	Time Period 1
			Time Period 2

The Access® database was exported to Excel® spreadsheet format, as previously described. The extrapolated and repeated variables previously described were entered into the spreadsheet. The final spreadsheet was imported into SAS® version 9.3 for the analysis. Refer to *Appendix C* for the codebook.

Descriptive statistics were determined and reported, regarding the hospitals, pharmacies, sample population, and general observation data. Summary statistics of each hour were calculated by activity and task. The data was then checked for normality with a comparison of the means and medians of the CPOE versus the non-CPOE activities.

If a normal distribution was found, a MANCOVA analysis would be performed using the variables in *Table 8* for the activity analysis. Post-hoc ANCOVAs would be calculated with Scheffe adjustments.

If a non-normal distribution was found, non-parametric regressions would be calculated. The predicted values would be saved and then tested for significance using Wilcoxon rank-sum tests (the *p*-value of the Wilcoxon 2-sided t-approximation was used).

Many of the tasks will be non-parametric, due to low representation of certain tasks. For this reason, all tasks were analyzed using Wilcoxon rank-sum tests.

In all tests, a *p*-value of less than 0.05 was considered statistically significant.

Statistical Hypothesis

The statistical hypothesis is as follows:

H_0 : Multivariate Test:

τ Non-$CPOE_i$ = τ $CPOE_i$ = 0

There is no statistically significant difference between the time spent by pharmacists across the four activities.

Where i is defined as: 1) Clinical Activity

2) Distributive Activity

3) Administrative Activity

4) Miscellaneous Activity

τ = Multivariate mean minutes / hour spent by pharmacists

Chapter 4

Results

Results of the data collection are presented in this chapter. Descriptive statistics results are followed by the statistical analysis, including tests for normality and correlation tests. Since the data would be found to be non-parametric, non-parametric linear regressions are presented, by activity and sub-activity (additionally, the distributive activity was analyzed by sub-activities to give insight into the activity where the majority of the pharmacist's time is spent). The predicted values of the activity and sub-activity analysis were analyzed. The chapter will end with the analysis of the individual tasks.

Descriptive Statistics

The data collection period spanned from April 2, 2012 to October 2, 2012. A total of 340 hours of observations were conducted, of which 311 hours met the inclusion criteria. A total of 114 hours were spent observing non-CPOE sites, while 197 hours were spent observing CPOE sites. Refer to *Table 9* for overall study statistics.

Table 9. Study Statistics

Description	Number of Hours (Number of Tasks)		
	Non-CPOE	CPOE	Total
Practice observations †	6 (169)	21 (835)	27 (1004)
Overall study observations	126 (3345)	214 (7454)	340 (10799)
Final study observations	114 (2972)	197 (6859)	311 (9831)

† Includes 1 hour of validation with an expert

The number of different pharmacists observed at each site ranged from 9 to 11, most were female (ranging from 55% to 82% at each pharmacy). The number of different types of order entry pharmacists ranged from 4 to 6. Refer to *Table 10* for pharmacist characteristics.

Table 10. Pharmacist Characteristics

Description	Site			
	Intervention	Control	Treatment Control 1	Treatment Control 2
Number of Pharmacists observed	10	11	11	9
Number of Female Pharmacists, (%)	6 (60%)	7 (55%)	9 (82%)	7 (78%)
Pharmacist Experience 0 – 1 year, n (%) 1 – 10 years, n (%) > 10 years, n (%)	 0 (0%) 8 (80%) 2 (20%)	 1 (9%) 5 (46%) 5 (46%)	 0 9 (82%) 2 (18%)	 1 (11%) 6 (67%) 2 (22%)
Types of Order Entry Pharmacists	5	6	4	5

A total of 9831 different tasks were recorded. The number of tasks per hour ranged from 5 to 62. The three non-CPOE sets of observations had the lowest means, with 27.1, 25.4, and 25.7 tasks per hour. Refer to *Table 11* for the tasks per hour summary and the number of hours recorded at each site by time period.

Table 11. Number of Tasks, Hours, and Tasks/Hour by Site and Time Period

Site	Time Period	CPOE †	No. of Tasks	No. of Hours	Tasks / Hour		
					Mean	Min.	Max.
Intervention	1	0	1002	37	27.1	5	44
	2	1	1304	42	31.0	10	47
Control	1	0	915	36	25.4	5	39
	2	0	1055	41	25.7	6	41
Treatment Control 1	1	1	1093	37	29.5	9	51
	2	1	1725	41	42.1	15	62
Treatment Control 2	1	1	1253	34	36.9	18	55
	2	1	1484	43	34.5	17	60
Totals			9831	311	31.6	5	62

† CPOE=1, non-CPOE=0.

Normality Test

A comparison between the means and medians, by activity, was performed to test the data for normality. The results of this comparison of the means and medians of the activities by hour are in *Table 12*.

Table 12. Test for Normality Comparing Means and Medians by Activity, in Minutes / Hour

Activity	CPOE †	Mean ± S.D., minutes/hr.	Median, minutes/hr.
Clinical	0	5.10 ± 6.09	2.65
	1	3.83 ± 4.37	2.48
Distributive	0	44.55 ± 10.31	46.30
	1	47.61 ± 8.44	49.28
Administrative	0	7.25 ± 8.17	4.77
	1	6.67 ± 7.17	4.50
Miscellaneous	0	3.11 ± 4.01	1.39
	1	1.89 ± 3.06	0

† CPOE=1, non-CPOE=0.

The test for normality resulted in the determination that the data was non-parametric. Only the means and the medians found in the distributive activity could be considered to have a normal distribution. None of the other comparisons between the means and the medians were close enough to be considered to have a normal distribution. This result rendered the MANCOVA and associated post-hoc comparisons to be not applicable to this data. Instead, non-parametric linear regressions and analysis were performed.

Correlation Tests

Prior to performing the non-parametric linear regression, the variables were first tested for correlation. First, the correlation between the dependent and independent variables was conducted. Refer to *Table* 13 for the results of this correlation test.

Table 13. Correlation test – Dependent versus Independent Variables

		Pearson Correlation Coefficient (*p*-value)			
		Dependent Variables			
		Activity – Clinical	Activity - Distributive	Activity - Administrative	Activity - Miscellaneous
Independent Variable	CPOE status	0.12 0.0344	0.15 0.0077	0.03 0.5843	0.15 0.0084
Covariates	Hospital	0.14 0.0131	0.02 0.7066	0.08 0.1743	0.09 0.1300
	Time Period	0.08 0.1334	0.09 0.1249	0.01 0.8096	0.13 0.0247

The Pearson correlation coefficients were all less than 0.15, which was acceptable.

Next, the correlation among the independent variables was conducted. Refer to *Table* 14 for the results of this correlation test.

Table 14. Correlation Test – Independent Variables

		Pearson Correlation Coefficient (*p*-value)		
		Independent Variable	Covariates	
		CPOE status	Hospital	Time Period
Independent Variable	CPOE status	1	0.56 <0.0001	0.02 0.7482
Covariates	Hospital	0.56 <0.0001	1	0.05 0.3185
	Time Period	0.02 0.7482	0.05 0.3185	1

None of the correlations between the dependent and the independent variables, nor any of the correlations amongst the independent variables were large enough to warrant further investigation. Therefore, there was no issue with multicollinearity and the regression could proceed.

Non-Parametric Linear Regression by Activity

The general linear regression model was:

$$ACTIVITY = \beta_0 + \beta_1 (CPOE\_STATUS) + \beta_2 (HOSPITAL) + \beta_3 (TIME\_PERIOD)$$

where:	*ACTIVITY* =	Time spent (in minutes per hour) for clinical, distributive, administrative, or miscellaneous activities
	CPOE_STATUS =	Either CPOE or non-CPOE (CPOE was the base)
	HOSPITAL =	Intervention, control, treatment control 1, or treatment control 2 site (Dummy variables were created to capture each parameter) (the intervention site was the base)
	TIME_PERIOD =	Time Period 1 or Time Period 2 (Time Period 1 was the base)

The results of the non-parametric regressions for the four activities are as follows. Refer to *Table 15* for the results of the clinical activity non-parametric regression.

Table 15. Non-Parametric Regression – Clinical Activity

Parameter (Clinical Activity)	Parameter Estimate	Standard Error	*t*-value	*p*-value
Intercept	0.30770	0.97292	0.32	0.7520
non-CPOE	1.69996	1.25220	1.36	0.1756
Control site	3.75151	1.01646	3.69	0.0003
Treatment Control 1 site	2.67080	0.96541	2.77	0.0060
Treatment Control 2 site	3.77854	0.96118	3.93	0.0001
Time Period 1	1.54945	0.63178	2.45	0.0147

Holding all other variables in the model constant, a CPOE site had approximately 1.7 minutes/hour less time in the clinical activity than a non-CPOE site. This result was not statistically significant.

Refer to *Table 16* for the results of the distributive activity non-parametric regression.

Table 16. Non-Parametric Regression – Distributive Activity

Parameter (Distributive Activity)	Parameter Estimate	Standard Error	*t*-value	*p*-value
Intercept	51.65846	1.85350	27.87	<0.0001
non-CPOE	-6.41251	2.38554	-2.69	0.0076
Control site	0.19619	1.93644	0.10	0.9194
Treatment Control 1 site	-3.76451	1.83920	-2.05	0.0415
Treatment Control 2 site	-2.76756	1.83113	-1.51	0.1317
Time Period 1	-2.31084	1.20359	-1.92	0.0558

Holding all other variables in the model constant, a CPOE site had approximately 6.4 minutes/hour more time in the distributive activity than a non-CPOE site. This result was statistically significant.

Refer to *Table 17* for the results of the administrative activity non-parametric regression.

Table 17. Non-Parametric Regression – Administrative Activity

Parameter (Administrative Activity)	Parameter Estimate	Standard Error	*t*-value	*p*-value
Intercept	6.18503	1.50110	4.12	<0.0001
non-CPOE	4.43028	1.93198	2.29	0.0225
Control site	-4.90528	1.56827	-3.13	0.0019
Treatment Control 1 site	2.10736	1.48951	1.41	0.1581
Treatment Control 2 site	-0.65404	1.48298	-0.44	0.6595
Time Period 1	-0.14852	0.97475	-0.15	0.8790

Holding all other variables in the model constant, a CPOE site had approximately 4.4 minutes/hour less time in the administrative activity than a non-CPOE site. This result was statistically significant.

Refer to *Table 18* for the results of the miscellaneous activity non-parametric regression.

Table 18. Non-parametric Regression –Miscellaneous Activity

Parameter (Miscellaneous Activity)	Parameter Estimate	Standard Error	*t*-value	*p*-value
Intercept	1.84882	0.68681	2.69	0.0075
non-CPOE	0.28226	0.88396	0.32	0.7497
Control site	0.95758	0.71755	1.33	0.1830
Treatment Control 1 site	-1.01364	0.68151	-1.49	0.1380
Treatment Control 2 site	-0.35695	0.67852	-0.53	0.5992
Time Period 1	0.90991	0.44599	2.04	0.0422

Holding all other variables in the model constant, a CPOE site had approximately 0.3 minutes/hour less time in the miscellaneous activity than a non-CPOE site. This result was not statistically significant.

Non-Parametric Linear Regression by Sub-Activity

The distributive activity was where the majority of the order entry pharmacist's time was spent (approximately ¾ of the observed time). To further explore this activity, it was divided into three sub-activities, and then non-parametric linear regressions were performed for each sub-activity. Order entry was the first sub-activity. It consisted of all tasks associated with non-CPOE: order entry, chemo mixing review, and TPN mixing review. The second sub-activity was order verification. It consisted of the only task associated with CPOE: order verification. The third sub-activity was other. It consisted of all the other tasks comprising the distributive activity.

Refer to *Table 19* for the results of the non-parametric regression for the order entry sub-activity.

Table 19. Non-Parametric Regression – Order Entry (Distributive Sub-Activity)

Parameter (Order Entry sub-activity)	Parameter Estimate	Standard Error	*t*-value	*p*-value
Intercept	16.37980	2.10876	7.77	<0.001
non-CPOE	5.34047	2.71407	1.97	0.0500
Control site	9.46584	2.20312	4.30	<0.0001
Treatment Control 1 site	-4.44714	2.09248	-2.13	0.0344
Treatment Control 2 site	2.97829	2.08330	1.43	0.1539
Time Period 1	-3.07107	1.36934	-2.24	0.0256

Holding all other variables in the model constant, a CPOE site had approximately 5.3 minutes/hour less time in the order entry sub-activity than a non-CPOE site. This result was not statistically significant.

Refer to *Table 20* for the results of the non-parametric regression for the order verification sub-activity.

Table 20. Non-Parametric Regression – Order Verification (Distributive Sub-Activity)

Parameter (Order Verification sub-activity)	Parameter Estimate	Standard Error	*t*-value	*p*-value
Intercept	18.38122	1.56065	11.78	<0.0001
non-CPOE	-11.71726	2.00863	-5.83	<0.0001
Control site	-6.38030	1.63048	-3.91	0.0001
Treatment Control 1 site	-2.40205	1.54861	-1.55	0.1219
Treatment Control 2 site	-5.05940	1.54181	-3.28	0.0012
Time Period 1	1.14735	1.01342	1.13	0.2585

Holding all other variables in the model constant, a CPOE site had approximately 11.7 minutes/hour more time in the order verification sub-activity than a non-CPOE site. This result was statistically significant.

Refer to *Table 21* for the results of the non-parametric regression for the other sub-activity.

Table 21. Non-Parametric Regression – Other (Distributive Sub-Activity)

Parameter (Other sub-activity)	Parameter Estimate	Standard Error	*t*-value	*p*-value
Intercept	16.89743	1.77851	9.50	<0.0001
non-CPOE	-0.03572	2.28902	-0.02	0.9876
Control site	-2.88935	1.85809	-1.56	0.1210
Treatment Control 1 site	3.08468	1.76479	1.75	0.0815
Treatment Control 2 site	-0.68645	1.75704	-0.39	0.6963
Time Period 1	-0.38711	1.15489	-0.34	0.7377

Holding all other variables in the model constant, a CPOE site had approximately 0.04 minutes/hour more time in the other sub-activity than a non-CPOE site. This result was not statistically significant.

Activity and Sub-Activity Analysis

The predicted values from all the above regressions were saved and compared by using the Wilcoxon rank-sum test, along with the original unadjusted means. The results of these tests are shown below.

Refer to *Table 22* for the results of the Wilcoxon rank-sum tests across the activities, comparing non-CPOE and CPOE.

Table 22. Average Time (Minutes) Spent by Pharmacists per Hour, by Activity

Activity	CPOE †	Unadjusted Mean ± S.D. (Unadjusted Median), minutes/hour	*p*-value ‡ based on Unadjusted Values	Predicted Mean ± S.D. (Predicted Median), minutes/hour	*p*-value ‡ based on Predicted Values
Clinical	0	5.10 ± 6.09 (2.65)	0.3163	5.10 ± 2.24 (5.76)	<0.0001
	1	3.83 ± 4.37 (2.48)		3.83 ± 1.34 (4.08)	
Distributive	0	44.55 ± 10.31 (46.30)	0.0127	44.55 ± 1.07 (45.25)	<0.0001
	1	47.61 ± 8.44 (49.28)		47.61 ± 1.43 (47.89)	
Administrative	0	7.25 ± 8.17 (4.77)	0.5850	7.25 ± 2.34 (5.71)	0.0091
	1	6.67 ± 7.17 (4.50)		6.67 ± 1.28 (6.04)	
Miscellaneous	0	3.11 ± 4.01 (1.39)	0.0095	3.11 ± 0.77 (3.09)	<0.0001
	1	1.89 ± 3.06 (0)		1.89 ± 0.68 (1.75)	

† CPOE=1, Non-CPOE=0
‡ Wilcoxon Rank-Sum Test

With the comparison of the analysis of the unadjusted means and medians side by side the predicted means and medians, the *p*-values all became either statistically significant or more statistically significant with the predicted values versus the unadjusted values. After CPOE implementation, less time was spent in the clinical, administrative, and miscellaneous activities, while more time was spent in the distributive activity.

Refer to *Table 23* for the results of the Wilcoxon rank-sum tests across the distributive sub-activities, comparing non-CPOE and CPOE.

Table 23. Average Time (Minutes) Spent by Pharmacists per Hour, by Distributive Sub-Activity

Distributive Sub-Activity	CPOE †	Unadjusted Mean ± S.D. (Unadjusted Median), minutes/hour	*p*-value ‡ based on Unadjusted Values	Predicted Mean ± S.D. (Predicted Median), minutes/hour	*p*-value ‡ based on Predicted Values
Order Entry	0	27.01 ± 12.30 (26.48)	<0.0001	27.01 ± 3.89 (28.12)	<0.0001
	1	13.82 ± 10.11 (11.63)		13.82 ± 3.54 (13.31)	
Order Verification	0	2.77 ± 4.30 (0.54)	<0.0001	2.77 ± 2.75 (1.43)	<0.0001
	1	16.19 ± 9.51 (15.32)		16.19 ± 2.16 (15.98)	
Other	0	14.77 ± 9.60 (11.70)	0.0012	14.77 ± 1.46 (13.97)	<0.0001
	1	17.60 ± 8.42 (16.90)		17.60 ± 1.78 (16.51)	

† CPOE=1, Non-CPOE=0
‡ Wilcoxon Rank-Sum Test

With the comparison of the analysis of the unadjusted means and medians next to the predicted means and medians, the *p*-values all became more statistically significant with the predicted values versus the unadjusted values. After CPOE implementation, less time was spent in the order entry sub-activity, while more time was spent in the order verification and other sub-activities.

Task Analysis

The analysis for each individual task was performed using the Wilcoxon rank-sum test, designed for non-parametric data.

Refer to *Table 24* for the results of the clinical activity task analysis.

Table 24. Average Time (Minutes) Spent by Pharmacists per Hour - Clinical Tasks

Task	Non-CPOE		CPOE		*p*-value †
	Mean ± S.D., minutes/hr (hours)	No. of Tasks (task/hr)	Mean ± S.D., minutes/hr (hours)	No. of Tasks (task/hr)	
Clinical Intervention	0.47 ± 1.28 (114)	38 (0.33)	0.18 ± 0.88 (197)	33 (0.17)	0.0058
Direct Patient Care	-	-	-	-	-
Drug Information	1.01 ± 2.30 (114)	63 (0.55)	1.37 ± 2.00 (197)	241 (1.22)	0.0021
E-Mar / Lab Review	1.17 ± 1.84 (114)	119 (1.04)	1.46 ± 2.03 (197)	298 (1.51)	0.0696
Consult RPh – Clinical	0.03 ± 0.32 (114)	1 (0.01)	0.03 ± 0.35 (197)	3 (0.02)	0.9086
Pt. Consult – Discharge	0.31 ± 2.43 (114)	3 (0.03)	-	-	0.0640
Pt. Consult – Warfarin	0.09 ± 0.94 (114)	1 (0.01)	-	-	0.1915
Rounds	-	-	0.06 ± 0.59 (197)	2 (0.01)	0.2845
Physician's Order Form	0.27 ± 0.82 (114)	18 (0.16)	0.30 ± 1.22 (197)	28 (0.14)	0.3546
Other – Clinical	1.76 ± 3.89 (114)	79 (0.69)	0.43 ± 2.04 (197)	43 (0.22)	<0.0001

† Wilcoxon Rank-Sum test.

The results of the clinical activity task analysis revealed three of the ten tasks to be statistically significant. The tasks which were statistically significantly different were: clinical intervention (approximately 0.3 minutes/hour less for CPOE versus non-CPOE sites); drug information (approximately 0.4 minutes/hour more for CPOE versus non-CPOE sites); and other-clinical (approximately 1.3 minutes/hour less for CPOE versus non-CPOE sites).

Refer to *Table 25* for the results of the distributive activity task analysis.

Table 25. Average Time (Minutes) Spent by Pharmacists per Hour - Distributive Tasks

Task	Non-CPOE		CPOE		*p*-value †
	Mean ± S.D., minutes/hr (hours)	No. of Tasks (task/hr)	Mean ± S.D., minutes/hr (hours)	No. of Tasks (task/hr)	
Order Entry	25.74 ± 12.49 (114)	906 (7.95)	10.76 ± 8.25 (197)	1035 (5.25)	<0.0001
Order Verification	2.77 ± 4.30 (114)	200 (1.75)	16.19 ± 9.51 (197)	1528 (7.76)	<0.0001
Clarification – Nurse	2.83 ± 2.66 (114)	290 (2.54)	3.72 ± 3.39 (197)	708 (3.59)	0.0167
Clarificat-Physician	0.07 ± 0.34 (114)	7 (0.06)	0.07 ± 0.36 (197)	15 (0.08)	0.7659
Tech Chk: Non-IV Rm	2.35 ± 3.13 (114)	205 (1.80)	3.18 ± 3.24 (197)	670 (3.40)	0.0001
Tech Check: IV Room	2.06 ± 5.43 (114)	54 (0.47)	0.96 ± 3.05 (197)	42 (0.21)	0.0007
Med. Prep / Deliv	0.20 ± 1.02 (114)	12 (0.11)	0.16 ± 0.42 (197)	55 (0.28)	0.0262
IT Support	0.12 ± 0.99 (114)	3 (0.03)	0.09 ± 0.70 (197)	6 (0.03)	0.8726
Consult RPh – Distrib	2.94 ± 4.30 (114)	192 (1.68)	2.75 ± 3.09 (197)	441 (2.24)	0.4452
Consult Tech	2.01 ± 3.07 (114)	179 (1.57)	1.91 ± 2.02 (197)	436 (2.21)	0.0426
Chemo Order Review	0.35 ± 1.39 (114)	13 (0.11)	0.13 ± 1.01 (197)	10 (0.05)	0.0276
Chemo Mixing Chk	0.07 ± 0.46 (114)	3 (0.03)	0.09 ± 0.73 (197)	4 (0.02)	0.5073
TPN Order Review	0.92 ± 2.63 (114)	33 (0.29)	2.93 ± 7.06 (197)	187 (0.95)	0.0198
TPN Mixing Check	0.49 ± 1.79 (114)	9 (0.08)	0.48 ± 3.23 (197)	11 (0.06)	0.3110
Pyxis Fill Cart Check	0.83 ± 3.03 (114)	20 (0.18)	1.78 ± 3.44 (197)	108 (0.55)	<0.0001
SCIP / HOP Review	-	-	0.73 ± 3.82 (197)	38 (0.19)	0.0020
Other – Distributive	0.82 ± 2.50 (114)	45 (0.39)	1.67 ± 3.36 (197)	142 (0.72)	0.0012

† Wilcoxon Rank-Sum test.

The results of the distributive activity task analysis revealed twelve of the seventeen tasks to be statistically significant. Some of the tasks which were statistically significantly different were: order entry (approximately 15.0 minutes/hour less for CPOE versus non-CPOE sites); order verification (approximately 13.4 minutes/hour more for CPOE versus non-CPOE sites); clarification-nurse (approximately 0.9 minutes/hour

more for CPOE versus non-CPOE sites); tech check-non IV room (approximately 0.8 minutes/hour more for CPOE versus non-CPOE sites); pyxis fill cart check (approximately 1.0 minutes/hour more for CPOE versus non-CPOE sites); and other-distributive (approximately 0.9 minutes/hour more for CPOE versus non-CPOE sites).

Other findings were as follows. On average: fewer order entry tasks were conducted by the CPOE versus the non-CPOE sites (5.25 tasks/hour versus 7.95 tasks/hour); more than four times the number of order verification tasks were conducted by the CPOE versus the non-CPOE sites (7.76 tasks/hour versus 1.75 tasks/hour); and more than three times the number of TPN order reviews were conducted by the CPOE versus the non-CPOE sites (0.95 tasks/hour versus 0.29 tasks/hour).

Refer to *Table 26* for the results of the administrative activity task analysis.

Table 26. Average Time (Minutes) Spent by Pharmacists per Hour - Administrative Tasks

Task	Non-CPOE		CPOE		*p*-value †
	Mean ± S.D., minutes/hr (hours)	No. of Tasks (task/hr)	Mean ± S.D., minutes/hr (hours)	No. of Tasks (task/hr)	
Meeting	0.07 ± 0.57 (114)	2 (0.02)	0.09 ± 0.58 (197)	5 (0.03)	0.6574
Huddle	0.17 ± 1.27 (114)	2 (0.02)	0.56 ± 2.91 (197)	14 (0.07)	0.1917
Shift Report	0.39 ± 1.58 (114)	13 (0.11)	0.32 ± 1.52 (197)	28 (0.14)	0.8756
Schedule	0.01 ± 0.15 (114)	1 (0.01)	0.15 ± 0.82 (197)	15 (0.08)	0.1062
Emails	3.17 ± 4.84 (114)	156 (1.37)	1.82 ± 2.58 (197)	231 (1.17)	0.1728
Q and A	1.30 ± 3.03 (114)	57 (0.50)	1.02 ± 2.99 (197)	72 (0.37)	0.7517
Teaching / Mentoring	0.40 ± 1.45 (114)	29 (0.25)	0.66 ± 2.67 (197)	52 (0.26)	0.9394
Documentation	1.09 ± 2.26 (114)	73 (0.64)	0.81 ± 1.89 (197)	149 (0.76)	0.5930
Other – Admin	0.65 ± 3.20 (114)	32 (0.28)	1.23 ± 2.93 (197)	102 (0.52)	0.0047

† Wilcoxon Rank-Sum test.

The results of the administrative activity task analysis revealed one of the nine tasks to be statistically significant. That task was: other-administrative (approximately 0.6 minutes/hour more for CPOE versus non-CPOE sites). On average, the other-administrative task was conducted almost twice as often for the CPOE versus the non-CPOE sites (0.52 tasks/hour versus 0.28 tasks/hour).

Refer to *Table 27* for the results of the miscellaneous activity task analysis.

Table 27. Average Time (Minutes) Spent by Pharmacists per Hour - Miscellaneous Tasks

Task	Non-CPOE		CPOE		*p*-value †
	Mean ± S.D., minutes/hr (hours)	No. of Tasks (task/hr)	Mean ± S.D., minutes/hr (hours)	No. of Tasks (task/hr)	
Personal Time	3.11 ± 4.01 (114)	114 (1.00)	1.89 ± 3.06 (197)	107 (0.54)	0.0114

† Wilcoxon Rank-Sum test.

The result of the miscellaneous activity task analysis revealed the personal time task to be statistically significant (approximately 1.2 minutes/hour more for CPOE versus non-CPOE sites). On average, the personal time task was conducted approximately half as often for the CPOE versus the non-CPOE sites (0.54 tasks/hour versus 1.00 tasks/hour).

Chapter 5

Discussion and Conclusion

This chapter will explore the results in further detail with a discussion and possible implications as to the reasons for certain findings. This will be followed by some recommendations for future studies. The limitations and strengths of the study will be outlined before the final conclusion.

Discussion

Twenty-nine hours could not be used for the study due to any number of reasons (see *Table 9*). The most common reason was the unanticipated absence of the order entry pharmacist being observed, typically for the lunch break. This resulted in the loss of many hours, though the original criteria of using only hours which had 75% of value-added work remained intact. This allowed for more robust analysis of the actual workflow of the order entry pharmacist, rather than an account which included more personal time.

To a great extent, the pharmacist characteristics were quite comparable across all four sites (refer to *Table 10*). The number of pharmacists, the number of female pharmacists, and the types of order entry pharmacists were very similar. The only apparent difference was in the experience of the pharmacists where the mix at the control site had a greater number of pharmacists with over 10 years of pharmacist experience.

The number of different tasks performed per hour varied greatly (refer to *Table 11*). As a general rule, the fewer number of tasks that a person has to perform in any given hour, the more productive that person can be. While not always the case, the fewer number of tasks performed in any given hour can be thought of as the individual having fewer interruptions, either external or internal. Fewer interruptions usually translates to greater productivity.

Each pharmacy observed operated in a different and unique way, depending on the pharmacy management's discretion, the daily assignments of the pharmacists, the unique needs of the hospital, the volume of medications processed by each pharmacy, the mix of individuals in the pharmacy (for example: pharmacists, pharmacy technicians, management, and volunteers), individual work ethic, physical layout of the pharmacy, and similar factors.

It was interesting to observe the lowest means of tasks performed in each hour were during the three sets of observations where CPOE had not been implemented. Further study of these results should be performed.

All of the individual activities had relatively low (<0.15) correlations with the independent variable and the covariates (refer to *Table 13*). Similarly, none of the independent variables were correlated any more that 0.56 (between the CPOE status and the Hospital, which was anticipated, since only the intervention site changed CPOE status during the study and all others CPOE status remained constant) (refer to *Table 14*). The other two correlations were very low: 0.02 and 0.05, though they were not

statistically significant. These results were a positive indication that the correct variables were chosen to predict the dependent variables.

In reviewing the results of the non-parametric linear regression models found in *Tables 15-21*, the results showed that each of the independent variables was statistically significant for both the regressions by activity and the distributive sub-activities. While none of the models had 100% of the parameters statistically significant, five of the seven models had 50% or more of their parameters considered to be statistically significant. Indeed, comparing the predicted means and medians with the unadjusted means and medians, one can see that the non-parametric regressions were very well representative of the data (refer to *Table 22*).

Holding all other variables in the model fixed, the implementation of CPOE resulted in approximately 1.7 minutes/hour less of clinical work than that of a non-CPOE site. This was not statistically significant (refer to *Table 15*). Unfortunately, this was not the result that was hoped for. Instead of freeing up more pharmacist time for clinical work, less time was spent in this activity.

From *Table 16*, the CPOE sites had approximately 6.4 minutes/hour more time spent in the distributive activity than those which had not implemented CPOE, holding all other variables in the model fixed. This was statistically significant. This is a relative large amount of time difference between CPOE and non-CPOE (approximately 10% of each hour). One can suspect that if the CPOE sites had less time spent in this activity, more time could be freed for additional clinical work.

From *Table 17*, the CPOE sites had approximately 4.4 minutes/hour less time spent in the administrative activity than those which had not implemented CPOE, holding all other variables in the model fixed. This was statistically significant.

From *Table 18*, the CPOE sites had approximately 0.3 minutes/hour less time spent in the miscellaneous activity than those which had not implemented CPOE, holding all other variables in the model fixed. This was not statistically significant.

It should be noted that these results are not seemingly consistent with the Cox study in 2011 (Cox 2011). In that study, two different sites were observed, one had implemented CPOE and the other was non-CPOE. The statistically significant findings included greater amount of time spent in the clinical and administrative activities, and a lesser amount of time in the distributive activity for the CPOE versus the non-CPOE site. The miscellaneous activity had a lesser amount of time for the CPOE versus the non-CPOE site, though this finding was not statistically significant. These findings did not take into account the other variables which were controlled for in this study. Also, since the sites were different, it is difficult to determine the extent to which the organizational structure and other factors in each pharmacy played a role in these results.

The Cox study, however, did include data regarding the number of order actions and order verifications performed for the hours observed. There was a greater number (approximately 1.7 times) of order actions performed by the CPOE site versus the non-CPOE site. There was a greater number (approximately 1.4 times) of order verifications (completed orders) performed by the CPOE site versus the non-CPOE site. Both of these

findings were statistically significant. While the number of order actions and order verifications for this study's sample were not available at the time of this publication, one would expect similar findings in terms of productivity for this study's CPOE versus non-CPOE sites. A subsequent study which includes this data will be performed in the future.

In reviewing the results of the breakdown of the distributive activity, the CPOE sites had approximately 5.3 minutes/hour less time spent in the order entry sub-activity than those which had not implemented CPOE, holding all other variables in the model fixed (refer to *Table 19*). Even though this was not statistically significant, the finding is logical. Fewer orders would be processed by order entry after CPOE was implemented, resulting in less time required for this task.

Similarly, the results in *Table 20* agree with this same logic. Holding all other factors in the model fixed, the CPOE sites had approximately 11.7 minutes/hour more time in the order verification sub-activity. This finding was statistically significant.

While there was approximately 5.3 fewer minutes/hour spent in the order entry sub-activity, it was more than offset by the approximately 11.7 additional minutes/hour spent in the order verification sub-activity. That translates to a net increase in the distributive activity of approximately 6.4 additional minutes/hour due to order verification alone. The amount of order actions and order verifications would need to be analyzed for these study hours to investigate if the additional time spent in the distributive category is proportional to the number of orders actually completed by the pharmacists.

The results in *Table 21* show that there is an almost imperceptible increase (approximately 0.04 minutes/hour) in the amount of time spent at the CPOE sites versus non-CPOE sites for the other sub-activity. This finding was not statistically significant. The fact that it was not statistically significant, coupled with the small difference in this other sub-activity, means that the increased time spent by the CPOE sites in the distributive activity was due solely to the net difference in time spent by pharmacists performing order verifications (CPOE) over order entry (non-CPOE) tasks. This means that after the implementation of CPOE, more time was spent in the distributive activity due to the increased time spent on CPOE orders than non-CPOE orders.

Assuming that more orders can be processed in a shorter amount of time with the implementation of CPOE, more time should be spent on the other sub-activity tasks, due to the greater volume. However, virtually the same amount of time was spent on these other tasks, holding all other factors in the model fixed. This lack of increase should be investigated further.

With the analysis of the unadjusted means and medians side by side the predicted means and medians (refer to *Tables 22-23*), the *p*-values all became either statistically significant or more statistically significant. After CPOE implementation, less time was spent in the clinical, administrative, and miscellaneous activities, while more time was spent in the distributive activity. After CPOE implementation, less time was spent in the order entry sub-activity, while more time was spent in the order verification and other sub-activities. It should be noted that the difference found here in the predicted values of the other sub-activity shows a difference, while the results of the

non-parametric linear regression did not. This is due to the different number of hours spent at the different sites, each with different independent variables.

In *Tables 24-27*, the number of tasks which were significant for each activity were as follows: 3 – clinical (3%); 12 – distributive (70%); 1 – administrative (11%); and 1 – miscellaneous (100%). In total, 17 of the 37 (46%) were found to be statistically significantly different. Highlights of tasks of statistical significance include: clinical intervention (non-CPOE > CPOE by approximately 0.3 minutes/hour); drug information (CPOE > non-CPOE by approximately 0.4 minutes/hour); other-clinical (non-CPOE > CPOE by approximately 1.3 minutes/hour); clarification-nurse (CPOE > non-CPOE by approximately 0.9 minutes/hour); tech check – non-IV room (CPOE > non-CPOE by approximately 0.8 minutes/hour); other-administration (CPOE > non-CPOE by approximately 0.6 minutes/hour); and personal time (non-CPOE > CPOE by approximately 1.22 minutes/hour).

Of particular interest was the greater amount of time spent by non-CPOE versus CPOE in the tasks of clinical intervention and other-clinical. The CPOE sites, however, had more time spent in drug intervention and e-MAR/lab review, as well as a greater quantity of these tasks per hour than the non-CPOE sites (1.22 tasks/hour versus 0.55 tasks/hour and 1.51 tasks/hour versus 1.04 tasks/hour, respectively). If one of the goals post-CPOE implementation was to increase the amount of clinical work in terms of time, this was not found to be the case. It appears that CPOE actually decreased the amount of time spent by order entry pharmacists in clinical work. It is also possible that this

could to be a case of differences in emphasis by individual pharmacy management. The true cause is beyond the scope of this study, but worthy of investigation.

Implications

The implementation of CPOE can certainly have a positive influence regarding patient safety. However, management needs to remain vigilant for unintended consequences after its implementation. Just because a system has become automated or more computerized does not necessarily mean that all outcomes will be improved.

There are many factors which influence outcomes regarding the implementation of CPOE in a hospital pharmacy setting. One is the software itself. Different software packages will render different results in different settings. Proper research into which type of software package will be the most advantageous for a particular setting needs to be performed by hospital and pharmacy management prior to making any decision.

A corollary to this recommendation is the proper vetting and customization of order sets by the physicians, nurses, and the pharmacists. An order set which requires even slight modifications every time it is used, will affect the workflow and productivity of the pharmacist in having to alter it at each occurrence. Likewise, if a physician is consistently sending an order which needs to be modified, not only will pharmacist productivity suffer, but there may be possible consequences to the patient if the modification is missed.

The organizational structure of the pharmacy has a tremendous influence on pharmacist productivity. Such policies as “Tech-Check-Tech”, where pharmacy

technicians are allowed to check each other on Pyxis fills, for instance, can alleviate the workload of the pharmacist. Also, a pharmacy which has a "buffer"system, wherein one pharmacist is the lead person charged with: interacting with the nursing or physicians regarding incoming calls; performing technician checks on first doses; and fielding pharmacy technician issues; can alleviate interruptions to other order entry pharmacists. This could make these other order entry pharmacists more productive. Separating the hospital by floor or department can also help to increase familiarity of the pharmacist with that aspect of the hospital and therefore improve productivity for the pharmacist.

Prior to implementation of any technological intervention, metrics need to be put in place to assess the progress of such implementation efforts. In terms of productivity of CPOE implementation regarding the pharmacists, such metrics can be: time spent per activity and the number of order actions and order verifications performed in a certain time.

It needs to be understood that productivity, while a worthy goal, is obviously no tradeoff for performing all aspects of pharmacist duties well. Management needs to be diligent in making any changes in the pharmacy setting. The implementation of a CPOE system is no exception. Unintended consequences need to be anticipated as much as possible. Management needs to constantly monitor and verify proper and successful implementation of these systems in order to assure successful outcomes for the future.

Recommendations for Future Study

Many studies act as a catalyst for future studies. This study is no different. Following are some recommendations for further research.

Additional time and motion studies regarding the workflow of order entry pharmacists in both in these pharmacies and in different settings are recommended. Additional data may help to give insight as to the extent that certain variables determine workflow.

The effect of the number of tasks performed by the order entry pharmacist per hour on workflow and productivity are still largely unknown. It was interesting to observe the lowest means of tasks performed per hour were during the three sets of observations where CPOE had not been implemented. Further investigation into these results should be performed.

While the number of order actions and order verifications for this study's sample were not available at the time of this publication, one would expect similar findings to the Cox study in terms of productivity. A subsequent analysis which includes this data should be performed in the future.

It appears that CPOE actually decreased the amount of time spent by order entry pharmacists in clinical work. It is also possible that this could to be a case of differences in emphasis by individual pharmacy management. The true cause is beyond the scope of this study, but worthy of investigation.

Limitations

While every effort was given to minimize the limitations of this study, there are some which exist. This study's limitations include:

- The generalizability of this study is limited to the hospital system, the study sites, and the CPOE system implemented. While it is not unreasonable to extrapolate general trends found in this study, caution should be used before doing so;
- The observations were limited to the hours of 7:00 am to 5:00 pm during weekdays, so the findings may or may not represent any other times;
- The Hawthorne effect, though minimized as much as possible;
- Possible observer bias, as with any time and motion study;
- The temporary unavailability of productivity measures, such as the number of order entries and order verifications per pharmacist per hour;
- Unable to account for different hospital order severity; and
- Not an entirely random selection process, since other considerations were taken into account, as previously listed.

Strengths

The strengths of this study are substantial. They include:

- A relatively large sample size;
- The study design: an Enhanced Pretest-Posttest Control Group design, including controls for the control and controls for the treatment;
- Use of a single observer, therefore limiting any possible observer bias to be at least consistent.

Conclusion

The implementation of computerized provider order entry (CPOE) affected pharmacist workflow across every activity: clinical, distributive, administrative, and miscellaneous. Less time was spent in the clinical, administrative, and miscellaneous activities, while more time was spent in the distributive activity after CPOE implementation.

Chapter 6

Summary

Technological interventions have, and will continue to, affect the hospital pharmacy. Computerized provider order entry (CPOE) has the promise to deliver improved outcomes for patients, while at the same time affecting the workflow of the order entry pharmacist.

CPOE is the electronic entry of orders by an authorized provider. These orders were traditionally handwritten and communicated to the pharmacy by one of many methods (scanning is the current method) for processing and dispensing. However, with a CPOE system, a provider will directly enter the orders into the computer. These orders are typically available to the pharmacist for verification immediately upon completion by the provider.

The objective of this research was to perform a time and motion study to quantify the amount of time which an inpatient order entry pharmacist spends on various activities in a non-CPOE versus a CPOE setting.

The study design was an experimental, enhanced pretest-posttest, prospective, time and motion study. Order entry pharmacists from four inpatient pharmacies were observed over two separate time periods. All four pharmacies were within the Memorial Hermann Healthcare System, located in the Houston, Texas area. The intervention pharmacy was observed first as a non-CPOE pharmacy and then later, after CPOE had been implemented. The control pharmacy was non-CPOE for both time

periods. There were two treatment control pharmacies, both of which had previously implemented CPOE for both time periods.

A Microsoft Access® database was used as the recording instrument. It was originally designed to capture time and motion observations. It was modified to record the tasks of interest in this study.

In an effort to quantify the differences in workflow between CPOE and non-CPOE pharmacies, comparisons of the amount of time spent by the order entry pharmacist in each of four different activities (comprised of the 37 tasks): clinical, distributive, administrative, and miscellaneous; were conducted.

The order entry activity was where the majority (approximately ¾) of the pharmacist time was spent. This activity was divided into three sub-activities: order entry; order verification; and other - for further analysis.

The data was tested for normality and found to be not normally distributed. Therefore, non-parametric tests would be used in the analysis. Non-parametric linear regressions were performed for the activities and the sub-activities. Predicted means were generated from these regressions and analyzed using Wilcoxon rank-sum tests.

Analysis of individual tasks was performed using Wilcoxon rank-sum tests.

All descriptive and statistical analysis was performed using SAS® version 9.3. Statistical significance was set at 0.05.

A total of 340 hours of observation were conducted, of which 311 hours met the inclusion criteria. A total of 9831 tasks were recorded and 42 order entry pharmacists were observed.

The non-parametric linear regression results for the activities were as follows.

Holding all other variables in the model constant, a CPOE site had approximately 1.7 minutes/hour less time in the clinical activity than a non-CPOE site. This result was not statistically significant.

Holding all other variables in the model constant, a CPOE site had approximately 6.4 minutes/hour more time in the distributive activity than a non-CPOE site. This result was statistically significant.

Holding all other variables in the model constant, a CPOE site had approximately 4.4 minutes/hour less time in the administrative activity than a non-CPOE site. This result was statistically significant.

Holding all other variables in the model constant, a CPOE site had approximately 0.3 minutes/hour less time in the miscellaneous activity than a non-CPOE site. This result was not statistically significant.

The non-parametric linear regression results for the sub-activities were as follows.

Holding all other variables in the model constant, a CPOE site had approximately 5.3 minutes/hour less time in the order entry sub-activity than a non-CPOE site. This result was not statistically significant.

Holding all other variables in the model constant, a CPOE site had approximately 11.7 minutes/hour more time in the order verification sub-activity than a non-CPOE site. This result was statistically significant.

Holding all other variables in the model constant, a CPOE site had approximately 0.04 minutes/hour more time in the other sub-activity than a non-CPOE site. This result was not statistically significant.

The results of the analysis of the predicted means and medians for the activities and the distributive sub-activities were as follows.

Regarding the activities, after CPOE implementation, less time was spent in the clinical, administrative, and miscellaneous activities, while more time was spent in the distributive activity. These results were all statistically significant.

Regarding the sub-activities, after CPOE implementation, less time was spent in the order entry sub-activity, while more time was spent in the order verification and other sub-activities. These results were all statistically significant.

Some of the important results of the analysis of the individual tasks were as follows.

The tasks which were statistically significantly different were: clinical intervention (approximately 0.3 minutes/hour less for CPOE versus non-CPOE sites); drug information (approximately 0.4 minutes/hour more for CPOE versus non-CPOE sites); other-clinical (approximately 1.3 minutes/hour less for CPOE versus non-CPOE sites); order entry (approximately 15.0 minutes/hour less for CPOE versus non-CPOE sites); order verification (approximately 13.4 minutes/hour more for CPOE versus non-CPOE sites); clarification-nurse (approximately 0.9 minutes/hour more for CPOE versus non-CPOE sites); tech check-non IV room (approximately 0.8 minutes/hour more for CPOE versus non-CPOE sites); pyxis fill cart check (approximately 1.0 minutes/hour more

for CPOE versus non-CPOE sites); other-distributive (approximately 0.9 minutes/hour more for CPOE versus non-CPOE sites); and other-administrative (approximately 0.6 minutes/hour more for CPOE versus non-CPOE sites).

Other findings were as follows. On average: fewer order entry tasks were conducted by the CPOE versus the non-CPOE sites (5.25 tasks/hour versus 7.95 tasks/hour); more than four times the number of order verification tasks were conducted by the CPOE versus the non-CPOE sites (7.76 tasks/hour versus 1.75 tasks/hour); and more than three times the number of TPN order reviews were conducted by the CPOE versus the non-CPOE sites (0.95 tasks/hour versus 0.29 tasks/hour).

These results were very insightful. Each pharmacy observed operated in a different and unique way, depending on the pharmacy management's discretion, the daily assignments of the pharmacists, the unique needs of the hospital, the volume of medications processed by each pharmacy, the mix of individuals in the pharmacy (for example: pharmacists, pharmacy technicians, management, and volunteers), individual work ethic, physical layout of the pharmacy, and similar factors. This had a direct effect on the results.

The result of the clinical activity regression analysis was that approximately 1.7 minutes/hour less were spent by CPOE versus non-CPOE sites. Unfortunately, this was not the result that was hoped for. Instead of freeing up more pharmacist time for clinical work, less time was spent in this activity.

The result of the distributive activity regression analysis was that the CPOE sites had approximately 6.4 minutes/hour more time than those which had not implemented CPOE, holding all other variables in the model fixed. This is a relative large amount of time difference between CPOE and non-CPOE (approximately 10% of each hour). One can suspect that if the CPOE sites had less time spent in this activity, more time could be freed for additional clinical work.

The result of the regressions of the three distributive sub-activities was a net increase in time spent in order verification over order entry for CPOE versus non-CPOE. The other sub-activity was not a major factor. This means that after the implementation of CPOE, more time was spent in the distributive activity due to the increased time spent on CPOE orders than non-CPOE orders. Without the burden of interpreting handwriting, one would have expected the opposite to be true. Further research needs to be performed to discover if a proportionally greater number of order actions and order verifications were conducted as a result of this increase in time, therefore justifying the increase.

In conclusion, the results showed that there was less time spent in the clinical, administrative, and miscellaneous activities, while more time was spent in the distributive activity after CPOE implementation.

It needs to be understood that productivity, while a worthy goal, is obviously no tradeoff for performing all aspects of pharmacist duties well. Management needs to be diligent in making any changes in the pharmacy setting. The implementation of a CPOE system is no exception. Unintended consequences need to be anticipated as much as

possible. Management needs to constantly monitor and verify proper and successful implementation of these systems in order to assure successful outcomes for the future.

Appendix A

Letter of consent to participate in research

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CONSENT TO PARTICIPATE IN RESEARCH

Dear Pharmacist,

We are requesting your participation in a research project titled "The Impact of Computer Physician Order Entry on Medication Order Processing and Workflow Efficiency by Pharmacists: A Time in Motion Study". The project is undertaken and conducted by a graduate student as part of his thesis work requirement, under the guidance of Dr. Sujit Sansgiry, Associate Professor, Division of Pharmacy Administration and Public Health, Department of Clinical Sciences and Administration, College of Pharmacy, University of Houston.

The purpose of the study is to quantify the different activities performed by pharmacists and their duration over a specified time period. We anticipate collecting data randomly on the different activities performed by the pharmacist. You will be one of approximately 30 pharmacists invited to participate in this study. If you agree to participate, a data collection assistant will proceed with the observation. Your activities should not be affected in any way during the observation.

There are no foreseeable risks associated with this project to you or your patients. While you will not directly benefit from participation, we anticipate that the project may help investigators better understand pharmacy workflow. The indirect benefit would be improved workflow efficiency in hospitals.

Your participation is voluntary and you may refuse to participate or withdraw at any time without penalty or loss of benefits to which you are otherwise entitled. You may also refuse to answer any question. A decision to participate or not or to withdraw your participation will have no effect on your standing. Your participation in this project is confidential and no identifiers will be recorded in this study.

The results of this study may be published in professional and/or scientific journals. It may also be used for educational purposes or for professional presentations. However, no individual subject will be identified. Only aggregate data will be reported.

If you have any questions, you may contact Mark Hatfield at 713-795-8342 or Dr. Sujit S. Sansgiry at 713-795-8392. **Any questions regarding your rights as a research subject may be addressed to the University of Houston Committee for the Protection of Human Subjects at 713-743-9204. All research projects that are carried out by investigators at the University of Houston are governed by requirements of the University and the Federal Government.**

Please keep this page for your records. If you agree to participate, please indicate so to the Observer. Your cooperation is greatly appreciated. Thank you for your help by participating in this study.

Sincerely,

Mark Hatfield
Graduate Student

Sujit S. Sansgiry, PhD
Faculty Advisor

Appendix B

Definitions of Tasks, by Activity

Clinical Activity

Clinical Intervention: Documentation of a clinical intervention in the MedKeeper® system.

Direct Patient Care: Direct care involved in the presence of the patient.

Drug Information: Researching pharmaceutical and therapeutic drug information with either reference books or internet references.

E-MAR / Lab Review: Referencing patient electronic medical record or lab results.

Consult Rph – Clinical: Consultation with another pharmacist regarding clinical aspects.

Pt. Consult – Discharge: Consultation with a patient regarding discharge medication(s) instructions.

Pt. Consult – Warfarin: Consultation with a patient regarding Warfarin medication instructions.

Rounds: Rounds spent consulting with patients, nurses, and / or physicians.

Physician's Order Form: Filling out a Physician's Order Form on the physician's behalf for future verification by the physician.

Other – Clinical: Any other clinical activity not included in any other clinical task.

Distributive Activity

Order Entry: Manual entry of medication orders via written (scanned) or verbal communication. (Non-CPOE orders.)

Order Verification: Any of the actions performed on orders received through the PharmNet® system. (CPOE orders.)

Clarification – Nurse: Communication with a nurse, typically by phone, regarding distributive aspects.

Clarification – Physician: Communication with a physician, typically by phone, regarding distributive aspects.

Tech Check: Non-IV room: Physical verification of medications prepared by a pharmacy technician by the pharmacist in the central pharmacy.

Tech Check: IV room: Physical verification of medications prepared by a pharmacy technician by the pharmacist in the IV room.

Medication Prep / Delivery: Physical preparation or delivery (typically using the hospital tubing system) of medications by the pharmacist.

IT support: Pharmacist request for support of the hospital IT department.

Consult Rph – Distributive: Consultation with another pharmacist regarding distributive aspects.

Consult Tech: Consultation with a pharmacy technician regarding distributive aspects.

Chemo Order Review: Order entry of Chemo orders.

Chemo Mixing Check: Physical verification of Chemo order(s) prepared by a pharmacy technician.

TPN Order Review: Order entry of TPN orders.

TPN Mixing Check: Physical verification of TPN order(s) prepared by a pharmacy technician.

Pyxis Fill Cart Check: Physical verification of medications intended to re-fill the Pyxis machines on the hospital floors.

SCIP / HOP Review: Inpatient and outpatient surgery order reviews and order entry. Also includes meeting time with surgery team.

Other – Distributive: Any other distributive activity not included in any other distributive task.

Administrative Activity

Meeting: Attendance at any formal meeting.

Huddle: Attendance at the meeting for all pharmacy personnel (pharmacy management, order entry pharmacists, and pharmacy technicians). Can be daily or weekly – at the discretion of pharmacy management.

Shift Report: Preparation of shift summary reports required by pharmacy management.

Schedule: Checking of the pharmacy schedule, discussion of the pharmacy schedule, or work on creating the pharmacy schedule.

Emails: Work related emails.

Q and A: Questions and answers with pharmacy management regarding pharmacy operations.

Teaching / Mentoring: The active teaching or mentoring of a pharmacist in training, a resident pharmacist, or a student pharmacist.

Documentation: The act of filling out a form which is non-clinical and non-distributive; filing of paperwork; printing; or scanning.

Other – Administrative: Any other administrative activity not included in any other administrative task.

Miscellaneous Activity

Personal time: Any non-work related time.

Appendix C

Codebook

Variable	Description	Values
Excel_ID	Observation number (ID) in Microsoft Excel	Varies
Access_ID	Observation number (ID) in Microsoft Access instrument	Varies
Sitting_No	Number different sessions (Not used)	1 to 79
Keep_Obs	Keep or Delete the observation	0 = Delete observation 1 = Keep observation
Date	Date in DD-MMM-YY format	Varies
Day_No	Day of observation	1 to 39
Time	Time of day in HH:MM:SS format	Varies
Elapsed_time	Time in HH:MM:SS format of time spent per observation	Varies
Minutes	Time in decimal format of time spent per observation	Varies
TC	Time Code - Hour of the day	1 = 7am to 8am 2 = 8am to 9am 3 = 9am to 10am 4 = 10am to 11am 5 = 11am to 12pm 6 = 12pm to 1pm 7 = 1pm to 2pm 8 = 2pm to 3pm 9 = 3pm to 4pm 10 = 4pm to 5pm 11 = 5pm to 6pm
Hr	Hour of observation	1 to 340
Retain_Hr	Retain or Delete the hour of observation	0 = Delete hour 1 = Retain hour
Post	Pre or Post intervention observation	0 = Pre 1 = Post
HID	Hospital ID	1 = Memorial City 2 = The Woodlands 3 = Katy 4 = Southeast
CMI	Medicare Case Mix Index, by hospital	1.6264 = Memorial City 1.6764 = The Woodlands, Southeast, and 2 other hospitals combined (not specific to TW or SE) 1.5216 = Katy
CPOE	CPOE or Non-CPOE pharmacy	0 = Non-CPOE 1 = CPOE
Experiment_ID	Experiment ID	1 = Memorial City, Pre, Non-CPOE 2 = Memorial City, Post, CPOE 3 = The Woodlands, Pre, Non-CPOE 4 = The Woodlands, Post, Non-CPOE 5 = Katy, Pre, CPOE 6 = Katy, Post, CPOE 7 = Southeast, Pre, CPOE 8 = Southeast, Post, CPOE
Beds	Number of hosptial beds, per hosptial	426 = Memorial City 252 = The Woodlands 142 = Katy 274 = Southeast
Census	Hospital Census, by day	Varies
Ch_Census	Change in Hospital Census from the previous day, in decimal form ((current day census - previous day census) / (current day census))	Varies
Pct_Cap	Percent of hospital capacity, in decimal form (Census / Beds)	Varies
Rph	Pharmacist ID	1 to 63
Gender	Pharmacist Gender	0 = Male 1 = Female
Exp	Pharmacist institutional experience	0 = 0 to 1 year 1 = 1 to 10 years 2 = 10+ years

Variable	Description	Values
Rph_Type	Pharmacist type of responsibilities (varies by shift, HID)	1 = A = Pharmacist A, day shift - Memorial City 2 = B = Pharmacist B, day shift - Memorial City 3 = A2 = Pharmacist A, evening shift - Memorial City 4 = B2 = Pharmacist B, evening shift - Memorial City 5 = N = Night pharmacist - Memorial City 6 = 1 = Pharmacist 1 - The Woodlands 7 = 2 = Pharmacist 2 - The Woodlands 8 = 3 = Pharmacist 3 - The Woodlands 9 = IV = Pharmacist IV - The Woodlands 10 = OE = Pharmacist OE - The Woodlands 11 = T = Pharmacist Other - The Woodlands 12 = 0630 = Pharmacist 0630 - Katy 13 = 0800 = Pharmacist 0800 - Katy 14 = 1330 = Pharmacist 1330 - Katy 15 = 1430 = Pharmacist 1430 - Katy 16 = 0700 = Pharmacist 0700 - Southeast 17 = 1000 = Pharmacist 1000 - Southeast 18 = 1430 = Pharmacist 1430 - Southeast 19 = IV = Pharmacist IV - Southeast 20 = 3B = Pharmacist 3B - Southeast
OA	Number of Order Actions per hour, per pharmacist	Varies
OE	Number of Order Entries per hour, per pharmacist	Varies
Task_Ch	Number of different tasks per hour, per pharmacist	Varies
Task	Task ID	1 = Clinical Intervention documented in MedKeeper 2 = Direct Patient Care 3 = Med Therapy Recommendation (Not used) 10 = Other - Clinical Category 11 = Order Entry (non-CPOE orders) 12 = Order Verification (CPOE orders) 13 = Clarification - Nurse 14 = Clarification - Physician 15 = Technician Check 16 = Med Request (Not used) 17 = Medication Prep / Delivery 18 = Consult RPh - Distributive Category 19 = Consult Tech 20 = Meeting 21 = Shift Report 22 = Emails 23 = Q and A with Management 24 = Other - Administrative Category 25 = Drug Information research 26 = Other - Distributive Category 27 = Consult RPh - Clinical Category 28 = Technician Check in IV Room 29 = Answering Dispensing Questions (Not used) 30 = IT Support 31 = E-Mar / Lab Review 32 = Phone Triage (Not used) 33 = Pt. Consult - Discharge 34 = Pt. Consult - Warfarin 35 = Pt. Consult - Other 36 = Rounds 37 = Physician's Order Form 38 = Chemo Order Review & Entry 39 = Chemo Mixing Check 40 = TPN Order Review & Entry 41 = TPN Mixing Check 42 = Pyxis Fill Cart Check 43 = SCIP / HOP Review (IP & OP surgeries) 44 = Teaching / Mentoring 45 = Documentation 46 = Huddle 47 = RPh Schedule - review or management 63 = Internet (Not used) 64 = Personal Time 65 = Colleague/Staff for Non-Pt. (Not used) 71 = Other - Miscellaneous Category (Not used)

Variable	Description	Values
Categ	Activity	1 = Clinical Activity 2 = Distributive Activity 3 = Administrative Activity 4 = Miscellaneous Activity
Cat1	Minutes spent in Clinical Activity by observation	Varies
Cat2	Minutes spent in Distributive Activity by observation	Varies
Cat3	Minutes spent in Administrative Activity by observation	Varies
Cat4	Minutes spent in Miscellaneous Activity by observation	Varies
Cat2_OE	Minutes spent in Distributive Activity by observation for all tasks involving Order Entry (includes Tasks 11, 38, & 40)	Varies
Cat2_OV	Minutes spent in Distributive Activity by observation for all tasks involving Order Verification (includes Task 12 only)	Varies
Cat2_OE_OV	Minutes spent in Distributive Activity by observation for all tasks involving Order Entry and Verification, combined (includes Tasks 11, 12, 38, & 40) (Not used)	Varies
Cat2_Oth	Minutes spent in Distributive Activity by observation for all tasks NOT involving either Order Entry or Order Verification	Varies
Calls	Number of incoming calls to pharmacy per observation	Varies
Calls_ans_Rph	Number of incoming calls answered by a pharmacist	Varies
Rph_OD	Number of pharmacists on duty, by hour	Varies
Tech_OD	Number of technicians on duty, by hour	Varies
Comment	Comments made by observer, by observation	Varies

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