

IMPACT OF THE BAR CODE MEDICATION ADMINISTRATION (BCMA)
SYSTEM ON MEDICATION ADMINISTRATION ERRORS

by

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SIGNED: Mary Davis Doyle

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This dissertation is dedicated to my father, John R. Davis, without whose unquestioning and unwavering support I could not have accomplished this goal.

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ABSTRACT

Medication errors are the second most frequent cause of injury among all types of medical errors (Leape, et al., 1991). Of concern to nursing practice, medication administration errors (MAE) are second only to ordering errors (Bates, Cullen, et al., 1995). The introduction of information technology designed to promote safe medication practice, such as the Bar Code Medication Administration (BCMA) system, offers new opportunities for reducing MAE. BCMA was developed to improve patient safety, improve documentation of medication administration, decrease medication errors, and capture medication accountability data. The overall goal of this study was to evaluate the impact of BCMA on medication administration errors: wrong patient, medication, dose, time, and route. Rogers' (1995) theory, organizational diffusion of innovations, provided the study's framework.

A descriptive comparative design examined incidence of MAEs before (Time 1) and after implementation (Time 2) of BCMA on eight units in one medical center. MAE incidence was calculated using MAE and patient-days data. Nurse adherence to BCMA usage procedure was assessed with a questionnaire created for the study.

Findings indicated that total MAEs increased from Time 1 to Time 2, however, wrong patient and wrong dose errors decreased. There was a statistically significant ($p < 0.05$) increase in wrong route errors at Time 2. Comparing these findings with previous research demonstrated a diversity of methods, limiting conclusions. Nurse adherence findings indicated high overall adherence. However, completion of certain steps was hindered by software, equipment, or the work environment.

Study findings were significant to nursing, informatics and patient safety research. Findings demonstrated the early state of BCMA research, added to knowledge about MAE detection methods, and brought a nursing perspective to information technology research on a process primarily within nursing purview. Implications for future research include improvement in MAE definitions and detection methods to support reliable data collection for research and quality improvement analysis. Also, sociotechnical theory recognizes health care as an interwoven, heterogeneous environment with complex roles and work practices, and may provide a more appropriate framework for evaluation of medication safety technology innovations than the linear model used in this study.

CHAPTER I

Introduction

Medications errors are the second most frequent cause of injury among all types of medical errors (Leape, et al., 1991). It has been projected that medication errors may be responsible for up to 7,000 deaths annually (Phillips, Christenfeld, & Glynn, 1998). Of particular concern to nursing practice, medication administration errors are second only to errors in ordering (Bates, Cullen, et al., 1995). Medication administration is a fundamental nursing responsibility, as is ensuring safe medication administration practice. The introduction of information technology designed to promote safe medication practice offers new opportunities for reducing or preventing medication administration errors.

This study estimated the impact of one innovative information technology intervention, the Bar Code Medication Administration (BCMA) system, on errors associated with medication administration by nurse using a pre- and post-test design. Initially developed by the federal government, this innovation has been gaining support within the private sector. However, the effectiveness of this information technology has received little scrutiny.

Statement of the Problem

Medication Errors

The Institute of Medicine's (IOM) report on errors in health care was based on research about the scope and impact of errors (Kohn, Corrigan, & Donaldson, 2000).

Two studies using similar methodologies, one published in 1991 with data collected in 1984 in the state of New York and the other published in 2000 with data collected in 1992 in Colorado and Utah, were cited by the IOM (Leape, et al., 1991; Thomas, et al., 2000). Widely referenced was an estimate of the number of deaths (48,000 from the Colorado/Utah data to 98,000 from the New York data) attributable to medical errors when the findings were extended to annual hospital admissions in the United States. The New York investigators had categorized types of medical error that resulted in adverse events (AEs) (Leape, et al., 1991). They found that medication-related adverse events had the second highest incidence (19.4%) of all adverse events, following operative-related AEs. Specific errors associated with these AEs were further analyzed to determine whether they were preventable, not preventable, or potentially preventable (Leape, Lawthers, Brennan, & Johnson, 1993). Of all preventable AEs, only 10% of medication use errors were deemed preventable. The study concluded that while a large percent of drug-related AEs were not preventable, the high incidence of drug-related AEs justified developing strategies that targeted medication errors to prevent AEs.

Medication error research has focused on the stages of the medication process (Bates, Cullen, et al., 1995). The medication process is defined as having four stages: ordering, transcribing, dispensing and administering. In this study, for each of the preventable ADEs discovered, a medication error judged to be the most likely cause was identified in order to categorize the distribution of errors across the four stages.

Medication errors occurred most frequently in two stages: ordering (56%) and

administration (34%). It was estimated that prevention of medication errors at the ordering and administration stages could reduce preventable ADEs by 90%.

For this study, medication administration errors are defined as displayed in Table 1.

TABLE 1. Operationalization of Medication Administration Error Variables

Wrong patient	Medication administered to someone other than for whom it was ordered
Wrong medication	Patient is given a medication that has not been ordered
Wrong dose	Patient is given an incorrect amount of medication
Wrong time	Medication is administered outside the accepted range of time for administration or at a time inappropriate for that medication's type or purpose
Wrong route	A medication is administered to a patient by a route that is inappropriate for that medication, that dose, or the order

Reports of the distribution of medication administration errors varies in the literature: wrong dose (17 - 53%), wrong medication (4 - 12%), wrong time (7 - 43%) and wrong route (2 - 5%) (Bates, Cullen, et al., 1995; Bates, Boyle, Vander Vliet, Schneider, & Leape, 1995; Barker, Flynn, Pepper, Bates, & Mikeal, 2002). Comparison of these findings is limited due to methodological differences, yet the findings do point to a need to reduce preventable medication administration errors.

Nursing Medication Administration

Nurses administer medications multiple times per shift according to a study of nursing interventions (Bulechek, McCloskey, Titler, & Denehey, 1994). As an intervention, medication administration had the second greatest frequency of all interventions, trailing only active listening. Since medication administration is such an integral component of nursing practice, medication errors have been identified as an appropriate outcome indicator for nursing practice (American Nurses Association [ANA], 1995).

Patient safety and accuracy have been emphasized in nursing standards for medication administration (Taylor, Lillis, & LeMone, 2001). Nurses are taught to follow the *five rights*, also known as the 5 Rs, “The nurse gives the (1) *right medicine* to the (2) *right patient* in the (3) *right dosage* through the (4) *right route* at the (5) *right time*” (p. 581).

During preparations for medication administration, the nurse is responsible for confirming the order, the administration time, and selecting the correct medication and dose. At the point of administration, it is the nurse’s responsibility to identify the correct patient and use the correct route of administration. Traditionally the standard of care has been that the nurse confirms patients by reading their armbands and verbally confirming their names where appropriate. Over the last decade however, information technology interventions have been created to reduce the most frequently occurring and preventable medication errors, with one intervention in particular, the Bar Code Medication

Administration system, designed to be incorporated into the medication administration process.

Bar Code Medication Administration (BCMA)

Bar code technology has been used for material management and sales for over forty years (Simpson, 2001). Bar coding replaces manual documentation with electronic scanning of unique identifier codes that are transmitted to a database (Grotting, Yang, Kelly, Brown & Trohimovich, 2002). By the mid-1980s this technology was being suggested as a strategy for reducing medication administration errors (Nold & Williams, 1985). When the federal government's Veterans Health Affairs (VHA) became aware of medication administration accuracy and documentation issues, the stage was set for adopting an innovative solution (Johnson, Carlson, Tucker, & Willette, 2002). The original clinical application, the Bar Code Medication Administration (BCMA) system, was developed by the VHA in the 1990's. The specific goals of BCMA were to improve patient safety, improve the documentation of medication administration, decrease medication errors, and capture medication accountability data.

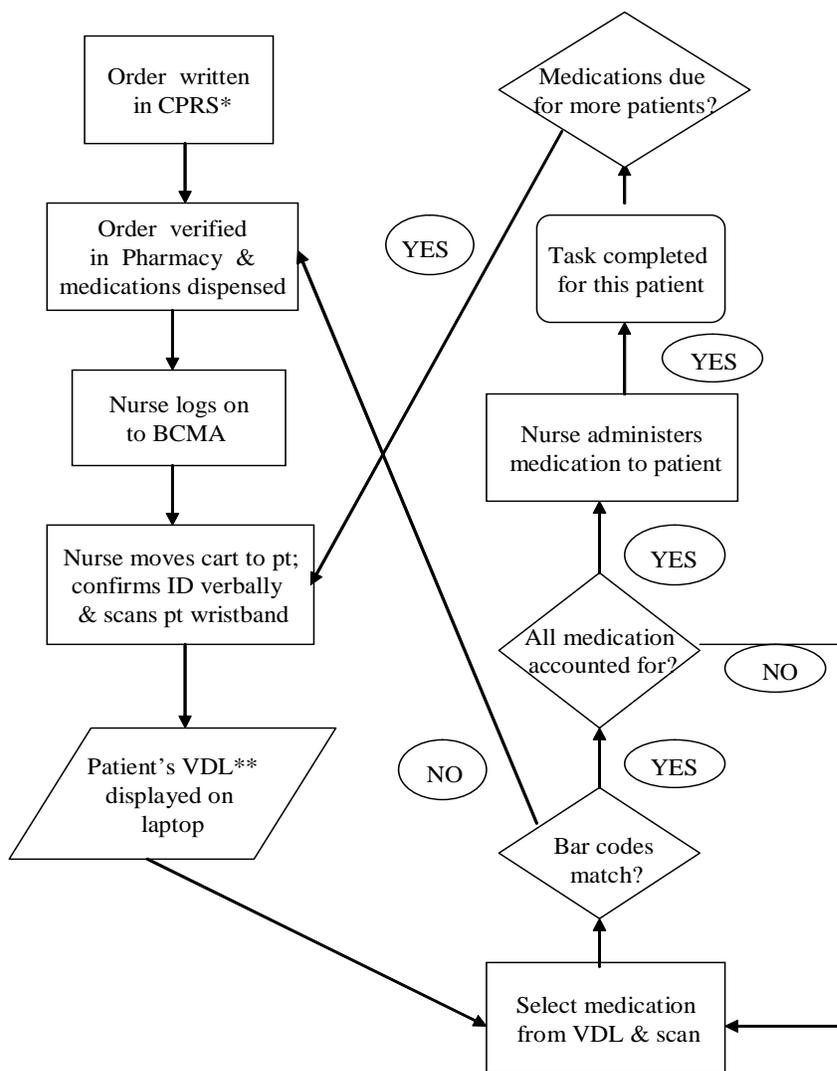
BCMA Innovation

The BCMA system has been used at VHA medical centers across the country since 1999. BCMA is a clinical information module residing within each facility's health information system. The module is accessible from computer work stations and mobile computers on each nursing unit. From work station computers staff may view medication order reports and look up medication administration information. The module is accessed via wireless connectivity from a laptop computer mounted on a wheeled

medication cart. Each cart has either a wireless or tethered handheld scanner. The carts have a number of individual patient medication drawers, corresponding to the number of patients served per cart.

BCMA Process

The BCMA medication process is diagramed in Figure 1.



*CPRS=Computerized Patient Record System

**VDL=Virtual Due List

FIGURE 1. Bar Code Medication Administration Diagram

Adapted with permission from the Southern Arizona Veterans Administration Health Care System (SAVAHCS) Training Guide, 2000

The process begins with a provider entering medication orders into the medical center's electronic health record. Next a pharmacist verifies the order and medication is dispensed to the nursing unit. At the beginning of each shift, a report of all medications due for assigned patients is printed by the nurse responsible for administering the medications. This informs the nurse of patient medication administration times. The nurse logs onto the BCMA system when it is time to begin administering medications. Then the nurse moves the medication cart to the room or bedside of the patient to be medicated. The next step is to verbally identify the patient and scan the unique identifier bar code on the patient's armband.

This action brings up on the laptop screen the Virtual Due List (VDL) of medications to be administered within the next hour for that patient. The nurse retrieves a unit dose of the medication from the cart drawer and scans its bar code. The VDL will show whether there is a match between the patient and medication identifiers, and if there are any alerts or prompt messages requiring action. If more medications for the same patient are due at that time, the nurse continues to select and scan the unit doses until all medications have been selected. The scanning triggers automatic documentation of medications given (which can be manually corrected if a dose is refused or held). If the patient and medication bar codes are compatible, the nurse administers the medication. At the end of the shift, a missing medication report can be printed to determine if all doses were given.

The first version of BCMA was not designed to include intravenous (IV) fluids and medications (Department of Veterans Affairs [DVA] VHA, 2002). Version 2

extended the functionality of BCMA to IV fluids and was introduced in 2002. That development enabled critical care units, which administered a majority of patient medications via IV, to implement BCMA.

Policies and procedures within the VHA may be developed at the Central Office level, the regional division levels, and at the individual medical center level. For BCMA implementation, suggested BCMA guidelines were available from the Central Office (DVA Office of Information, 1999). However, each inpatient medical center was responsible for selecting and purchasing the necessary hardware, devising their own training, developing implementation plans and writing medication administration procedures incorporating BCMA (SAVAHCS, 2000).

Theoretical Framework

Rogers' (1995) organizational diffusion of innovations (ODOI) theory provided the framework for this study. The original organizational innovation process consists of two phases with five stages (Figure 2).

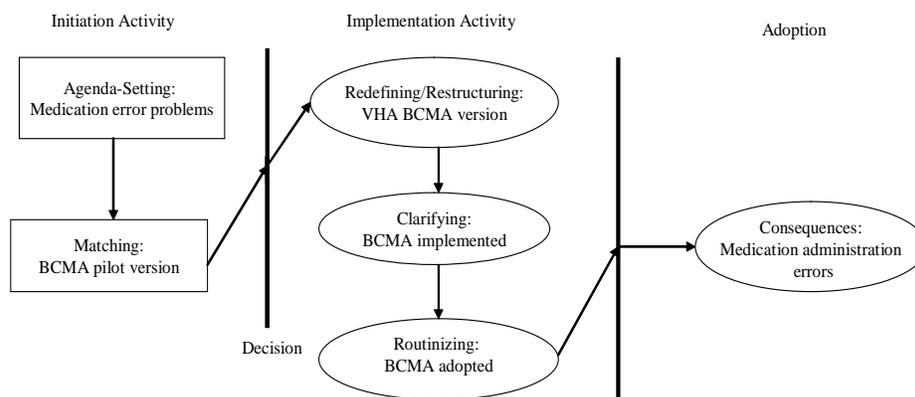


FIGURE 2. Organizational BCMA Innovation Process
Adapted from Rogers, 1995

While the VHA did not use this process, ODOI provides a useful framework for understanding how the BCMA system innovation was transitioned from an idea to an information technology program by the VHA. The ODOI process begins at the Initiation Activity phase which is comprised of two stages: *agenda setting* and *matching*. *Agenda-setting* is defined as the process by which organizations prioritize “needs, problems, and issues” (Rogers, p. 391). This stage reflected how the VHA identified system-wide problems related to medication. Prior to the Institute of Medicine report that prompted broad scale attention on errors, the federal Government Affairs Office in 1991 recommended that surveillance systems be instituted to address issues with controlled substance accountability.

The next stage, *matching*, is defined as “the stage at which a problem from the organization’s agenda is fit with an innovation” (Rogers, 1995, p. 394). In this study *matching* describes the process by which an innovative solution was selected to address medication errors and accountability. As the VHA Central Office worked to develop surveillance measures, they learned about the efforts of an interdisciplinary team at a mid-western VHA medical center. That site was subsequently funded to develop a prototype automated medication administration system. A nurse was credited with the inspiration to develop a bar code scanning process after observing in 1992 the technology used for car rentals. Development proceeded with initial piloting on a thirty-bed long-term care ward in June 1994. The system was extended to the entire medical center by September 1995. When the VHA Director was introduced to the prototype, a decision was made that the program be further developed for implementation in all VHA medical centers. With that decision, the Implementation Activity phase of the BCMA innovation process commenced.

Refining/restructuring is defined as the re-invention of the innovation “to accommodate the organization’s needs and structure more closely, and when the organization’s structure is modified to fit with the innovation” (Rogers, 1995, p. 394). This stage describes how BCMA was modified for adoption throughout the VHA system of 172 medical centers. BCMA version 1 was created from the prototype, training and education manuals were written, and training plans and schedules were devised, all at the VHA headquarters level. Training of representatives from all facilities was conducted.

These representatives, in turn, were responsible for preparing their own medical centers for BCMA as the process transitioned to the *clarifying* stage.

The *clarifying* stage is defined as how the meaning of an innovation “gradually becomes clearer to the organization’s members” (Rogers, 1995, p. 399). During the *clarifying* stage BCMA was introduced at each VHA medical center. The innovation progressed from the macro to micro level of the organization, becoming “imbedded” [sic] (p. 399). At SAVAHCS, the ‘BCMA Team’ prepared for and conducted the training of all personnel prior to the implementation date. The purpose of implementation by local, not central office, teams was that problems unique to the local organization would be handled at that level if possible, with feedback given to the VHA on issues not resolvable at the local level.

The final stage, *routinizing*, is defined as when “the innovation process in an organization is complete” (Rogers, 1995, p. 399). *Routinizing* occurred when BCMA was no longer viewed as new and external to the local organization but as a regular part of patient care delivery. BCMA was *routinized* into patient care by virtue of its incorporation into practice on several inpatient units at SAVAHCS for the last four years.

Rogers (1995) believed that the innovation process must be understood by evaluators of innovation before consequences or outcomes could be analyzed. Application of the innovation process to the VHA system informed how BCMA was created, implemented, and adopted and provided a context within which to understand the consequences of the BCMA innovation. For this study, the implementation process was assumed to have been completed, so that the addition of consequences to the model

emphasized that outcomes, not process, were the clinical variables of interest. The ODOI theoretical framework provided a context for describing outcomes of BCMA that is, medication administration errors.

A second focus of this study is concerned with the *routinizing* stage. Rogers (1995) reports that until recently a major assumption of the original diffusion of innovation theory was that adopted innovations would be performed as designed and result in positive outcomes. However, as the theory was broadened to encompass organizational level adoption, more in-depth analysis of the nature of consequences was explored, resulting in three classifications: “desirable versus undesirable”, “direct versus indirect”, and “anticipated versus unanticipated” (p. 412). Another assumption of this study was that describing how the BCMA innovation was incorporated into daily nursing practice could provide some insight regarding the nature of the consequences to be described. According to the ODOI framework, “unwanted side-effects” occur (p. 399) during the *clarifying* stage and if these aren’t recognized and corrected, the cause of the side-effects will be routinized and incorporated into the medication administration practice. Therefore, a second construct of this study was created to describe the extent to which nurses adhered to BCMA procedure.

A key limitation of ODOI theory is the lack of evidence regarding innovation adoption consequences (Rogers, 1995). In the case of the BCMA innovation, the limited reports on consequences have been retrospective, based on quality assurance methods, and have tended to focus on the research and development phases of innovation. Previous studies had not identified the extent or degree to which BCMA had become

routine. This study contributed to extant knowledge about how the organizational innovation process can be applied to the diffusion of medication safety technology in nursing practice.

Research Questions

The overall goal of the study was to examine the impact of BCMA on medication administration errors (MAEs) after implementation of BCMA on selected nursing units. The study assessed the incidence of medication administration errors before BCMA was introduced and compared that incidence to post-implementation MAE incidence. In addition, the study examined the extent to which staff reported adherence to BCMA practice policy and procedures.

The research questions were:

1. What is the incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) pre-implementation of BCMA?
2. What is the incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) post-implementation of BCMA?
3. What is the difference in incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) from pre-BCMA implementation to post-BCMA implementation?
4. What is the degree of adherence to the BCMA procedure by nurses?

Summary

Medication administration errors have increasingly come under scrutiny by health care researchers during the past several years. Nurses are responsible for the preponderance of medication administration so it is at this stage of the medication administration process that the nursing profession can have the most impact on improving patient medication safety (ANA, 1995). Within the last decade patient medication safety approaches have been created specifically to reduce the incidence of medication errors. This study analyzed the effectiveness of one innovative information technology, the Bar Code Medication Administration (BCMA) system, on errors specifically due to medication administration by nurses. Rogers' (1995) Organizational Diffusion of Innovation Theory framed the study. Specifically the study addressed the incidence of medication administration errors before and after implementation of BCMA, and the degree of adherence of nurses to the BCMA procedure.

CHAPTER II - LITERATURE REVIEW

Introduction

This chapter describes studies underpinning current information about medication errors and, more specifically, medication administration errors. The potential of innovative information technology to reduce medication administration errors is discussed. Examples of anecdotal publications and pertinent research-based reports on bar coding for medication administration and the Bar Code Medication Administration system are reviewed.

Medication Errors

Research on medication errors, effects, and solutions has been ongoing for three decades. The Harvard Medical Practice Study was undertaken in 1984 using data from a random sample of hospitals in New York State (Brennan, et al., 1991). (For purposes of comparison here this study is referred to as the New York study.) Additional analysis of data from the New York study by Leape, et al., (1991) found complications associated with drugs were the greatest (19.4%) non-operative cause of adverse events (Leape, et al., 1991). Although those drug-related events were determined to be largely not preventable, due to unpredictable responses such as allergies, or to expected side effects of treatments such as chemotherapy, in a third publication Leape and colleagues (1993) recommended that drug related adverse events receive further attention in error prevention research.

Another study was conducted in Utah and Colorado, based on data collected in 1991 and attempted to replicate the New York state methodology (Thomas, et al., 2000).

From a stratified convenience sample of hospitals a random sample of discharges were screened by medical personnel and approved for further review if potential adverse events were discovered. Adverse events due to medications were found to have the second greatest frequency (19.3%), second to operative causes. Thomas and colleagues argued that the risk for adverse events, particularly due to medications was relatively unchanged since the New York study. They concurred with the recommendation of the New York study team that new system-level approaches to improve patient medication safety were needed (Leape, et al., 1995). In terms of the ODOI model, the *agenda-setting* accomplished by these two studies provided a foundation for subsequent research.

Three subsequent studies conducted by Classen, Pestotnik, Evans, & Burke (1991), Bates, Cullen, et al. (1995), and Bates, Boyle, et al. (1995), added new information regarding rates of adverse drug events. These were prospective studies but used different denominators for quantifying adverse drug events rates. Each study also employed different adverse drug events detection methods.

Classen and colleagues (1991) developed a computerized monitor that was programmed to capture potential adverse drug event signals, for example, abnormal laboratory values and certain medications when stopped or ordered. On a daily basis a pharmacist reviewed the records of patients identified as having experienced a potential event. Only adverse drug events (as opposed to medication errors) were reported. A total of 731 adverse drug events were detected in 648 patients over 36, 653 admissions for an adverse drug event rate of 1.67%, or 1 adverse drug event per 50 admissions.

The first study by Bates, Cullen, et al. (1995) focused on adverse drug event incidence and identified adverse drug events through a combination of independent and prompted self-report and daily chart reviews. An adjusted rate of 6.5 adverse drug events per 100 admissions was reported or 1 adverse drug event per 15 admissions. A total of 334 medication errors were associated with 247 identified adverse drug events in a second article reporting on that study (Leape, et al., 1995). Based on 2,412 patient-days, there were 0.02 errors per patient-day or 1 error per 64 patient-days.

The Bates, Boyle, et al. (1995) study more closely analyzed the association between medication errors and adverse drug events using self report and patient record reviews. A total of 5 adverse drug events occurred over 379 admissions, a rate of 1.3% or 1 adverse drug event per 76 admissions. A total of 530 medication errors were detected over 1704 patient-days, representing 0.3 medication errors per patient-day, or approximately 1 error per 3 patient-days.

While these three studies contributed to extant knowledge regarding medication errors and adverse drug events, congruent with the *agenda-setting* stage of ODOI, the lack of uniformity of methods and how error rates were calculated have been a hindrance to clearer understanding of the scope of the medication error problem. However, Bates and colleagues in two different studies (1995a and 1995b) continued to examine the medication errors in more detail, further illuminating appropriate foci for reducing errors.

Medication Administration Errors

The two studies discussed in the preceding section also provided some information on how errors were distributed by stage in the medication process. At one

facility Bates, Boyle, et al. (1995) identified 530 errors in 10,000 medication orders. The distribution of errors was missing dose (53%), other dose errors (15%), route (5%), and frequency (8%).

In the second study, Bates, Cullen, et al. (1995) identified adverse drug events, and a medication error associated with each, by stage of the medication process. Ordering errors (56%) and administration error (34%) accounted for the majority of medication errors. From these same data, the frequency of MAE in a total of 334 errors was described: wrong dose (27%), wrong medication (12%), wrong time (7%) and wrong route (2%) (Leape, et al., 1995).

These findings had implications for creating information technology interventions directed at the ordering and administration stages, reflecting the *matching* stage of ODOI where a solution is sought. Particularly designed to curb ordering errors, computerized provider order entry programs became the subject of development and research.

More recently, a study conducted in a randomized sample of health care facilities in Colorado and Georgia identified types of administration errors by observation (Barker, 2002). The participating centers were accredited hospitals, nonaccredited hospitals and skilled nursing facilities. Overall, there were 605 MAEs in observed administration of 3,216 doses. The MAE were distributed as follows: wrong time (43%), omission (30%), wrong dose (17%), and unauthorized drug (4%). The authors concluded those findings supported the Institute of Medicine's report of excessive medication errors, further reflecting the *agenda-setting* stage about the extent and currency of the problem.

Bar Coding Innovation

Limited evidence was available from health care literature on the effectiveness of bar coding for medication administration but the technology has been reported to have decreased error in other industries (Bates, 2000). Over the last few years publications have reported reductions in medication error rates in facilities that have adopted proprietary medication administration bar code applications (Puckett, 1995; Thielke, 2003). The results and conclusions have limited value due to their anecdotal nature but do illustrate how bar code innovations for medication administration have been matched, refined and restructured by some health care systems as a promising approach to reducing medication administration errors. Two articles are reviewed here as examples of the type of information published about the effectiveness of bar coding for medication administration. Limited information regarding activities associated with the *clarifying* and *routinizing* stages was reported in either article.

A proprietary bar code system was implemented as a component of a point-of-care information system in one regional medical center (Puckett, 1995). After selecting the patient's name or scanning the wristband bar code and the medication bar code, the medication system would confirm the match for the patient, medication, dose, route and time. If any error was discovered, the system would generate an alert to the nurse. Based on incident report data, this facility reported total medication error rates per number of doses administered pre-implementation (0.17%), after using bar coding one year (0.07%), and after two years of use (0.05%). Adjusting for patient days, decreases in wrong drug (33%), wrong time (43%) and omitted doses (52%) were reported. No changes in rates

occurred for wrong patient (5%) or wrong dose (18%). There was no information about the timeframe used to measure for change, for example, one year post-implementation or two years.

A second example came from a university medical center that was a beta site for a different proprietary bar code system (Thielke, 2003). One unit with twenty-eight beds piloted the system. No timeframe was stated for elapsed time between measurement points. The author reported an annualized error rate pre-implementation of 9.09% based on direct observation; the post-implementation error rate was reduced by 87%, based again on direct observation for seventeen days. The report estimated that 11,518 medication administration errors annually would be eliminated for that unit, from 13,340 to 1,822 per year. The reported change in types of medication administration errors over time was considerable: wrong dose and wrong dosage form errors were decreased 100%, followed by decreases for omitted dose (92%), wrong time (77%), and wrong drug (51%).

In contrast, a more scientifically rigorous review of research-based bar coding literature was conducted as part of a review of a variety of information technologies designed to decrease medication errors and ADEs (Oren, Shaffer, & Guglielmo, 2003). Seven prospective studies from 1988 to 1997 met the criteria for inclusion in the review, but none were specifically about bar code medication administration systems. Instead, the applications were materials management, pharmacy inventory, dispensing and data entry, and billing. Five of the seven studies measured medication errors and ADEs as outcomes. The article did not provide details of those studies claiming a positive impact

on errors and ADEs, but concluded that the existing research was not sufficient for drawing any conclusions regarding the effectiveness or benefits of any of the technologies on error reduction.

BCMA Process

Research-based literature on the Veterans Health Administration's (VHA) BCMA system is limited. In an article describing the development and implementation of BCMA, figures from the VHA medical center that created the prototype were presented and have since been cited extensively (Johnson, et al., 2002). According to the authors, no medication administration errors were documented from 1994 after BCMA had been implemented on all units through March 2001. In addition, BCMA was credited with preventing 549,000 errors out of about 8 million doses dispensed. Improvements in error rates per doses dispensed were based on an overall decrease in number of incident reports, from pre-implementation of BCMA (0.0217%) to after 8 years of use (0.0030%), an 86.2% improvement. The number of reported medication errors decreased from 409 to 22, with the following rates of improvement: wrong medication (75.47%), wrong dose (61.97%), wrong patient (93.48%), wrong time (87.41%), and omission errors (70.34%). The article provided no additional information about statistical findings.

A retrospective comparative study on BCMA use was conducted on two nursing units at a different VHA medical center (Low & Belcher, 2002). Medication errors per doses dispensed from 12 months prior to implementing BCMA and 12 months immediately post-implementation were compared. Pre-implementation data were collected from incident report summaries. Post-implementation errors were available

from a BCMA log that was designed to record late dose, missing dose, omitted dose, wrong dose, and wrong medication.¹ However, no data were provided regarding type of MAE.

The study reported an increase in all MAEs from Time 1 (n = 37) to Time 2 (n = 40), and identified an 18% increase in the medication error rate per 1,000 doses post-implementation; however that finding was not statistically significant. The authors concluded that the smaller number of Time 1 errors reflected reliance on self-report and that increase in errors at Time 2 was possibly related to the nurses' learning process with the BCMA software. However, they also noted that the increase in errors from Time 1 to Time 2 was anticipated due to the increased collection of error data by the BCMA log.

Summary

This chapter reviewed representative literature demonstrating the progression of research on the incidence of medication errors and adverse drug events to specific medication administration error incidence. The initial stages of ODOI theory informed the increasing awareness of the extent of medication administration errors and the search for a solution. Studies of medication errors reported on the distribution of errors by stage of the medication process, of which medication administration had the second greatest rate of occurrence. Within the medication administration stage, the distribution of types of medication administration errors was also reported.

The pre-bar coding studies have added to knowledge about the extent of

¹ The BCMA log accessed in the Low and Belcher study was not available in the version of BCMA used in this study.

problems with medication administration, contributing to the health care industry's foundation for *agenda-setting*. Developing information technology interventions to reduce medication administration errors as a *matching* activity was endorsed. Anecdotal and research studies on one such intervention, bar coding, were presented. Comparison of the research and anecdotal reports revealed a continued disparity in data detection approaches, measurement, and analysis, reflecting the state of the science in this field and opportunities for improvement. These studies demonstrate that much work remains to be done before meaningful comparative analysis of consequences can occur.

CHAPTER III – METHODOLOGY

Introduction

This chapter provides a description of the methodology used to address research questions. The research design, Human Subjects procedures, the research site, and criteria for survey sample selection are described. The medication administration error (MAE) database, from which the MAE data were drawn for secondary analysis, is also described. Measurement approaches used to conduct the secondary analysis of the MAE database and survey Registered Nurse BCMA users are discussed. Finally, data management and analysis strategies are presented.

The research questions were:

1. What is the incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) pre-implementation of BCMA?
2. What is the incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) post-implementation of BCMA?
3. What is the difference in incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) from pre-BCMA implementation to post-BCMA implementation?
4. What is the degree of adherence to the BCMA procedure by nurses?

Research Design

Since the implementation of BCMA occurred in the “natural course of events” a descriptive, comparative design was used (Polit & Hungler, 1997, p. 168). Selection of a descriptive design was appropriate because the data were known to be accessible from an existing database. The comparative dimension of the design was appropriate for research questions that asked about differences between groups. The design was also appropriate for the dependent variables (MAE incidence) that could be described, quantified, and compared. The descriptive design was also appropriate for analyzing the responses of RNs on the BCMA Utilization Questionnaire.

Setting

The setting for this study was a Veterans Health Affairs (VHA) medical center in the Southwestern United States. The medical center was established in 1928 as a public health hospital for veterans suffering from tuberculosis and exposure to toxic gases (Southern Arizona Veterans Administration Health Care System [SAVAHCS], 2003). More than 75 years later, it was a 302-bed tertiary-care medical center that serves veterans from several Southwestern states and Mexico. The medical center is a referral center for cardiology service and research is an integral service. In fiscal year 2002 it received \$4.4 million in research funding.

Eight medical-surgical units at the medical center were included in the study. The selection criteria for the units were: 1) likelihood of medication administration errors and 2) continuous use of BCMA during the post-implementation data collection period. Critical care and medical/surgical patient care units have been found to be associated

with more medication errors than other types of hospital patient care units (Classen, et al., 1991; Bates, Leape, & Petrycki, 1993). Patients on these types of units tend to be sicker and receive more medications per day from classifications associated with medication error incidence in contrast to units that serve obstetrical or psychiatric patients.

Medication classifications commonly associated with medication errors include analgesics and narcotics, antibiotics, cardiovascular, antitumor, anticoagulants and bronchodilators (Classen, et al.; Leape, et al., 1991; Bates, et al.).

The eight patient care units that were included in the study were surgical, medical, cardiac, critical care, intermediate care step down, sub-acute rehabilitation, hospice, and interim care. The surgical unit had a bed capacity of 27. Patient surgical procedures included open heart, vascular, craniectomies, laminectomies, colostomies, and other gastrointestinal surgeries. The medical unit had a bed capacity of 30 patients with conditions including chronic obstructive pulmonary disease (COPD), pneumonia, diabetes, tuberculosis, acute alcohol or drug withdrawal and pancreatitis. The cardiac unit had a bed capacity of 12 and admitted patients with a variety of cardio-vascular diagnoses including rule/out myocardial infarction, unstable angina, arrhythmias, and congestive heart failure (CHF). The critical care unit had a bed capacity of 19 patients with a range of medical and surgical conditions. The intermediate care step down unit had a bed capacity of 6 and served patients transitioning from critical care or the operating room to the medical, cardiac or surgical units. The sub-acute rehabilitation unit had a bed capacity of 18. The predominant patient conditions were hip and knee replacements, cerebral vascular accidents, and spinal cord related injuries. The hospice

unit had 18 beds for patients receiving terminal, palliative, and respite care. The interim care unit had a bed capacity of 38 and served patients with diagnoses such as post-operative wounds, CHF, and COPD. Comparisons of this study's findings to other studies are limited due to the inclusion of the sub-acute rehabilitation and hospice units because these are not units included in previously cited research. The sub-acute rehabilitation unit was included due to the increasing number of patients with medically complex conditions in addition to rehabilitation needs. The hospice unit was included due to the routine use of narcotics and analgesics, a category of medication associated with increased risk of medication errors.

Data

The data for research questions 1, 2 and 3 were individual medication administration errors derived from the hospital's MAE database. The data for research question 4 were Registered Nurse (RN) BCMA users from the eight study units.

Medication Administration Errors

All MAEs for six months immediately prior to BCMA implementation data (Time 1) and for a more current six months after BCMA implementation (Time 2) were extracted from the medical center's Incident Report Database to address research questions 1, 2, and 3. An administrative database for patient-days was used to calculate MAE incidence for research questions 1, 2, and 3.

The primary criterion for the selection of MAE from the Incident Report database was based on the medical center's definitions. The medical center defined MAEs as not meeting one of the 5 Rights: patient, drug, dose, time, or route. These categories of

MAEs were congruent with those in the medical center's Incident Report database, i.e., wrong patient, wrong medication, wrong dose, wrong time, and wrong route. An assumption of the study was that these categorical definitions were applied consistently as the MAEs were entered into the database by persons discovering an error and by analysts responsible for database queries and reports.

Research questions 1 and 2 were addressed by describing MAE incidence from a six month period (Time 1) prior to the introduction of BCMA and from a second six month period (Time 2) approximately 4 years later in the same setting. The MAE data were examined using frequency distributions. As reflected in Table 2, there were a total of thirty nine MAEs reported in Time 1 and forty four MAEs in Time 2.

TABLE 2. Number and Frequency of Medication Administration Errors at Time 1 and Time 2

TYPE OF MEDICATION ADMINISTRATION ERROR	TIME 1		TIME 2	
	N	FREQUENCY	N	FREQUENCY
Wrong Patient	11	28%	7	16%
Wrong Medication	8	21%	11	25%
Wrong Dose	11	28%	7	16%
Wrong Time	8	21%	10	23%
Wrong Route	1	2%	9	21%
TOTAL	39		44	

At Time 1, the fewest errors were reported for wrong route ($n = 1$) with the greatest reported for wrong patient and wrong dose ($n = 11$). At Time 2, the fewest errors were reported for wrong patient and wrong dose ($n = 7$) with the greatest number of

errors reported for wrong medication (11). Two MAE types decreased from Time 1 to Time 2 (wrong patient and wrong dose); the remaining three types increased from Time 1 to Time 2 (wrong medication, wrong time, and wrong route).

Patient-days data were obtained to standardize comparison of MAE incidence. Patient-days data were an appropriate denominator for calculating medication administration error incidence and had been utilized in previous medication error research (Bates, et al., 1993; Bates, Boyle, et al., 1995; Bates, Cullen, et al., 1995). As shown in Table 3, there were a total of 23,251 patient-days on the eight study units at Time 1 with a mean of 2,906.38 and a range from 755 to 5,544 days.

TABLE 3. Number, Mean, and Range of Patient-Days at Time 1 and Time 2

	N	MEAN	RANGE
Time 1	23,251	2906.38	755 - 5544
Time 2	25,878	3234.75	755 - 6248

At Time 2, total patient-days were 25,878 with a mean of 3,234.75 and a range from 755 to 6,248 days.

Survey

The fourth research question on degree of adherence to the BCMA procedure was intended to provide a contextual perspective of how BCMA had been incorporated as a routine medication administration practice in nursing. The data for research question 4 was obtained from RNs assigned to the eight study units. The BCMA Utilization

Questionnaire Section I, BCMA User Profile, was used to collect specific demographic information about the RNs (Appendix A).

The criterion for RN eligibility was that they worked with BCMA on those units during the complete six month post-implementation period. Only RNs were asked to complete the questionnaire because the critical care, intermediate care step down and cardiac units were staffed exclusively with RNs. The remaining units (medical, surgical, rehabilitation, hospice and interim care) utilized a team nursing model with LPNs as medication nurses. While on these units LPNs might have used BCMA more routinely than RNs. However, an RN supervised that activity, was accountable for how the procedure was carried out, and were assumed to be knowledgeable about how LPNs incorporated BCMA as a routine medication administration practice. In addition, LPNs did not administer all categories of medications due to licensure restrictions.

One hundred and thirty four survey packets were distributed and forty nine usable packets were returned. This represented a response rate of 37%. The rate limited generalizability of findings. Lower response rates are not uncommon for mailed surveys (Trochim, 2000). Analysis of those RNs who did not participate was not possible due to the lack of identifying individual or unit information.

Seven respondents did not meet the length of experience with BCMA requirement and were not eligible to be included. Two returned surveys included questionable responses (one indicating experience beyond availability of BCMA and the other stating “1 year or 5 months” as a response to how long they had used BCMA) so no length of time was entered for either. However, those respondents were assumed to have worked

with BCMA for more than 6 months so responses to all other items were used. All responses given as *Years* were converted to *Months* for calculation purposes. Other decisions made about responses were collected on a data management record in order to interpret all responses consistently.

As displayed in Table 4, RNs (n = 49) reported using BCMA for a range of 6 to 84 months, with a mean of 31.83 months, or 2 years and 8 months.

TABLE 4. Demographics of RNs Using BCMA

ITEM	FREQUENCY	%
2. What initial training did you receive on BCMA?		
Inservice	24	40%
New Employee Orientation	20	33%
Unit Orientation	16	27%
Other	3	5%
Total responses*	60	
3. How often do you use BCMA?		
Less Than Once Per Shift	3	6%
Once Per Shift	4	8%
More Than Once Per Shift	38	75%
Other	6	18%
Total responses*	51	
4. For what purposes do you use BCMA?		
Routine & PRN, not including IVs	27	39%
PRN Only	6	9%
IVs Only	9	13%
Other	8	11%
Routine, PRN, and IVs	20	29%
Total responses*	70	

(* Some RNs selected more than one response)

Responses to question 2 indicated that initial BCMA training was received at inservices (n = 24, 40%), followed by new employee orientation (n = 20, 33%) and unit-specific training (n = 16, 27%).

Responses to question 3 revealed that the predominant RN usage of BCMA was more than once per shift (n = 38, 75%), followed by once per shift (n = 4, 8%) and less than once a shift (n = 3, 6%). Five (18%) of the 6 *Other* responses included a written comment about using BCMA multiple times per shift.

The majority (n = 27, 39%) of responses to question 4 indicated BCMA was used to administer routine and PRN medications. BCMA was used for only IVs (n = 9, 13%) and only PRN medication (n = 6, 9%) less often. BCMA was used by 29% of RNs (n = 20) for routine, PRN, and IVs medication administration.

Overall demographic data indicated that RNs were experienced BCMA users and that they had received extensive training in the use of the system. They also reported frequent use of the system during the medication administration process.

Measurement

Two measurement approaches were used in the study. MAE secondary data from a pre-existing medical center database were used to answer research questions 1, 2 and 3, and a survey questionnaire, designed specifically for the study, was used to answer research question 4. Table 5 displays the constructs, variables, and measures used in the study, which will be discussed in the following section.

TABLE 5. Operationalization of Study Variables

RESEARCH QUESTIONS	CONSTRUCT	VARIABLES	MEASURE	TIME 1 Pre- implementation of BCMA	TIME 2 Post- implementation of BCMA
1, 2 & 3	BCMA Consequences	Medication administration error incidence	Wrong patient Wrong medication Wrong dose Wrong time Wrong route MAE Incidence	X X X X X X	X X X X X X
4	Adherence to BCMA	BCMA procedure adherence	Survey		X

Medication Administration Errors

The research construct for questions 1, 2, and 3 was BCMA Consequences. In this study BCMA Consequences were defined as medication administration errors. There were five types of MAE: wrong patient, wrong medication, wrong dose, wrong time, and wrong route. Since one of the primary purposes of BCMA was to prevent medication errors occurring during the administration phase, MAE incidence was the variable of interest.

The pre-implementation data point (T1) included the six months immediately prior to BCMA implementation in April 2000, from October 1, 1999 through March 31, 2000. Six months of data were anticipated as necessary to obtain sufficient data for analysis, due to the small volume of MAEs in the Incident Report database. From 1996 through 2001 the annual range of medication errors was 108 to 158 for all inpatient units at this setting.

Following implementation of BCMA, Time 2 (T2) data were included from June 1, 2004 through November 30, 2004, the most recent and complete 6 months of data available at the time of analysis. The ex post facto design of the study did not allow for control for changes between time periods in procedures, personnel, staffing patterns, and other variables that could have been expected to influence medication administration errors. The months for Time 2 were selected to describe the most current MAE data available.

The study's timeframe reflected the natural timeline of BCMA implementation. Extending the elapsed time between pre- and post-implementation comparison has been supported by researchers who recognize it may take an extended time, even years, to identify the impact of innovation (Rogers, 1995; Blignaut, McDonald & Tolmie, 2001).

Additional justification for using the most current data for T2 was that 1) critical care units did not implement BCMA until 2002 because the system had not originally been designed for intravenous fluids and medications. Critical care units had been found to experience a greater incidence of medication errors so to exclude these units would also have affected the volume of errors available for analysis (Classen, et al., 1991; Bates, et al., 1993). Secondly, measuring MAE at Time 2 ensured that RNs on those units would have experienced BCMA as technology routinely used in their medication administration practice.

Using secondary data had important implications for the study. Advantages of using secondary data included: 1) no patients had to be enrolled and therefore risks of any adverse impact on these individuals were avoided; 2) data were easily accessible from

existing databases; 3) this avoided introduction of investigator bias because no subjective interpretation of types of MAE was required; and 4) data were complete since all reported MAE were included (Krowchuk, Moore, & Richardson, 1995; McEvoy, 1999).

Threats to internal reliability were the inherent disadvantages of using an existing source of data. These threats included potential assessment bias and a lack of opportunity to ask questions about data and the context of data collection (Krowchuk, et al., 1995; McEvoy, 1999). Assessment bias may have been introduced by staff, following VHA procedures, that made the initial error report and by quality assurance staff who reviewed and categorized medication administration errors according to type of error. Reporting staff members made a decision that an error had occurred, based on their interpretation of a medication administration event, which may have reflected an individual's bias regarding what is reportable and what is an error. The Incident Report format asks for narrative description of errors instead of selecting the type of error from a list of options. Quality assurance staff that was responsible for data entry and generating reports determined what type of MAE had occurred based on their interpretation of the narrative, providing another point at which assessment bias might have been introduced.

The decision to report MAE could have been influenced by an individual's knowledge of definitions of errors, or by organizational culture regarding error reporting. Despite the recommendation of the Institute of Medicine and researchers to create organizational cultures of safety, fear of reprisal has continued to influence the extent of self-reporting (Leape, et al., 1995; Kohn, et al., 2000).

Another threat to reliability is that data collection via a self report process such as incident reports has been recognized as the least reliable MAE detection method (Barker & McConnell, 1962; Classen, et al., 1991; Flynn, Barker, Pepper, Bates, & Mikeal, 2002). This position was supported in a study that compared the number of adverse drug events identified by a computer-based adverse event monitor (45%) with chart review (65%) and prompted self-reporting (4%) (Jha, et al., 1998). Chart reviews have been considered the “gold standard” of detection (Bates, et al., 2003). However, self-report is the least costly detection approach and is the source of MAE data in VHA medical centers.

The retrospective nature of the data prevented any opportunity for the investigator to question the reporting and analysis staff or to learn more about contextual elements surrounding data collection (Krowchuk, et al., 1995; McEvoy, 1999). While personnel reviewing original incident reports may have had an opportunity to gather more descriptive information, that option was not possible in this study.

The primary assumptions in this study were that study unit health care providers documented all MAE via incident reports for the identified study time periods and that these MAEs were consistently classified correctly.

Survey

Section I is a BCMA User Profile that is used to collect respondent demographic data. This section was described in the survey sample section.

The BCMA Utilization Questionnaire Section II, BCMA Usage Procedure, was developed to measure the second study construct, the degree of adherence to the BCMA

procedure by RN staff (Appendix A). This construct referred to the medical center's BCMA procedure and how closely nurses adhered to this procedure, an indicator for the last stage of the ODOI framework, *routinizing*. For measurement purposes, adherence was defined as the extent to which RNs followed BCMA procedure and was measured on a five point likert-type scale.

The BCMA Utilization Questionnaire Section II is comprised of twelve items with a response range of 0 = Never to 4 = Always. Items were paraphrased statements taken from the medical center's procedure for medication administration with BCMA (SAVAHCS, Inpatient Medication and Treatment Orders, 2002). The higher the rating, the more agreement by RN respondents that procedure was followed by nurses on their unit. Initial drafts of the BCMA Utilization Questionnaire were reviewed by nursing managers at the study setting to estimate whether the BCMA procedure items reflected the practice of using BCMA for content validity (Trochim, 2000). The managers were appropriate reviewers because they were responsible for ensuring RNs were adequately oriented and trained to use BCMA, and that the RNs followed facility procedures. Reliability analysis estimated a Cronbach's alpha of .78 for all responses from twelve items, exceeding the usual range criterion of .30 to .70 (Cronbach, 1951).

Data Collection

Two data collection strategies were used in the study. First, secondary MAE data were extracted from the medical center's MAE database to address research questions 1, 2, and 3. Second, a survey process was used to address research question 4. These two data collection approaches are described in the following sections. Human subjects

approval was obtained from the University of Arizona's Internal Review Board and the SAVAHCS Research and Development Department prior to data collection activities (Appendix B).

Medication Administration Errors

Permission to obtain medication administration error and patient-days data was obtained from the SAVAHCS Nurse Executive in a letter of approval (Appendix C). Prior to releasing the MAE and patient-days data, medical center personnel formatted both as delimited databases in compliance with the Health Insurance Portability and Accountability Act (HIPAA) of 2000 (Centers for Medicare and Medicaid Services, 2002). MAE data were not identifiable by specific date, only by time period. Patient-days data consisted of only unit names, Time 1 and Time 2 months, and data. All data were entered by the investigator into a password-protected computer network file directory.

Medication administration error and the patient-days data used to calculate MAE incidence were originally collected by employees of the medical center. The medical center's procedure for reporting MAEs required the health care provider discovering an error to initiate documentation via the medical center's electronic Incident Report database module (SAVAHCS, Automated Incident Report, 2002). The report prompted the writer to enter narrative documentation describing the error. A quality improvement staff member reviewed each incident and made a subjective determination of the category of medication error. The final determination of MAE type was confirmed by a supervisory physician who was required to sign off on the report.

Patient-days were available in an administrative database and were used to calculate MAE incidence for research questions 1, 2, and 3. Clerical staff members from every nursing unit were responsible for entering patient admission, transfer and discharge dates from which patient-days was calculated. Data were retained in a VISTA Fileman database (DVA Office of Information, 2002). An administrative staff member utilized a template to query the database on a monthly basis for a report named “Ward Stats”. Patient-days were one element of this report.

Survey

A survey of nursing staff was conducted to measure the extent of adherence by Registered Nurses to written BCMA procedure. Steps taken to avoid fostering a sense of coercion among the nurses included a disclaimer (Appendix D) informing them that their participation was voluntary, that only the investigator would have access to their individual responses, and that no personal identifying information was being collected. A list of RNs assigned to study units was obtained from the medical center to guide survey distribution to eligible RNs.

The study was announced to potential subjects by the Nurse Executive in an email sent to RNs and managers on study units. Questionnaires were distributed with the disclaimer and a return envelope in a sealed envelope addressed to each RN. The return envelope’s label stated only the investigator’s name and facility address for internal mail return.

There are a number of advantages to using a mailed questionnaire in comparison to other self-report methods (Trochim, 2000). Privacy concerning subjects’ identification

was more easily maintained with the mailed survey than with in-person or telephone contacts; longer response categories could have been utilized than compared to verbal survey; and mailed surveys were relatively inexpensive in terms of financial and human resources compared with in-person or telephone surveys. Further, respondents controlled how much time they wanted to consider their answers.

Disadvantages of using a mailed survey that might have impacted this study could be characterized by a lack of flexibility. For example, without personal contact the investigator was unable to provide further information about the study or item clarification (Trochim, 2000). The lower response rate, when compared to some other methods, was another weakness that has been associated with mailed surveys. Anticipating a potentially lower response rate, this study included a reminder email sent to RNs one week after survey packet distribution. In addition, data collection was extended one week to allow RNs more time to complete the questionnaire and return them.

Data Management and Analysis

Specific data management and analysis procedures were used for the two study components. The following sections will summarize these procedures for both MAE and survey data management and analysis.

Medication Administration Errors

The individual level of analysis was used to describe the incidence of five types of MAE at T1 and T2 on each unit to answer research questions 1 and 2. Research question 3 was addressed with comparative analysis of T1 and T2 MAE incidence for five types of MAE on each unit. Research question 4 was answered by descriptive analysis of questionnaire responses.

Research Questions One and Two

Individual level of analysis was used on MAE data using descriptive statistics. Patient-days, which have previously been utilized in medication error research to calculate incidence, were used to determine MAE incidence (Bates, Boyle, et al., 1995). One unit had the same total number of patient-days (N=755) for Time 1 and Time 2; however the month by month data were unique. Data entry by the investigator into an electronic workbook was compared to the original data and no errors found.

MAE data were visually inspected for missing and inconsistent values, such as less than whole numbers and very high values (>20). For one study unit, no type of MAE was reported in Time 2. The employee who created the database was contacted and confirmed that this was correct and that no MAE reports had been submitted. Next, data entry by the investigator into an electronic workbook was compared to the original data and no errors were identified. The MAE incidence data from all study units for T1 and T2 by type of MAE were calculated as N/Patient-Days times 1000.

Research Question Three

To answer research question 3, a comparative analysis was conducted to examine differences in the mean incidence of each type of MAE at two periods of time across units. An independent samples t-test was conducted to determine if there was a statistically significant difference ($p < .05$) for any type of MAE. The independent samples t-test was selected as the appropriate parametric statistic because MAE data were from two mutually exclusive groups and were only collected from two time periods.

Survey

Questionnaires were reviewed and assigned an identification number prior to data entry in the Statistical Package for Social Services (SPSS) v. 12 (SPSS, Inc., 2003). Survey data were analyzed by descriptive statistics. All data were examined prior to data entry and analysis. A record was created of all comments and item response changes added to individual questionnaires. Unanswered items were coded as "9". Central tendency and variance were run on each item and no wrong values or outliers were identified. Accuracy of data entry for both sections was confirmed by inspection of every 5th questionnaire (20%) and no errors were found.

Responses from all RNs on all units were described by mean, standard deviation and range. The mean for each item was labeled as the mean item adherence score.

Summary

A descriptive comparative design was used to examine the incidence of MAEs before and after implementation of BCMA in an urban medical center. The data for research questions 1, 2 and 3 were individual MAE and the data for research question 4

were Registered Nurses from eight study units. Human subjects approval was obtained prior to accessing and collecting data. MAE data were obtained from an existing Incident Report Database provided in delimited format. Patient-days data were used as the denominator to calculate MAE incidence. Secondary data analysis quality issues were identified. A BCMA procedure questionnaire was created and reliability of the tool reported. RNs from units that met study criteria and who were assigned to the participating units during the second MAE data collection period were asked to complete the questionnaire. Survey quality issues were presented. Data management was described. Data analysis was conducted at the individual level using descriptive and comparative techniques. Changes in MAE incidence between Time 1 and Time 2 were analyzed using an independent sample t-test.

CHAPTER IV - RESULTS

Introduction

Secondary data on five types of medication administration errors (MAE) (wrong patient, wrong medication, wrong dose, wrong time, and wrong route) were obtained at two time periods. Those data and patient-days data were transformed into MAE incidence. Survey data were collected from Registered Nurses (RN) BCMA users on study units to address research question 4. Survey findings describe current BCMA use and the degree of practice adherence to the medical center BCMA usage policy. This chapter will present and discuss results for the four primary study questions.

Research Questions One and Two

As displayed in Table 6, the MAE incidences were calculated using the total number of patient-days from the eight study units for T1 and T2 and multiplying by 1000.

TABLE 6. MAE Incidence per 1000 Patient-Days at Time 1 and Time 2

MAE CATEGORY	TIME 1		TIME 2		SIGNIFICANCE
	MAE	INCIDENCE	MAE	INCIDENCE	
Wrong Patient	11	0.47	7	0.27	.497
Wrong Medication	8	0.34	11	0.43	.664
Wrong Dose	11	0.47	7	0.27	.346
Wrong Time	8	0.34	10	0.39	.736
Wrong Route	1	0.04	9	0.35	.031*
TOTAL	39		44		

*p < .05

Research question 1 asked what is the incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) pre-implementation of BCMA. The number of MAE per category was divided by a total of 23,551 patient-days from eight study units at Time 1. The MAE incidences for T1 ranged from least for wrong route (0.04), increasing to wrong medication and wrong time (0.34) and greatest for wrong patient and wrong dose (0.47).

Research question 2 asked what is the incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) post-implementation of BCMA. The number of MAE per category was divided by a total of 25,878 patient-days from eight study units at Time 2. The MAEs with the smallest incidence at Time 2 were wrong patient and wrong dose (0.27) followed by wrong route (0.35), wrong time (0.39) and wrong medication (0.43).

Research Question Three

Research question 3 asked what is the difference in incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) from pre-BCMA implementation to post-BCMA implementation. An independent samples t-test demonstrated a significant difference $t_{14} = -2.397$, $p = .031$ for wrong route ($p < 0.05$). Wrong route error incidence increased from Time 1 to Time 2 (T1 = 0.04 to T2 = 0.35). While not statistically significant, the findings of decreased MAE incidence for wrong patient and wrong dose from Time 1 to Time 2 were clinically of interest since fewer MAEs promote patient safety. Also of clinical importance were

increases in MAE incidence at Time 2 for wrong medication, wrong time and wrong route.

BCMA is designed to prevent the wrong medication from being administered. If the scanning of bar codes on the patient's armband and the medication package do not match, this information is displayed on the Virtual Due List (VDL) screen. At this time no data are available about near-misses (errors that were about to occur but were caught) averted due to that information. The increase in reported wrong medication errors could be attributed to increased awareness among nurses of the importance of reporting errors.

Wrong time errors may be due to giving a medication outside of the accepted time range, but can also occur if there are errors in the order, for example not specifying if a once-daily dose must be given at 9 AM or 9 PM, or due to dispensing if there are delays in filling a new order. Wrong time errors can also occur if the nurse does not know in advance every time medications are due for a patient. This type of error may be prevented by a routine practice of running a time-due report at the beginning of each shift. Similarly medications not given may be discovered by running a different report at the end of the shift. The later report may have contributed to the increase in wrong time errors.

BCMA system programming does not identify or capture conflicting routes so prevention of this type of error is dependent on nursing practice and adherence to the 5 Rights of medication administration: right patient, right medication, right dose, right time, and right route. The increase in this category of MAE may indicate nurses are relying more on information on the computer screen than on the 5 Rights and their own critical thinking.

Research Question Four

The final research question asked what is the degree of adherence to the BCMA procedure by nurses. This question was included to provide a description of RNs' current use of BCMA and their adherence to the medical center's BCMA procedure reflecting the extent to which the BCMA system had become a *routine* part of medication administration practice. *Routinizing* is the last stage in ODOI theory, and represents when an innovation has been incorporated into the workflow and is no longer viewed as new (Rogers, 1995). The findings from the BCMA Utilization Questionnaire Section II are displayed on Table 7.

TABLE 7. Description of BCMA Utilization Questionnaire Section II Responses*

ITEMS	RESPONSES n=49	MEAN (M) ITEM ADHERENCE SCORE	(SD)	RANGE
1. Nurses log on to BCMA before administering medications.	48	3.63	0.67	2 - 4
2. Nurses move the medication cart to the room or bedside of each patient.	47	2.06	1.51	0 - 4
3. Nurses scan the bar code on the wristband of every patient.	49	3.06	0.99	1 - 4
4. Nurses confirm the Right Patient verbally.	49	3.16	1.07	0 - 4
5. Nurses confirm the Right Patient by checking the BCMA screen.	49	3.80	0.41	3 - 4
6. Nurses select the appropriate medication from the Virtual Due List (VDL).	48	3.67	0.78	0 - 4
7. Medications are verified by an RN prior to administration of the first dose.	49	3.53	0.74	1 - 4
8. Nurses scan the medication bar code.	49	3.35	0.60	2 - 4
9. Nurses check for agreement between the medication package and VDL.	49	3.55	0.82	0 - 4
10. Nurses act on any alerts and/or prompts.	48	3.54	0.74	1 - 4
11. Nurses check the VDL status column after scanning each medication to confirm authorization to administer.	49	3.63	0.64	2 - 4
12. Nurses document reasons a medication is: administered at the wrong time (more than 60 minutes before or after the scheduled time), held, or marked status is changed.	49	3.47	0.79	1 - 4

*Item Response Scale = 0 (Never) to 4 (Always)

Nurses on the study units logged on to BCMA prior to administering medications ($M = 3.63$, $SD = 0.67$) with responses ranging from 2 to 4 (0 = Never, 4 = Always scale). One RN wrote in “if need be” indicating that there may be situations when a nurse decides using BCMA is not necessary. Adherence scores for the second item regarding moving the medication cart to the patient room or bedside had the lowest mean ($M = 2.06$, $SD = 1.51$) with a range of 0 to 4. Comments written in for this item included several from the same unit reporting their unit doesn’t use medication carts because their computers are mounted outside of patient rooms with medications at the patient’s bedside. Another theme in comments for this item was that the carts were stationed in hallways on unnamed units with one RN noting carts may not work when moved.

The next three items, 3, 4, and 5, concerned identifying the patient by scanning the wristband bar code ($M = 3.06$, $SD = 0.99$, range 1 - 4), verbally confirming the patient ($M = 3.16$, $SD = 1.07$, range 1 - 4) and confirming the right patient on the BCMA screen ($M = 3.8$, $SD = 0.41$, range 3 - 4). Based on these scores the right patient is more likely to be confirmed by looking at the computer display than by scanning or verbally communicating with the patient. Comments of interest for these items pointed out that some patients are unable to communicate, for example due to intubation, while another RN reported keeping the patient’s wristband at the unit’s counter.

For item 6, RNs indicated that nurses on their units used the VDL list to determine which medications were due ($M = 3.67$, $SD = 0.78$), although the range of 0 – 4 indicates a few RNs did not. The low end responses may be a reflection of written comments for this item and subsequent items that indicated that some RNs didn’t know

what was meant by VDL. There was slightly less agreement with item 7 about RNs verifying medication before administering the first dose ($M = 3.53$, $SD = 0.74$, range 1 – 4).

Item 8 asked about scanning the medication bar code ($M = 3.35$, $SD = 0.60$, range 2 – 4). In contrast to item 3 on scanning the patient wristband bar code, nurses on the study units were more likely to scan the medication than the patient with less variation in performing that task, despite several comments about problems with scanning medications due to: 1) no scanner, 2) unreliable bar codes, or 3) unreliable scanning. For item 9, there was high adherence to checking for agreement between the medication package and the VDL screen after scanning ($M = 3.55$, $SD = 0.82$, range 0 – 4) although there was more variation in this behavior as evidenced by the range of responses. Item 11 indicated that there was greater adherence by nurses to checking that the VDL screen authorized administration ($M = 3.63$, $SD = 0.64$, range 2 - 4) than for items 8 and 9. In the absence of scanning or accurate bar codes, nurses may type in an identification number for the patient and still get confirmation of a patient-medication match.

The items 10 and 12 are about specific BCMA functions. For item 10, nurses on the study units usually responded to BCMA prompts or alerts ($M = 3.54$, $SD = .74$, 1 – 4) although there was one comment that stated these were “generally meaningless, time consuming”. Receiving slightly less agreement was item 12 ($M = 3.47$, $SD = 0.79$, range 1 – 4) on documenting when medication was administered early, late, held or having to change an automatic ‘given’ documentation, for example if a patient refuses to take a

medication after the medication has been scanned and matched within the BCMA program.

This last item is of further importance to nursing practice because the medication administration documentation function of BCMA violates a standard of nursing practice that no medications be documented as given until the nurse has witnessed that the medication given and received by the patient. This function of BCMA was included to improve documentation of medication administration by nurses. If, for example, a patient refuses to accept a medication after scanning has confirmed the patient-medication match, a nurse must correct the entry. Documentation in BCMA occurs in a different computer module, therefore, to make corrections a nurse must access another nursing module either during the medication administration process or afterwards, adding to the memory burden and time required to make the corrections.

Summary

This chapter presented the results of data analysis. Findings for research questions 1 and 2 were described for five types of medication administration error (MAE) incidence data at Time 1 and Time 2. Change in MAE incidence over time was analyzed by independent samples t-test to answer research question 3. Statistically and non-statistically significant differences were discussed. The findings of the BCMA Utilization Questionnaire on BCMA Usage were reported to answer research question 4.

CHAPTER V – DISCUSSION

Introduction

In this chapter the findings for research questions 1 and 2 are discussed and compared with findings from bar code and BCMA literature cited in Chapter 2. Limitations of comparisons of those descriptions are identified. Research question 3 findings are discussed and interpreted in terms of statistical and clinical significance. Research question 4 findings from the BCMA Utilization Questionnaire are addressed, highlighting problems that are appropriate for systems level intervention. A serendipitous finding related to the perceived and actual functions of BCMA is presented. The significance of this research in relation to information technology and nursing practice is offered. The chapter concludes with a discussion of implications for practice and future research.

Research Question One

The findings for research question 1, what is the incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) pre-implementation of BCMA, are compared with other similar research findings in Table 8.

TABLE 8. MAE Frequencies for Time 1 and Previous Research

MAE Category	TIME 1	Bates, Boyle, et al., 1995	Leape, et al., 1995	Barker, et al., 2002
Wrong medication	21%	-	12%	-
Wrong dose	28%	53%	27%	17%
Wrong time	21%	8%	7%	43%
Wrong route	2%	5%	2%	-

(Note. Dash mark indicates data not reported for that category.)

In this table the actual number of errors was used rather than incidence as a basis of comparison. The frequency of errors in the comparison studies was based on the total number of MAE detected from analysis of medication orders (Bates, Boyle, et al., 1995), voluntary report and chart review (Leape, et al., 1995) and direct observation (Barker, et al., 2002). The frequency of wrong patient was not reported in any of the comparison studies. Barker, et al. did not report wrong medication or wrong route errors using those terms. MAE frequencies for wrong medication reported by Leape, et al. (12%) was less than at Time 1 of this study (21%). Wrong dose error frequencies ranged from 17% (Barker, et al.) to 53% (Bates, Boyle, et al.). Frequency for wrong time ranged from 7% (Leape, et al.) to 43% (Barker, et al.). This study and the Leape, et al. study reported the same rate for wrong route (2%), while Bates, Boyle, et al. reported a frequency of 5%.

Variations in findings across these studies highlighted limitations due to research methods. In two of the comparison studies prospective data were collected from convenience samples of admissions to three units in one hospital (Bates, Boyle, et al., 1995), and admissions to eleven units in two hospitals (Leape, 1995). The third study

had a randomized sample of health care facilities in two states (Barker, et al., 2002). Adverse drug event data were used to identify MAEs and were collected from medication orders in Bates, Boyle, et al.'s study, and from chart review and prompted self-report in the Leape, et al. study. Only Barker, et al. collected MAE through direct observation. This diversity of methods underscores the difficulty in attempting comparisons of MAE across studies and emphasizes the need for continued research to more accurately describe the extent of MAEs.

Research Question Two

Research question 2 asked what is the incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) post-implementation of BCMA. The percent of change between Time 1 and Time 2 was calculated from the MAE frequencies since this was what the three studies reviewed in Chapter 2 reported to describe changes following implementation of BCMA, as shown in Table 9.

TABLE 9. Percent Change in MAE after Implementation of Bar Code Medication Administration Programs

MAE Category	TIME 2	Puckett, 1995	Johnson, et al., 2002	Thielke, 2003
Wrong patient	↓ 12%	0%	↓ 93%	-
Wrong medication	↑ 4%	↓ 33%	↓ 75%	↓ 51%
Wrong dose	↓ 12%	0%	↓ 62%	↓ 100%
Wrong time	↑ 2 %	↓ 43%	↓ 87%	↓ 77%

(Note. Dash mark indicates data not reported for that category)

The percent of change for wrong patient errors ranged from no change (Puckett, 1995) to 93% (Johnson, et al., 2002). Wrong medication errors decreased 33% (Puckett) to 75% (Johnson, et al.) in contrast to the increase of 4% for this study. Wrong dose errors decreased from 12% in this study to 100% (Thielke, 2003), with Puckett reporting no change. Wrong time errors decreased from 43% (Puckett) to 87% (Johnson, et al.) while this study showed a 2% increase in these errors. None of the post-implementation of BCMA studies reported on wrong route.

The inability to make meaningful comparisons with findings from Time 1, Time 2, and the cited literature was evident. In order to make meaningful comparisons studies such as these would benefit from citing explicit, standardized MAE definitions, with comparable error detection methods, sampling, settings, and measurement. And without baseline MAE data, the extent of changes no matter how analyzed will not be meaningful.

As found in the comparisons for research question 1, the extent of variations in methods across these studies constrained conclusions. The Puckett (1995) and Johnson, et al. (2002) studies' error data were collected from incident reports while Thielke (2003) reported using observation. None of the studies provided baseline pre-implementation MAE data. Convenience samples were used in each study: a regional medical center, the VHA medical center which created and piloted the BCMA prototype, and one unit in an academic medical center. No information was provided regarding definitions of errors.

These types of studies highlighting large and generally positive percentages of change represent some of the information available to adopters of bar code medication

administration programs in the industry media. The potential for bias among the authors exists based on reported relationships. Puckett's (1995) article did not indicate potential conflict of interest but Johnson, et al., (2002) were employees of a large government program which has incurred considerable expense with BCMA, and Thielke (2003) reported his facility was a beta test site, which could imply a special relationship between facility and vendor. Potential for bias should be considered when reviewing scientific and anecdotal literature about the effectiveness of bar coding for medication administration.

Research Question Three

Research question 3 asked what is the difference in incidence of medication administration errors (wrong patient, wrong medication, wrong dose, wrong time and wrong route) from pre-BCMA implementation to post-BCMA implementation. ODOI theory recognizes a range of consequences (outcomes) that are not solely due to completed adoption or *routinization*. This study identified a combination of outcomes: 1) desirable and anticipated, evidenced by decreased incidence of wrong patient and wrong dose errors, 2) undesirable and unanticipated, demonstrated by the increase of errors for medications, time and route, and 3) direct and indirect. Direct consequences are discovered in the changes required by BCMA for nursing medication administration practice.

Further conclusions are not possible due to the lack of control over other factors that may have impacted MAE occurrence in the interval between Time 1 and Time 2 such as changes in patient acuity, high risk medication usage, differences in skill mix and

nursing models on the study units, extent of nursing orientation to BCMA and changes in BCMA versions and procedures. Findings that supported the conclusion that BCMA met two of its intended goals, improving patient safety and decreasing medication errors, were lacking.

Future research on MAEs should be brought to a more robust level of analysis to explicate reliable and potentially generalizable descriptions of MAE. Future work would benefit from replicating aspects of the Barker, et al. (2002) study using direct observation, with randomized samples, of medication administration to detect errors. Multiple measurement points rather than a pre- and post-test design would provide more data for analysis.

Research Question Four

Research question 4 asked what is the degree of adherence to the BCMA procedure by nurses. This question was designed to provide a context for the Time 2 MAE incidence by describing how closely RN users of BCMA adhered to the BCMA usage steps in the medication administration procedure. This information was sought to inform the extent to which BCMA had become an accepted *routine*. An assumption of this study was that the greater the adherence to the BCMA usage procedure, the greater the impact on MAE incidence and the lower the MAE incidence.

Usability of BCMA

Although this was not a study of the BCMA process, the usability of BCMA and subsequent adherence of users has been a concern since implementation began, which the findings for research question 4 support. Some of the findings could be considered

indirect consequences of innovation adoption as described by Rogers (1995). Information technology adoption related problems related to network connectivity, changing patterns of communication among health care providers and unfamiliar software have contributed to a phenomenon known as a 'workaround' (Ash, et al., 2003). One definition of workarounds in the literature, "clever methods for getting done what the system does not let you do easily" acknowledges that usability issues may lead to adaptations of procedures to fit a specific environment (p. 195). Workarounds may occur for example if a procedural requirement makes a process inefficient or not in the best interests of patients. Lower adherence to some steps such as fixed computer workstations and unreliable functioning of portable carts when moved as barriers to that step were barriers beyond the control of individual nurses. Digressions such as these from the BCMA procedure, such as not moving the medication cart, could be anticipated to occur in the *clarifying* stage described in the ODOI theory. If not recognized early, workarounds can become a routine part of the BCMA medication administration practice. And just as workarounds can induce more opportunity for error, there are also concerns about technology-induced error, meaning that, even if BCMA is used correctly, unanticipated effects can occur (Patterson, Cook, & Render, 2002).

BCMA usability issues of BCMA technology have been reported specifically at this study's setting. A survey identified concerns of nursing staff that included difficulty maneuvering medication carts, difficulty scanning bar code armbands, and inability to view complete patient medication list on a single BCMA screen (Doyle & Rose, 2003).

The VHA has conducted several evaluations of BCMA to monitor the adoption

process and has identified changes needed in hardware, software, training, and procedures (BCMA Focus Team, 2001; Cordes, 2001; Patterson, et al., 2002; Patterson, Rogers, & Render, 2004). In response to those findings, revisions of BCMA have been occurring on a regular basis since 2002. This pattern suggests that the relationship between the *clarifying* and *routinizing* stages may be more iterative than the ODOI theory allows.

Adherence to BCMA

The findings for research question 4 suggested that, while overall adherence was high, some of the study's nurses did not follow all steps of the medication administration procedure that addressed BCMA, possibly making decisions of their own about the appropriateness for following procedure or not for individual patient care needs. Items confirming the right patient and right medication on the BCMA screen had high rates of adherence while RNs reported they were less likely to identify patients verbally and by scanning. In a critical care setting for example, a nurse may elect to not wake a sleeping patient for verbal confirmation or to position the arm with the wrist band so the scanner can be used

Some of the insights from these responses provide examples of how strategies for reducing or preventing MAEs, whether based in information technology or other methods, can negatively impact workflow and processes if sufficient pre-implementation analysis and formative evaluation post-implementation is not undertaken. Regardless of adherence ratings, both patient condition and equipment problems were barriers to full BCMA procedure adherence that represent organizational or systems level issues.

Recognizing systems level barriers to adherence is congruent with recommendations that health care organizations develop a culture of safety (Leape, et. al., 1995, Kohn, et al., 2000). A culture of safety promotes both the recognition that most errors are not due solely to individual mistakes and that reporting and responding to errors be done in a non-punitive manner. Since the late 1990's the VHA has been promoting a patient safety program under the guidance of the National Center for Patient Safety (Weeks and Bagian, 2000). A culture of safety has been advocated throughout the VHA network, and is specifically addressed in literature about BCMA (DVA Office of Information, 1999). The extent of awareness of a culture of safety among nurses could be a contributing factor to increased reporting of medication errors.

Adherence and Time 2 Findings

Findings were insufficient to support whether BCMA met two of its intended goals, improving patient safety and decreasing medication errors. In general with relatively high mean adherence scores, fewer MAEs of all types would be anticipated. Since more MAEs were reported, this raises the question of whether the survey respondents were demonstrating social acceptability by rating adherence to the BCMA procedure higher than actual usage would indicate in order to provide what they may believe to be the desired responses. However, many of the written comments appeared to be frank and intending to highlight problems or unrealistic expectations. The increase of MAEs considered with the range of responses on most of the questionnaire items is a snapshot of MAE reporting and BCMA usage on the study units several years after the implementation and adoption of this innovation. Rather than suggest that this is the

status at the end of a process, these findings may indicate the adoption process requires more time or that it is not as linear as ODOI indicates.

Serendipitous Findings

A discrepancy in VHA and SAVAHCS literature on BCMA was discovered after the statistical analysis was completed. The statistically significant finding for the increase in wrong route errors prompted further review of the functions of BCMA. VHA literature states that BCMA “validates that the medication is ordered, timely, and in the correct dose” (DVA Office of Information, p.1, 1999; DVA Office of Information, pp 6-7, 2002). However, in the SAVAHCS BCMA Training Guide Q & A section, it is stated that a “medication is scanned to assure it is the right drug, right dose, right route, for the right patient, at the right time” (p. 68, 2000). And the most recent SAVAHCS medication administration procedure states that the nurse will check “for agreement between the (medication) package and the VDL for Right Drug, Right Dose, and Right Route” (Inpatient Medication and Treatment Orders, p. 5, 2002). These differences in what BCMA is able to accomplish may be fostering unrealistic expectations of and reliance on BCMA. Although the medication administration process was not the focus of this study, accurate analysis of MAE outcomes remains dependent on an intervention that is stable and used in a manner consistent with its design.

Significance

The most significant contribution of this study was the focus on a patient medication safety approach designed to decrease medication errors. While few studies provide support for the effectiveness of BCMA and similar programs, bar coding for

medication administration has been recommended as a patient safety practice by the Agency for Health Care Practice Research, now the Agency for Healthcare Research and Quality (AHRQ) (2001). As evidenced by the studies reviewed here, the state of the science for research on bar code medication administration is primitive and has not progressed beyond descriptive design. The next area of significance however presents a major hurdle to advancing the sophistication of this research.

This study adds to informatics and nursing knowledge about the continued issues with reliable medication error detection methods. Continued reliance on self-report methods for research and quality improvement processes perpetuates unreliable databases and hinders efforts to promote cultures of safety. Regulatory bodies that create mandates based on findings from unreliable databases are also a concern. Archaic reporting methods are antithetical to a culture of safety.

This study also brought a unique and needed nursing perspective to information technology research in that it focused on a process primarily within nursing purview. Although medication safety research has benefited from interdisciplinary collaboration, those collaborations focused on medication safety technology such as computerized order entry or dispensing systems used predominately by physicians and pharmacists. Actual and potential adverse medical events that are preventable have increasingly become the outcomes of interest. From a nursing and informatics perspective it is of great importance to understand the actual scope of errors as a part of a comprehensive system analysis. Detailed definitions and enhanced data collection should be applied to collecting data on MAEs resulting in harm, MAEs not associated with harm, and near-misses.

This is particularly important when conclusions based on unreliable data are being used to select information technology solutions that then change nursing medication administration practice. Further, a culture of safety requires all errors, actual and potential should be identified and analyzed. It is not sufficient to base important and costly technology decisions on infrequent harmful events if more system-wide improvement is to be achieved.

Implications for Practice

The findings of this study have implications for improving medication error recognition and reporting in nursing practice at this setting and for future research on MAEs. Assumptions of uniform understanding and application of MAE definitions of by nurses should be addressed, as should MAE data collection.

Definitions

The current SAVAHCS medication administration procedure (2002) contains this definition:

A medication error includes, but is not limited to, the following occurrences:

1. A medication is administered to the wrong patient;
2. A medication is administered at the wrong time;
3. A medication is administered by the wrong route;
4. A medication is administered in the wrong dose;
5. The incorrect medication is administered;
6. A medication is administered in conflict with ordered instructions;
7. A medication is administered outside of the 2 hour administration window without valid justification as documented by BCMA comment;
8. A medication is ordered incorrectly.

By adopting a nationally recognized taxonomy of errors, the definition of medication administration errors could be given a broader context of error. The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP, 1998) has recommended the following definition:

A medication error is any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer. Such events may be related to professional practice, health care products, procedures, and systems, including prescribing; order communication; product labeling, packaging, and nomenclature; compounding; dispensing; distribution; administration; education; monitoring; and use. (p.1)

Fourteen categories of medication errors identified by NCC MERP (1998) may also suggest revisions for the SAVAHCS MAE definitions: dose omission, improper dose, wrong strength/concentration, wrong drug, wrong dosage form, wrong technique, wrong route of administration, wrong rate, wrong duration, wrong time, wrong patient, monitoring error, deteriorated drug error, and other.

Data Collection

Establishing clear and comprehensive definitions would provide a foundation for staff education on patient medication safety. Aligning the accepted definitions with the electronic Incident Report template and database would promote continuity of definitions and recognition of potential and actual errors.

Bates, et al. (2003) reviewed the literature of research using information technology-driven adverse event detection methods. They concluded that there is much promise for further development of tools utilizing event monitoring and natural language processing although the chart review remains the “gold standard.” The status of more

reliable and cost-effective data collection with computerized monitoring was not fully explored in this study but a possibility exists at SAVAHCS for an existing program that may be of benefit for capturing MAEs. The Adverse Event Tracking program is described as a module from which data can be extracted (SAVAHCS, 2003). Its primary focus is recognizing and reporting adverse drug reactions. Even if this particular program is not used, there are numerous innovative information technologies within the VHA that could be investigated for their medication administration error monitoring capacity. Another potential source of MAE data is the VHA's Computerized Patient Record System (CPRS) from which electronic nursing documentation may be accessible for exploration using natural language processing.

Implications for education include careful review and revision of training material to avoid conflicting statements about the capability of BCMA, and to emphasize critical thinking about the 5 Rights of medication administration. In addition, procedures for BCMA that cannot be accommodated due to unit environment or workflow should be studied further and addressed.

Theoretical Implications

Future research on MAEs and innovation technology may be better supported by sociotechnical theory than by Roger's ODOI theory (1995). Diffusion of innovation positions the technology as the focus that individuals and organizations are encouraged or persuaded to adopt, usually a top-down approach. It is a linear model that leaves little room for variation or iteration, both of which appear to be more necessary than not for innovation implementation and adoption. Sociotechnical theory also has been used to

guide technology adoption but has evolved over time to be more reflective of general systems theory's emphasis on the interrelatedness of parts (Berg, 1999). Berg describes health care as an interwoven, heterogeneous environment with complex roles and work practices. There is a need for cooperation with distributed decision-making among all health care providers in order to be immediately responsive to patient care needs which are dynamic and not usually satisfied by following rigid procedures. For example requiring scanning of armbands in all situations is not conducive to emergency situations when life saving medication must be administered *now*, not after scanning and reading information on the screen.

Sociotechnical theory applied to information technology adoption in health care requires that workflow be well understood by representatives from the entire network, not just those expected to be directly affected, due to the ripple affect of introducing change in systems. With a bottom-up approach information technology can be incorporated into health care environments that are better informed about the range of consequences that may occur.

Summary

This chapter compared and discussed Time 1 and Time 2 findings with previous research. Methodological limitations of those studies were identified. Findings for research question 3 on changes in MAAE incidence were discussed in relation to ODOI theory regarding consequences with recommendations for more rigorous study of outcomes. The results of the research question 4 survey were discussed, focusing on usability of and adherence to BCMA procedure. A serendipitous finding regarding

BCMA training material and wrong route was presented. The significance for nursing, informatics and patient safety research was described. Implication for practice focused on definitions and error detection methods. Finally, sociotechnical theory was proposed as a more appropriate framework for future evaluation of innovative technology such as BCMA.

APPENDIX A

QUESTIONNAIRE

BCMA Utilization Questionnaire

Section I: BCMA User Profile

Directions: Read each question and enter or mark the answer that best describes your use of BCMA. If "Other" is selected, provide an explanation.

1. How long have you used BCMA? _____ Year, or _____ Months

2. What initial training did you received on BCMA? (Select one)
 inservice prior to BCMA implementation
 new employee orientation
 unit orientation
 other: _____

3. How often do you use BCMA? (Select one)
 less than once every shift
 once every shift
 more than once each shift
 other: _____

4. For what purposes do you use BCMA? (Select one)
 routine and prn medication administration (not including IVs)
 PRN only
 IVs only
 Other: _____

Section II: BCMA Usage Procedure

Directions: Read each statement and circle the answer that best describes the medication administration process on the clinical unit on which you spend 50% or more of your time.

	Never Always				
1. Nurses log on to BCMA before administering medications.	0	1	2	3	4
2. Nurses move the medication cart to the room or bedside of each patient.	0	1	2	3	4
3. Nurses scan the bar code on the wristband of every patient.	0	1	2	3	4
4. Nurses confirm the Right Patient verbally.	0	1	2	3	4
5. Nurses confirm the Right Patient by checking the BCMA screen.	0	1	2	3	4
6. Nurses select the appropriate medication from the Virtual Due List (VDL).	0	1	2	3	4
7. Medications are verified by an RN prior to administration of the first dose.	0	1	2	3	4
8. Nurses scan the medication bar code.	0	1	2	3	4
9. Nurses check for agreement between the medication package and VDL.	0	1	2	3	4
10. Nurses act on any alerts and/or prompts.	0	1	2	3	4
11. Nurses check the VDL status column after scanning each medication to confirm authorization to administer.	0	1	2	3	4
12. Nurses document reasons a medication is: administered at the wrong time (more than 60 minutes before or after the scheduled time), held, or marked status is changed.	0	1	2	3	4

Return completed surveys to Mary Doyle at 3-11NH. Thank you for your participation.

APPENDIX B

HUMAN SUBJECTS APPROVAL

Human Subjects Protection Program
<http://www.irb.arizona.edu>

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17 September 2004

Mary Doyle, Ph.D. Candidate
Advisor: Rita Snyder, Ph.D.
College of Nursing
PO Box 210203

RE: IMPACT OF THE BAR CODE MEDICATION ADMINISTRATION (BCMA)
SYSTEM ON MEDICATION ADMINISTRATION ERRORS

Dear Ms. Doyle

We received documents concerning your above cited project. Regulations published by the U.S. Department of Health and Human Services [45 CFR Part 46.101(b) (2), (4)] exempt this type of research from review by our Institutional Review Board. **Note: A copy of your disclaimer form, with IRB approval stamp affixed, is enclosed for duplication and use in enrolling subjects.**

Exempt status is granted with the understanding that no further changes or additions will be made either to the procedures followed or to the consenting instrument used (copies of which we have on file) without the review and approval of the Human Subjects Committee and your College or Departmental Review Committee. Any research related physical or psychological harm to any subject must also be reported to each committee.

Thank you for informing us of your work. If you have any questions concerning the above, please contact this office.

Sincerely,



Rebecca Dahl, R.N., Ph.D.
Director
Human Subjects Protection Program

cc: Departmental/College Review Committee

Department of Veterans Affairs

Memorandum

Date: December 02, 2004

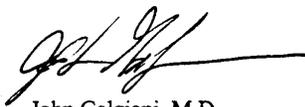
From: Chair, Research and Development Committee (151)

Subj: Review of Research Proposal

To: Mary D. Doyle, M.N., R.N. (3-11NH)

1. Your research proposal entitled "Impact of the Bar Code Medication Administration (BCMA) System on Medication Administration Errors" was reviewed by the following Research Committees on the dates indicated. The action taken by each Committee is shown. Your project number is 0002.

Research and Development Committee, 12/01/04. Approved



John Galgiani, M.D.

APPENDIX C

LETTERS OF PERMISSION



DEPARTMENT OF VETERANS AFFAIRS

In Reply Refer To: 3-11NH/678

November 26, 2003

Departmental Review Committee
College of Nursing
University of Arizona
Tucson, AZ 85721

Dear Committee Members:

This letter is to confirm I have given permission to doctoral candidate Mary D. Doyle, MN, RN to conduct her dissertation research at the Southern Arizona Veterans Administration Health Care System (SAVAHCS).

Sincerely,

A handwritten signature in cursive script that reads "Mary Walters".

Mary Walters, RN, MS
Nurse Executive
SAVAHCS
Tucson, Arizona 85723

**DEPARTMENT OF VETERANS AFFAIRS**

April 20, 2005

To Whom It May Concern:-

Mary D. Doyle, PhD, RN has been given my permission to use the Bar Code Medication Administration Diagram from the Southern Arizona Veterans Administration Health Care System (SAVAHCS) Training Guide, 2000 in her dissertation.

Sincerely,

A handwritten signature in cursive script that reads "Mary Walters".

Mary Walters, RN, MS
Nurse Executive
SAVAHCS
Tucson, Arizona 85723

APPENDIX D

DISCLAIMER

APPROVED BY UNIVERSITY OF AZ IRB.
THIS STAMP MUST APPEAR ON ALL
DOCUMENTS USED TO CONSENT SUBJECTS.

SUBJECT DISCLAIMER FORM

DATE: 09/17/04

Title of Project: The Impact of Bar Code Medication Administration (BCMA) on Medication Administration Errors

You are being invited to voluntarily participate in the above-titled research study. You are eligible to participate because you are an RN assigned to one of eight units that have been using BCMA for the last six months. The purpose of the study is to compare medication administration errors before and after the implementation of BCMA. This questionnaire will provide a description of nurses' medication administration practice using BCMA based on describing all the nurses' responses to each survey question.

SAVAHCS nursing leadership has reviewed and approves of this survey. The signature of Mary Walters is confirmation that you may complete the questionnaire on work time. Ms. Walters is also this study's co-principal investigator because the principal investigator does not meet the employment status required to conduct independent research within SAVAHCS. While the principal investigator, Mary Doyle, RN, MN, PhD Candidate, has worked at SAVAHCS in a per diem capacity in the past, she is currently focusing on her doctoral studies and has not worked there in approximately one year.

If you agree to participate, your participation will involve taking approximately 10 minutes of your work time to complete this questionnaire. You may choose not to answer some or all of the questions. However, it is crucial that your responses be as accurate as possible so the results can be properly described. Please place the completed questionnaire in the enclosed mailing envelope and return it through the SAVAHCS mailroom. If the envelope is misplaced, address another SAVAHCS envelope to the address listed below.

You may feel there is a risk that your personal responses or those of your unit will be identified and reported. In order to prevent this from occurring only Ms. Doyle, the principal investigator, and University of Arizona faculty involved with this dissertation research will have access to the information that you provide. Ms. Walters will not request or review any individual or unit level data from the questionnaires. Only Ms. Doyle will conduct the data analysis and summarize findings. There is no personal identifying information requested on the questionnaire so responses cannot be linked to you as an individual. The findings based on all responses will be reported in summary format only. The number of questionnaires returned will only be reported as a total for all units, not by unit. After the study is completed, returned questionnaires will be locked in a cabinet at the College of Nursing for six years.

Your decision to participate is not related to your employment. There is no cost to you and you will not be compensated for your participation. While there are no direct benefits for your participation, by doing so you will be contributing to an accurate description of medication administration practice on participating units at SAVAHCS. Across the hospital this information may identify a need for further support or education of nursing staff on BCMA. The findings will also contribute to what is known about the impact of

technology such as BCMA on nursing medication practice.

You can obtain further information from the principal investigator, Ms. Doyle at (520) 850-5980. It is not necessary to identify yourself or unit should you call. If you have questions concerning your rights as a research subject, you may call the University of Arizona Human Subjects Protection Program office at (520) 626-6721.

By completing and returning this questionnaire, you are giving permission for the principal investigator to use your information for research purposes. Withdrawal from the study once your responses have been returned will not be possible because without personal identifying information on the forms the principal investigator will not be able to distinguish between questionnaires.

Thank you.

<i>Mary Walters</i>	<i>12/21/04</i>	<i>Mary Doyle</i>	<i>12/21/04</i>
Mary Walters, RN, MS	Date	Mary Doyle, RN, MN	Date
Chief Nurse Executive		PhD Candidate	
		3-11NH	

REFERENCES

REFERENCES

- Agency for Healthcare Research and Quality. (July, 2001). Making Health Care Safer: A Critical Analysis of Patient Safety Practices: Summary. *Evidence Report/Technology Assessment: Number 34*. Retrieved 7/21/01 at <http://www.ahrp.gov/clinic/ptsafety/summary.htm>
- American Nurses Association. (1995). *Nursing Care Report Card for Acute Care*. Washington, DC: American Nurses Publishing.
- Ash, J.S., Gorman, P.N., Lavelle, M., Payne, T.H., Massaro, T.A., Frantz, G.L., & Lyman, J.A. (2003). A cross-site qualitative study of physician order entry. *Journal of the American Medical Informatics Association, 10*(2), 188-2000.
- BCMA Focus Team. (2001). Bar code medication administration (BCMA) safety and interim precautions. *Report of the BCMA Focus Team to the Under Secretary for Health*. Washington, DC: Author.
- Barker, K.N. & McConnell, W.E. (1962). The problems of detecting medication errors in hospitals. *American Journal of Hospital Pharmacy, 19*, 361-369.
- Barker, K.N., Flynn, E.A., Pepper, G.A., Bates, D.W., & Mikeal, R.L. (2002). Medication errors observed in 36 health care facilities. *Archives of Internal Medicine, 16*, 1897-1903.
- Bates, D.W. (2000). Using information technology to reduce rates of medication errors in hospitals. *British Medical Journal, 320*, 788-791.
- Bates, D.W., Leape, L.L., & Petrycki, S. (1993). Incidence and preventability of adverse drug events in hospitalized adults. *Journal of General Internal Medicine, 8*, 289-294.
- Bates, D.W., Cullen, D.J., Laird, N., Petersen, L.A., Small, S.D., Servi, D., et al. (1995). Incidence of adverse drug events and potential adverse drug events: Implications for prevention. *Journal of the American Medical Association, 274*(1), 29-34.
- Bates, D.W., Boyle, D.L., Vander Vliet, M.B., Schneider, J. & Leape, L. (1995). Relationship between medication errors and adverse drug events. *Journal of General Internal Medicine, 10*, 199-205.
- Bates, D.W., Evans, R.S., Murff, H., Stetson, P.D., Pizziferri, L. & Hripcsak, G. (2003). Detecting adverse events using information technology. *Journal of the American Medical Informatics Association, 10*(2), 111-128.

- Berg, M. (1999). Patient care information systems and health care work: a sociotechnical approach. *International Journal of Medical Informatics*, 55(2), 87-101.
- Blignaut, P.J., McDonald, T. & Tolmie, C.J. (2001). Predicting the learning and consultation time in a computerized primary healthcare clinic. *Computers in Nursing*, 19(3), 130-136.
- Brennan, T.A., Leape, L.L., Laird, N.M., Hebert, L., Localio, A.R., Lawthers, A.G., et al. (1991). Incidence of adverse events and negligence in hospitalized patients: Results of the Harvard Medical Practice Study I. *The New England Journal of Medicine*, 324(6), 370-376.
- Bulechek, G.M., McCloskey, J.C., Titler, M.G., & Denehey, J.A. (1994). Report on the NIC project: Nursing interventions used in practice. *American Journal of Nursing*, 12, 59-66.
- Centers for Medicare and Medicaid Services. (2002). *The Health Insurance Portability and Accountability Act of 1996 (HIPAA)*. Retrieved 5/3/04 at <http://www.cms.hhs.gov/hipaa/>
- Cronbach, L.J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 6, 671-684.
- Classen, D.C., Pestotnik, S.L., Evans, R.S. & Burke, J.P. (1991). Computerized surveillance of adverse drug events in hospital patients. *Journal of the American Medical Association*, 266(20), 2847-2851.
- Cordes, D. (2001). *Bar code medication administration program: A report on the National Survey Findings within the Veterans Health Administration*. Retrieved from VHA Intranet 9/11/02 at: <http://vaww.vista.med.va.gov/BCMA/implement/schedule/BCMA%20Final%20Report.pdf>
- Department of Veteran Affairs Office of Information. (1999). *Bar Code Medication Administration Pre-Implementation Guide*. Retrieved from VHA Intranet 9/11/02 at <http://vaww.vistau.med.va.gov/vistau/barcode/Version1/BCMAv1-TrainingMaterials-PreImpGuide.htm>
- Department of Veteran Affairs Office of Information. (2002). *Vista monograph 2003-2004*. Retrieved from VHA Intranet 10/08/02 at http://vista.med.va.gov/monograph/2002/12_02_03-04.htm#_Toc17793783.

- Department of Veteran Affairs Veterans Health Administration. (2002). *Mandated Bar Code Medication Administration Version 2.0 Implementation Period*. Retrieved from VHA Intranet 2/2/04 at <http://www.va.gov/publ/direc/health/direct/12002035.pdf>
- Doyle, M.D. & Rose, S. S. (2003). Bar Code Medication Administration (BCMA) Systems: A Case Illustration [Abstract]. *Proceedings of the Communicating Nursing Research Conference, Portland, OR, 36*, 171.
- Flynn, E.A., Barker, K.N., Pepper, G.A., Bates, D.W., & Mikeal, R.L. (2002). Comparison of methods for detecting medication errors in 36 hospitals and skilled-nursing facilities. *American Journal of Health-System Pharmacy, 59*(5), 436-446.
- Grotting, J.B., Yang, M., Kelly, J., Brown, M.M., & Trohimovich, B. (2002). *The Effect of Barcode-Enable Point-of-Care Technology on Patient Safety*. Literature Review by Bridge Medical, Inc. Retrieved 10/08/02 at: http://www.bridgemedical.com/pdf/whitepaper_barcode.pdf
- Jha, A.K., Kuperman, G.J., Teich, J. M., Leape, L., Shea, B., Rittenberg, E., et al. (1998). Identifying adverse drug events: Development of a computer-based monitor and comparison with chart review and stimulated voluntary report. *Journal of the American Medical Informatics Association, 5*(3), 305-314.
- Johnson, C.L., Carlson, R.A., Tucker, C.L., & Willette, C. (2002). Using software to improve patient safety in Veterans Administration Medical Centers. *Journal of Healthcare Information Management, 16*(1), 46-51.
- Kohn, L.T., Corrigan, J.M. & Donaldson, M.S. (Eds.). (2000). *To Err is Human*. Washington, DC: National Academy Press.
- Krowchuk, H.v., Moore, M.L. & Richardson, L. (1995). Using health care records as sources of data for research. *Journal of Nursing Measurement, 3*(1), 3-12.
- Leape, L.L., Brennan, T.A., Laird, N.M., Lawthers, A.G., Localio, A.R., Barnes, B.A., et al. (1991). The nature of adverse events in hospitalized patients: Results of the Harvard Medical Practice Study II. *The New England Journal of Medicine, 324*(6), 377-384.
- Leape, L.L., Lawthers, A.G., Brennan, T.A. , & Johnson, W.G. (1993). Preventing medical injury. *Quality Review Bulletin, 19*(5), 144-149.

- Leape, L.L., Bates, D.W., Cullen, D.J., Cooper, J., Demonaco, H.J., Gallivan, T., et al. (1995). Systems analysis of adverse drug events. *Journal of the American Medical Association*, 284(1), 95-97.
- Low, D.K. & Belcher, J.V.R. (2002). Reporting medication errors through computerized medication administration. *Computers, Informatics, Nursing*, 20(5), 178-183.
- McEvoy, P. (1999). Using patients' records as a source of data. *Nursing Standard*, 13(36), 33-36.
- National Coordinating Council for Medication Error Reporting and Prevention. (1998). *NCC MERP Taxonomy of Medication Errors*. Retrieved 3/04/03 at <http://www.nccmerp.org/aboutMedErrors.html>
- Nold, EG & Williams, T.C. (1985). Bar codes and their potential applications in hospital pharmacy. *American Journal of Hospital Pharmacy*, 20, 327-337.
- Oren, E., Shaffer, E.R., & Guglielmo, B.J. (2003). Impact of emerging technologies on medication errors and adverse drug events. *American Journal of Health System Pharmacy*, 60(14), 1447-1478.
- Patterson, E.S., Cook, R.I. & Render, M.L. (2002). Improving patient safety by identifying side effects from introducing bar coding in medication administration. *Journal of the American Medical Informatics Association*, 9(5), 540-553.
- Patterson, E.S., Rogers, M.L., & Render, M.L. (2004). Fifteen best practice recommendations for Bar-Code Medication Administration in the Veterans Health Administration. *Joint Commission Journal on Quality and Safety*, 30(7), 355-365.
- Phillips, D. P., Christenfeld, N., & Glynn, L. M. (1998). Increase in US medication-error deaths between 1983 and 1993. *The Lancet*, 351, 643-644.
- Polit, D. F. & Hungler, B. P. (1997). *Essentials of Nursing Research*. Philadelphia: Lippincott.
- Puckett, F. (1995). Medication-management component of a point-of-care information system. *American Journal of Health-System Pharmacy*, 52(12), 1305-1309.
- Rogers, E.M. (1995). *Diffusion of Innovations*. (4th ed.). New York: The Free Press.
- Simpson, N.J. (2001). *Advocacy White Paper: Bar Coding for Patient Safety*. Healthcare Information and Management Systems Society. Retrieved 11/10/02 at http://www.himss.org/content/files/Bar_Coding_White_Paper.pdf

- Statistical Package for Social Services, Inc. (2003). *SPSS for Windows, Rel. 12.0.0*
Chicago: Author.
- Southern Arizona Veterans Administration Health Care System. (2000). *Bar Code Medication Administration SAVAHCS - Training Guide*. Tucson, AZ: SAVAHCS BCMA Implementation Team.
- Southern Arizona Veterans Administration Health Care System. (2002). *Automated Incident Report*. Tucson, AZ: Author.
- Southern Arizona Veterans Administration Health Care System. (2002). *Inpatient Medication and Treatment Orders, Memorandum 05-02-16*. Tucson, AZ: Author.
- Southern Arizona Veterans Administration Health Care System. (2003). *Annual Report*. Tucson, AZ: Author.
- Taylor, C., Lillis, C. & LeMone, P. (2001). *Fundamentals of Nursing: The Art and Science of Nursing Care*. (4th ed.). Philadelphia: Lippincott.
- Thielke, T.S. (2003). The impact of bar code medication administration. In P.J. Schaefer (Ed.), *Proceedings from Bar Code Medication Administration Conference*. San Diego, CA.: ALARIS Center for Medication Safety and Clinical Improvement.
- Thomas, E.J., Studdert, D.M., Burstin, H.R., Orav, E.J., Zeena, T., Williams, E.J., et al. (2000). Incidence and types of adverse events and negligent care in Utah and Colorado. *Medical Care*, 38(3), 261-271.
- Trochim, W. M. (2000). *The Research Methods Knowledge Base* (2nd ed.). Retrieved 02/07/05 at: <http://www.socialresearchmethods.net/kb/>
- Weeks, W.B. & Bagian, J.P. (2000). Developing a culture of safety in the Veterans Health Administration. *Effective Clinical Practice*, 6, 270-276.