Bar-Code Technology and Nursing Adaptations

by

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DEDICATION

This dissertation is dedicated to all of the amazingly wonderful nurses who have been contributing to the safe and efficient medication administration practice with your wisdom, integrity, and sympathy. I have been privileged to observe your grace, diligence, and professionalism. Without your influence and support, this work never would have been started nor finished.

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Glossary

Operational Problems: "Any occurrence or state the makes goal accomplishment impossible, difficult, or unsatisfying in light of standards for timely and effective performance. [1]"

Workarounds: "Informal temporary practices for handling exceptions to normal workflow" [2], or "staff deviation actions that do not follow explicit or implicit rules, assumptions, workflow regulations, or intentions of system designers [3].".

Adaptations: "Any response to (perceived) problems in which a process or system is manipulated, in order to accomplish some pre-established goal relative to standards for timely and effective performance. [1]"

Frames: The different "situated" perspectives by health care providers on clinical work, in terms of clinical environment, the patient and family, their training experiences, and "surprises" aggregated during the process of healthcare [4, 5].

System Frames: "A way of considering the system's functionality and implementation as representative of the cumulative assumptions, decisions, priorities and perceived possibilities for problem-solving of the vendor, developers and implementation decision-makers. [4]"

Practice Frames: "A similar aggregation of the bedside nurses' perspective, as documented through observations and interviews. [4]"

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Abstract

Background: Medication administration errors (MAEs) have long been a prevalent problem and endanger patient safety. Bar-code medication administration (BCMA) systems were developed for the purpose of preventing the occurrence of MAEs. However, it has been demonstrated that the implementation of BCMA has brought about unanticipated consequences on nursing work and new, potential predictable paths to MAEs. More recently, investigators have introduced a new approach to describe the impact of BCMA on nursing work, which reflects nurses' adaptations to the operational problems of BCMA under difficult circumstances. A more complete understanding of the process of nurses' adaptations to technology will better inform intervention program for performance and safety improvement.

Specific Aims: The specific aims of this study were to: 1) conduct an integrative literature review about operational problems of BCMA, 2) validate a typology of operational problems of BCMA yielded in the literature review, and 3) assess nurses' adaptations to BCMA operational problems and describe their perceptions about the adaptations.

Conceptual Framework: The conceptual framework guided this study was an integration of the work system from the Systems Engineering Initiative for Patient Safety (SEIPS) model and the frames perspective. When there is a collision between the frames (system frame and practice frame), the operational problems occur, and then nurses make adaptations to the operational problems. In this study, it is considered that the "system frame" is functionalized as the "work system", which is the core of the SEIPS model.

Methods: A prospective, exploratory design was conducted to meet the study aims. This descriptive study included two convenience samples of registered nurses working on identified

medical and surgical adult acute care units. An observation of BCMA use and a semi-structured interview was conducted with each participant of one group of sample (N=22) to collect data about the operational problems of BCMA. Another group of sample (N=21) conducted scenario interviews and follow-up interviews to describe their adaptations to the operational problems of BCMA.

Results: This study found that 1) the triggers of operational problems of BCMA can be categorized according to the elements of the work system of the SEIPS model, which are technology and tools, tasks, person, environment, and organization; 2) the five elements of the SEIPS work system were validated for use as a typology of the triggers of operational problems of BCMA; 3) nurses conducted different adaptations with various strategies to accommodate to the operational problems of medication administration using BCMA; and 4) the perceptions of nurses about the adaptations to the operational problems of BCMA can be addressed by the sequential steps, implying nurses think in a logic and objective way during adaptations.

Conclusions: This study provides a new way to approach the impact of BCMA on nursing work – adaptations. This is one of the first studies that attempts to understand nurses' adaptations to the operational problems of BCMA, and also one of the first studies that investigates nurses' perceptions about adaptations. Future research should more rigorously study nurses' adaptive behaviors to operational problems.

Chapter 1

Introduction

Medication errors in hospitals have long been a prevalent problem [1-4] and endanger patient safety. Among the most common types of errors in hospital [1, 2, 5], medication errors are estimated to cause 1.5 million injuries and 7000 death per annum, and the treatment of medication errors related injuries cost the country $3.5 billion each year [6, 7]. There are 6.5 medication errors per 100 inpatient admissions, with approximately 34% occurring during medication administration [5, 8, 9]. The process of medication administration is complex; strategies have been developed for the purpose of preventing the occurrence of medication administration errors (MAEs). Bar-code medication administration (BCMA) systems were developed as an additional safeguard to prevent medication errors from reaching the patient's bedside. BCMA systems typically work by pairing electronic medication administration records (eMAR), computerized provider order entry (CPOE) with bar-coded medications and bar-coded patient identification. In this way, BCMA systems provide support for the long-standing safe medication administration practice of verifying the five rights or "5Rs" of right patient, right dose, right route, right time, and right medication [10-12]. If, at the point of care, the system cannot match the digital 5Rs, it alerts the nurse with visual warnings. In addition, most organizations maintain an extensive set of procedural guidelines that provide nurses with guidance on actions that represent best practice responses to BCMA alerts.

While a number of studies reported that BCMA systems do indeed reduce MAEs in hospitals [13-18], it has also been demonstrated that BCMA has led to unanticipated consequences on nursing work and new, potentially predictable paths to MAEs [16, 19-32]. A mounting number of studies specifically demonstrate that BCMA has a significant impact on nursing work when operational problems cause the nurse to alter task sequences, for example documenting the medication is delivered before it is actually given. Examples of operational problems include equipment issues such as large or bulky computer carts or scanners which cannot fit into the patient room, medications that are not available as expected, and incomplete, ambiguous, or erroneous information such as a warning regarding a discontinued medication because of CPOE and/or eMAR system issues [33, 34].

Efforts to understand BCMA's impact on nursing work have largely focused on nursing workarounds, which are generally considered as deviations from BCMA use protocols [22]. More recently, investigators have introduced the notion of "adaptation". When operational problems happen, nurses have to respond to those problems in order to accomplish pre-established task goals; this process is defined as "adaptation" [21]. It reflects nurses' attempts to create a fit when something does not fit [33]. A more complete understanding of the processes involved in nurses' adaptations to the operational problems may better inform intervention programs for performance and safety improvement [35, 36].

Little attention has been paid to factors that contribute to nurses' decision-making around adaptations to BCMA-related operational problems, when the function of BCMA as designed does not fit the protocol of medication administration. This will be one of the

first studies that systematically summarizes operational problems of BCMA implementation in work systems, and comprehensively assesses nurses' decision making to adapt to the operational problems in simulated environment. The objectives of this study are to better understand nurses' adaptations to the operational problems of BCMA and their perceptions about the adaptive behavior. The following specific aims were addressed in three studies as follows:

Specific Aim 1/ Study 1: To conduct an integrative literature review about operational problems of BCMA.

Specific Aim 2/ Study 2: To validate a typology of operational problems of BCMA yielded in the integrative literature review.

Specific Aim 3/ Study 3: To assess nurses' adaptations to BCMA operational problems and describe their perceptions about the adaptations.

Background

Medication Administration Errors (MAEs)

MAEs threaten patient safety and quality of care in hospitals. Despite accreditation standards, public policies and availability of evidence for reducing MAEs during hospitalization, MAEs have been a national patient safety issue [2, 6, 8, 37, 38]. This may be, in part, because the process of medication administration is complex, and a number of opportunities exist for MAEs to occur [18]. Error prevention has traditionally been reliant on adherence to the procedure of the "5Rs" of medication verification (right drug, right time, right patient, right dose, and right route) and documentation, all of which may be negatively influenced by, for example, environmental distractions and failure to follow standard protocols [18].

In the report *To Err Is Human*, the Institute of Medicine (IOM) suggested that most medication errors were the result of a system failure and recommended that the necessary path to improve quality and safety in healthcare should be focused on the improvement of care delivery systems [39]. Frameworks that emphasize human beings and their interactions with products, device, procedures, work space and the environment, are now accepted as a way to examine systems and suggests opportunities for improvements in quality and safety [40].

In order to mitigate the risk to patient safety, the use of BCMA systems to verify a patient's identity and the medication to be administered was introduced as a strategy for preventing MAEs.

Bar Code Medication Administration (BCMA) Systems

BCMA systems are comprised of an electronic administration records (eMAR), a computerized physician order entry (CPOE), hardware that contains a variety of bar code scanners, bar coded medications, bar coded patient identifiers, and portable computers [33]. An integrated process of medication administration with BCMA characteristically starts with medication orders originating from the CPOE system. Those orders are processed by the pharmacy, and then populate the eMAR. After the medications are distributed and retrieved from a dispensing system, nurses crosscheck the medications against the eMAR. Then, the nurse scans bar codes on the patient wristband and medication packaging, which allows the system to verify the "5Rs" between the patient identity and the medication. BCMA systems also generate an automatic documentation of the medication administration in the eMAR, including the time and the medication details. If there is a mismatch between what has been ordered and what is scanned, the

system will issue to the nurse a warning to a potential unsafe step in the medication administration process [28].

BCMA is being implemented in hospitals across the United States at an increasing pace with 27.5% of non-federal hospitals as of mid-2014 [41, 42]. In federal hospitals, the Veterans Administration (VA) has implemented BCMA in all 150 of its hospitals to assist preventing MAEs [43]. The final rule for Stage 2 Meaningful Use requires hospitals to "automatically track medications from order to administration using assistive technology in conjunction with an eMAR." [44]

Technology, Workarounds, and Adaptations

In the computer technology field, it is well accepted that "no technology is exception-free and no simple technology is available to remove exceptions from workflow." [36] It is known that the implementation of health IT introduces additional risks into the environment of care as a result of the unintended or unanticipated consequences of either design or implementation of the system [22, 45, 46]. Nurses, like other healthcare providers, are often expected to respond to the operational problems and alter their practices to accommodate the technology [47, 48]. When operational problems are considered as necessary consequences of the implementation of technology in a complex environment, nurses are necessarily engaged in operational problem solving, which is also known as "adaptations" [34, 48, 49].

A problem, from human factor and ergonomics perspectives, is defined as "any occurrence or state the makes goal accomplishment impossible, difficult, or unsatisfying in light of standards for timely and effective performance [21]." Problems are often caused by a mismatch between the demands and the resources; therefore, problems represent

variability in the entire work system. Adaptations, or problem-solving, are "any response to (perceived) problems in which a process or system is manipulated, in order to accomplish some pre-established goal relative to standards for timely and effective performance [21]." The definitions of "adaptations" to "operational problems" clearly explicate that adaptations are goal-oriented behavior.

Workarounds, a related concept, are defined as "informal temporary practices for handling exceptions to normal workflow" [50], or "staff deviation actions that do not follow explicit or implicit rules, assumptions, workflow regulations, or intentions of system designers" [51]. In contrast to "adaptations" which emphasize goal-oriented behaviors, the "workarounds" literature emphasizes behaviors as a consequence of the processes within a work system.

Furthermore, "adaptation" emphasizes the process of operational problem solving as a dynamic process, in which the communication between nurses and the environment has the potential to inform pathways to design or redesign the work system. Workarounds are often studied under the assumption that workarounds are inherently dangerous and a threat to patient safety [22, 52-54]; whereas, adaptations are beneficial attempts, reflecting the reactions and decisions in difficult situations. It has been noted that some of today's best practices were yesterday's adaptations; some of today's adaptations could also be tomorrow's best practices [33].

Studies Around the Technology, Workarounds, and Adaptations

Nurses' interaction with BCMA was studied from a human factors viewpoint by Carayon [20] in 2007. Eighteen different sequences of the BCMA process were identified; some of the steps identified were potentially unsafe. The most common workarounds in

steps sequences was documenting medication administration on the handheld device before the medication was given to and ingested by the patient. The elements in the work system, such as technology, organizational factors, physical environment, and individuals, were noted during observation and interviews as contributors to the problem. It is noteworthy that automation surprises, operationalized as unexpected, unpredictable responses by the technology [55], and interruptions, introduced from individuals, equipment and technology, and task itself, exclusively disorganized the pre-established steps of the medication administration process.

Koppel [22] applied a triangulated effort with a combination of 5 methods in one study, which was designed to systematically evaluate workarounds when using BCMA systems. Researchers identified 15 types of workarounds in 3 categories (omitted steps, incorrect sequence, and unauthorized steps), and related them to 31 types of causes of workarounds and possible consequences. Many workarounds were found engendered by difficulties with the technology and by interactions between BCMA and other factors, such as environment, other technologies, work processes, workloads, training, and policies. Some of the causes were obvious difficulties in using BCMA, along with staff-perceived limitations of BCMA and staff overestimation of BCMA's risk-elimination abilities. A significant contributor of difficulties was not malfunctioning technology; rather, it was barriers produced by how the technology was designed and used in organizations, and how staff responded to the difficulties.

Holden and Novak are the pioneers in the research area of studying nurses' adaptive behaviors to the operational problems of BCMA from engineering prospective. They conducted a series of researches collectively to observe and interview nurses about

their problem-solving behavior following the implementation of BCMA [56-59]. They found that sometimes, BCMA allowed nurses to invent new problem-solving behavior to deal with pre-existing problems, and sometimes, BCMA made it difficult or impossible to apply some problem-solving behaviors that were commonly used pre-BCMA, but often requiring nurses to use potentially risky workarounds to achieve their goals. In some other cases, BCMA even created new problems that nurses were either able to solve using familiar or novel problem-solving behaviors, or unable to solve effectively. Besides the individual adaptations that nurses adopted to accommodate the needs of the technology to achieve work goals, at the organizational level, management decisions are implemented to either endorse the impact the technology imposes, or to soften or alter the impact of the technology on work through explicit or implicit policies that reject aspects of the impact.

In summary, it is crucial to understand what operational difficulties a BCMA system might generate during medication administration process, how nurses will respond to those difficulties while interacting with other work system factors, as well as how nurses perceive the decisions they made in terms of causes, rationale, and impact of the behavior. This will be one of the first studies, which explores the nature of BCMA and adaptations by adapting the SEIPS model to the sociotechnical perspective. It is this study's objective to fill the research gap of considering the interaction between nurses and the BCMA from a broader and more systematic perspective than the "workarounds", and therefore to inform system redesign, intervention programs and educational campaigns for nurses' behaviors, and institutional protocol and policy making in order to improve patient safety and work efficiency.

Approaches to Understanding BCMA's Impact on Work

A growing number of impact-on-work studies reveal how the implementation of BCMA changes the nature of nursing work. There is evidence of creation of potentially unsafe task sequences; for example, nurses may document that the medication is administered in advance of actually delivering it [17, 19, 22, 48]. It has also been found that BCMA can interrupt workflow when alerts are triggered[16, 19, 20, 22, 26-28, 60], create workload imbalance when nurses tend to prioritize medication administration and delay, or even miss, other necessary nursing care [16, 20, 22, 27, 61], and bring about other problems, such as inaccurate medication information [16, 20, 24, 27, 48].

Although a number of studies have focused on the impact of BCMA on nursing work, most were conducted by observing the medication administration process and/ or interviewing nurses about the causes of observed behaviors as ways to collect data about workarounds. Few studies have addressed, however, the perceptions of nurses regarding the strategies they come up with. There has been a call for further research to better understand how an increase in emphasis on timely medication administration affects decision tradeoffs during goal conflicts [28]. No studies have explored the adaptations to operational problems of BCMA as a dynamic process. Factors that may contribute to this are unavailable methods in hospital for conducting a comprehensive assessment[33], complexity of studying the entwined processes of adaptations [22], BCMA's evolving nature and evolving work rules [22], and nurses' negative impression and resistance to the notion of workarounds. It is believed that when there are large gaps between intended practice, as recommended or mandated in policies and procedures, and actual practice, predictable problems emerges [62]. One alternative approach for minimizing the gap might

be to consider context of use during design, procurement, and implementation of system in order to make the technology useful, efficient, and usable for all settings of use [19].

Thus, it is imperative to understand existing operational problems that are hindering efficient medication administration, how nurses respond to operational problems by interacting with other elements in work system, and nurses' perception about the adaptations they made.

Conceptual Framework Guiding this Research

Work System Perspective

Carayon and colleges [63] described the Systems Engineering Initiative for Patient Safety (SEIPS) model of work system and patient safety as a framework to understand the structures, processes and outcomes in healthcare and their relationships. The SEIPS model nests the work system model [64, 65] in Donabedian's quality model [66, 67]. It clearly specifies the components of work system that can possibly contribute to the occurrence and control of medical errors, showing the nature of the interactions between the components, as well as displaying how the design of the work system can lead to acceptable and unacceptable processes [35, 64, 65] (see Figure 1.1).

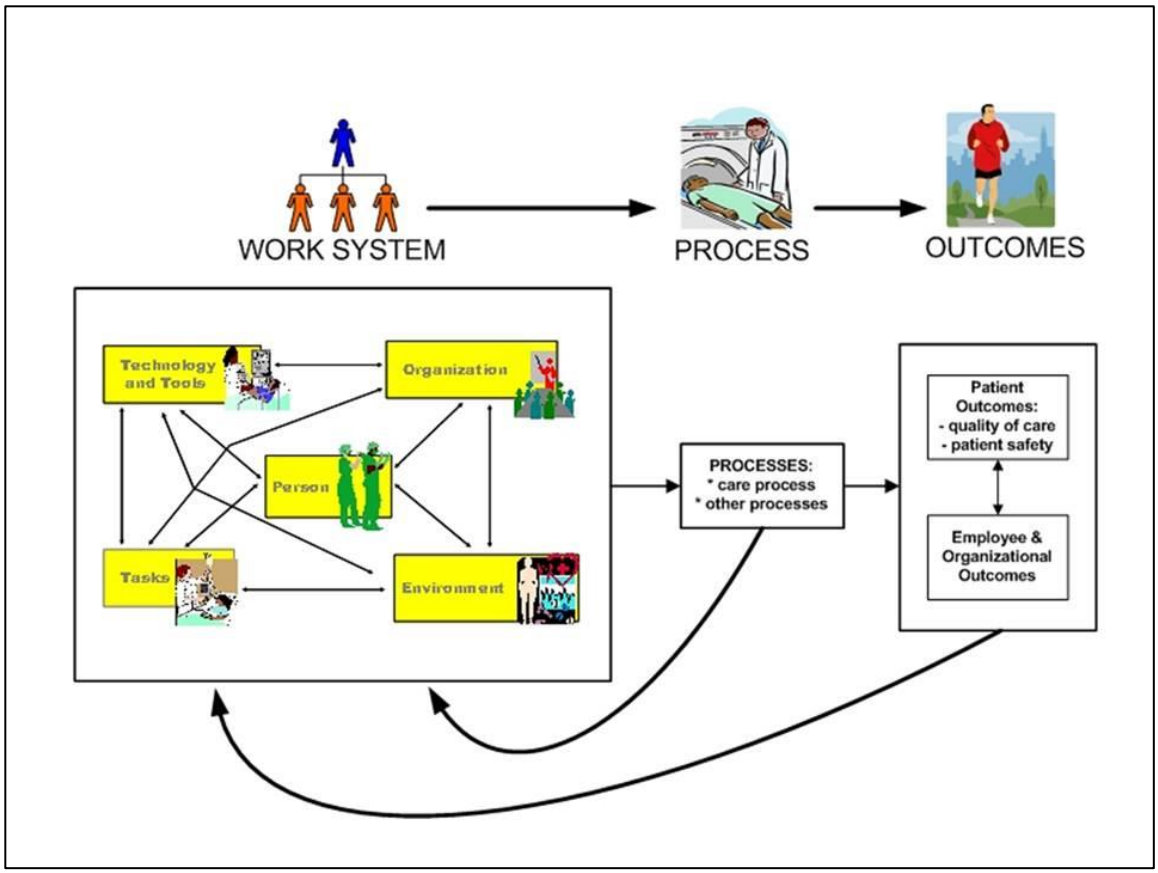

Figure 1.1. **SEIPS model of work system and patient safety.** Source: Carayon, P., Schoofs Hundt, A., Karsh, B. T., Gurses, A. P., Alvarado, C. J., Smith, M., & Flatley Brennan, P. (2006). Work system design for patient safety: the SEIPS model. *Qual Saf Health Care*, 15 Suppl 1, i50-58. doi: 10.1136/qshc.2005.015842

Frames Perspective

Frames are the different "situated" perspectives by health care providers on clinical work, in terms of clinical environment, the patient and family, their training experiences, and "surprises" aggregated during the process of healthcare [48, 68]. From a sociotechnical perspective, operational problems happen when "the System Frame" collides with "the Practice Frame". The "system frame" is "a way of considering the system's functionality and implementation as representative of the cumulative assumptions, decisions, priorities and perceived possibilities for problem-solving of the vendor, developers and implementation decision-makers."[48] The "practice frame" is "a

similar aggregation of the bedside nurses' perspective, as documented through observations and interviews."[48]

Integration of Two Perspectives: Work System and Frames

The conceptual framework for this study integrates the work system from the SEIPS model, and the frames perspective, the operational problems that occur when there is a collision between the frames, and the adaptations nurses make to the operational problems (see Figure 1.2). In this study, it is considered that the "System frame" is functionalized as the "work system", which is core to the SEIPS model [35, 64, 65]. The components of the work system serve as the triggers to the operational problems of BCMA. These components as operationalized in this research include: (1) tasks, or the number and type of medications, sequence and duration of the medication administration process, registered nurses' (RNs') observation of patient taking medication, sanitization of hands, and occurrence of handoffs; (2) technology, the BCMA system, (3) organizational factors in which BCMA observations took place and specifically refer to the coordination, collaboration, and communication between nurse and physicians and pharmacists; (4) physical environment of the specific unit where observation took place, i.e., lighting, noise, neatness, organization, and crowdedness of the patient room and medication room; and (5) person including patient factors (e.g., isolation), comments of nurse and patient during medication administration relating to the medication administration process.

The "Practice Frame" in this study includes the protocol or standards of the medication administration practice, including the use of the BCMA system and guidelines for addressing problems that arise when using the BCMA system. Importantly,

the overriding practice goal of nurse medication administration is the 5Rs, regardless of whether the practice is enabled by the BCMA system. That is, the practice frame reflects the practice goal of nurse.

When one or multiple factors of the work system cannot meet the requirement of the medication practice frame, the work frame and the practice frame collide and create. That is operational problems. When operational problems occur, they trigger nurses to adapt their performance to accomplish the goal of medication administration conformant with the 5Rs. How nurses perceive and adapt to an operational problem involving BCMA systems is the focus of this research.

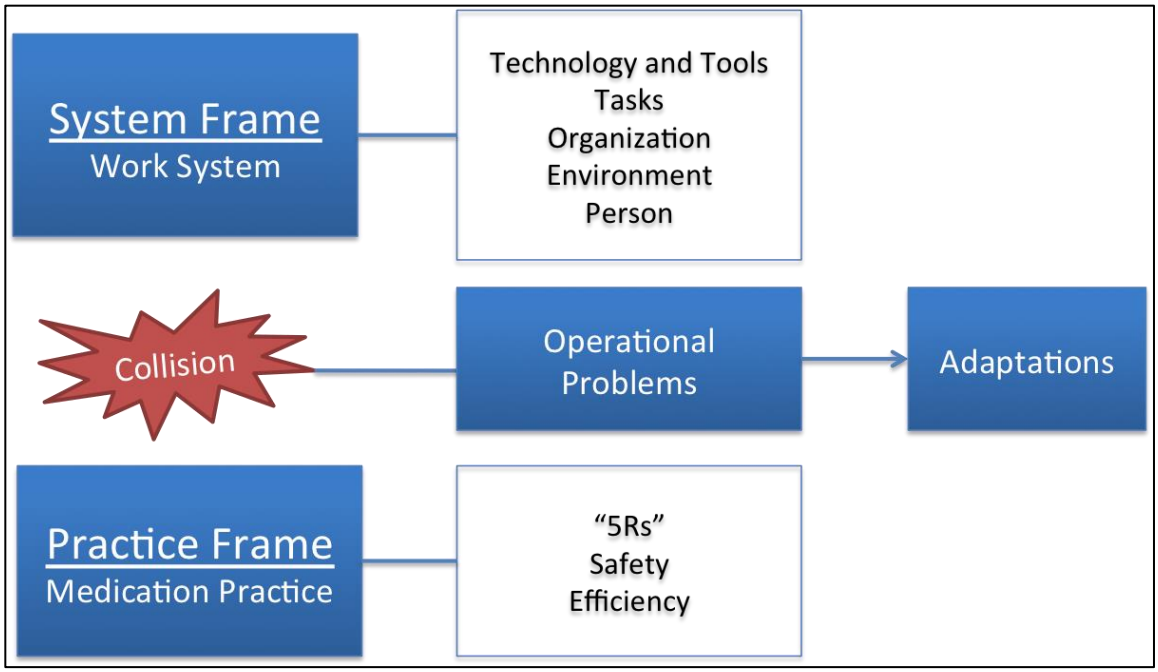

Figure 1.2. **BCMA and adaptation.**

In summary, the conceptual framework for this study includes a description of the work system as system frame, medication administration practice goals of assuring the 5Rs as the practice frame, and the collision between the system frame and the practice

frame as a source of operational problem. Nurses' adaptations to operational problems of BCMA are the primary focus of this research.

Overview of the Dissertation Chapters

This dissertation used the three-study/paper format option. Chapter One has introduced the background of this study and the conceptual framework used to guide this study. Chapter Two is an integrative literature review of operational problems of BCMA (Dissertation Paper One). Chapter Three validates the operational problems of BCMA yielded in the integrative literature review (Dissertation Paper Two). Chapter Four assesses the process of nurses' adaptations to BCMA operational problems and describes their perceptions about the adaptations (Dissertation Paper Three). Chapter Five summarizes the results of this dissertation and discusses the implications for future research and practice.

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Chapter II

Operational Problems of Barcode Medication Administration Systems: What Are They?

An Integrative Literature Review

Introduction

Barcode medication administration (BCMA) systems were developed as an additional safeguard to prevent medication administration errors (MAEs) from reaching the patient's bedside, by verifying a patient's identity and the appropriate medications (name, dose, time, and route) to be administered [1-5]. A mounting number of studies indicate that BCMA systems have a significant impact on nursing work related to, for example, the introduction of inadequate supplies and equipment to support BCMA, and at times generating incomplete, ambiguous, or erroneous information [6, 7]. In order to meet the goal of safe and timely medication administration, nurses may have to change behaviors for using the BCMA system; this process is defined as "adaptation" [8].

Adaptations reflect nurses' attempts to create a fit when something does not fit, which implies that, under difficult circumstances nurses come up with adaptations people can learn from and may become future best practice [6]. In fact, adaptations may be inevitable; necessary to accomplish work goals; can be learned from as new "best practice"; and consequently may need to be fostered and facilitated [9].

Researches on BCMA have emphasized workarounds, including a number of studies that have developed a typology of nurses' workarounds and the causes and

possible consequences of each workaround when using BCMA [10-13]. "Workarounds" is a related concept, however workarounds are performed at individual level, typically include only once single step in the BCMA process, are generally interpreted as negative behaviors because not compliant with the practice protocol, and typically are observed as an action at single point in time to deliver the medication. In contrast, adaptations can be performed at both individual level and institutional level, could comprise multiple steps in the process with multiple decisions to be made, are typically interpreted as neutral or positive behaviors even though not compliant with the practice protocol, and are considered as behaviors to make deliberate decisions to accommodate the work system.

It is important to take one step back to understand why nurses have workarounds or adaptations? What is the nature of the operational problems of BCMA, and where are they coming from? Operational problems of BCMA implementation remain understudied [14].

To the best of this researcher's knowledge, there is ***NOT*** a literature review regarding the operational problems of BCMA existing in the practice. The purpose of this article was to conduct an integrative literature review of BCMA implementation to identify the sources of the operational problems of BCMA.

Conceptual Framework

The conceptual framework guiding this review is an integration of the SEIPS model and a sociotechnical perspective considering that operational problems occur because of the collision between the "System Frame" and the "Practice Frame". The system frame is represented as the way the system is considered functionalized and implemented by the cumulative assumptions, decisions, priorities and perceived problem-

solving of the vendor, developers and implementation decision-makers [14]. The work system within the SEIPS model frames dimensions of the system frame relevant to BCMA. The practice frame that drives nurses medication administration practices includes safety, efficiency, and the "5Rs" (right patient, right medication, right time, right dose, and right route) of medication administration.

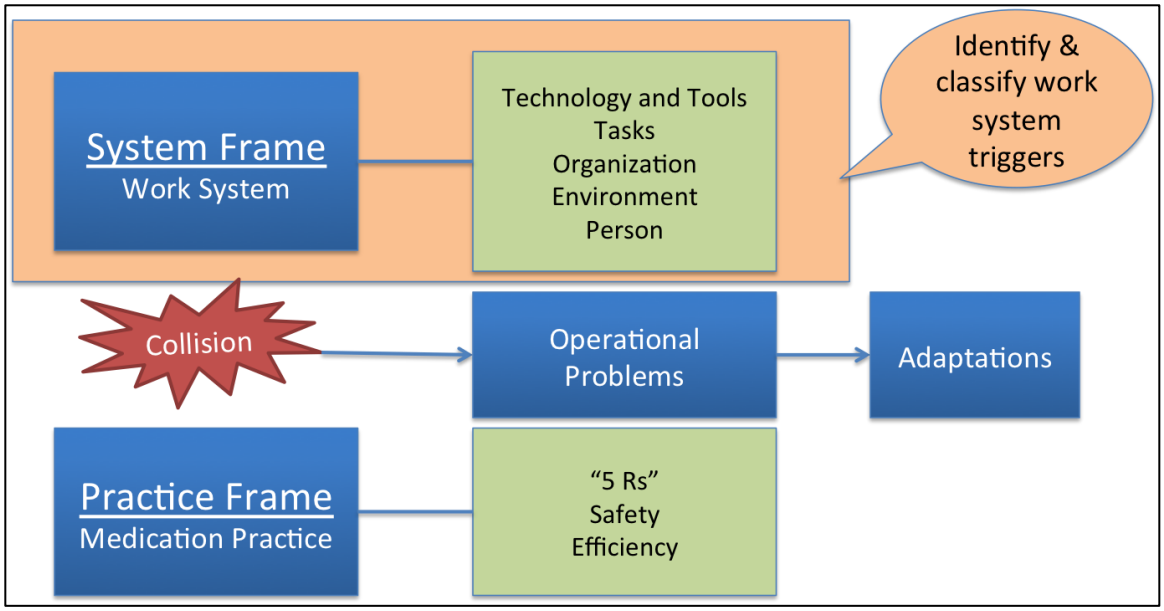

Figure 2.1. **BCMA and adaptation.**

When the components of the work system do not function well to meet the needs of the medication practice, nurses experience a collision between the work frame and practice frame and the result is operational problems; nurses then adapt their behavior to overcome the operational problems to meet the goal of the practice frame, i.e., medication administration in a timely and safe manner.

This integrative literature review focuses on factors of the "System Frame" that trigger collisions with the practice frame, and thus create operational problems of BCMA. The purpose of this integrative literature review was to identify BCMA operational problems triggered by the work system. In this way, the literature provides a foundation

for the two studies that follow, each with the goal of lending new insights into how collisions between the work or system frame and the practice frame influence nurse adaptations to operational problems encountered in BCMA.

Methods

A review of the peer-reviewed literature that evaluated the effect of the implementation of BCMA was conducted accessing MEDLINE®, PreMEDLINE®, International Pharmaceutical Abstracts®, and Pub Med® database. The studies of interest had to be published in English from 2000 to 2017. The start date of the search is because the BCMA system and associated hardware was first developed and adopted to administer medication in the Veteran's Health Administration (VA) since 2000 [15]. The keywords and terms used were barcode, bar code, barcoding, bar coding, barcode medication administration systems, medication systems, clinical pharmacy information systems, medication administration system, medication errors, hospital, nursing staff, evidence based nursing, nursing process. These keywords and terms were used independently and in various combinations to identify the studies synthesized for this literature review. A number of citations were found using the inclusion criteria (see Table 2.1) and then systematically reduced by review of abstracts and article full-text to determine relevance to the purpose of this review (see Figure 2.2).

Table 2.1
Article Literature Selection Criteria

Attribute	Selection Criteria
Aim, time & language	Studies that evaluate the effectiveness of the implementation of BCMA in hospitals, published in English from 2000 to current (October, 2017).
Type of study	Research Study.
Participants	Nurses administering medications are all registered nurses.
Setting	Patients are hospitalized in acute care hospitals.

One hundred and thirty eight publications were identified. After reading the article citations and abstracts, 88 records were excluded. Within the remaining 50 full-text articles, studies were excluded, if 1) the study was conducted in long-term care facility, 2) the research outcomes were MAE rate or the Adverse Drug Event (ADE) rate, the compliance rate or acceptance rate of the implementation of BCMA, the attitudes or satisfaction of nurses towards the implementation of BCMA, or change of the workflow or time distribution pattern after the implementation of BCMA, without describing the nature of the involved operational problems of BCMA, 3) only workarounds to BCMA were assessed without describing whether they were triggered by the occurrence of operational problems of BCMA, 4) those were editorial articles or single implementation case studies, or 5) the technology of the studies was not BCMA as a system, e.g., personal digital assistant (PDA), medication dispensing system, stand-alone BCMA without connecting to the EHR and COPE, etc. A final group of 12 research studies were retrieved and included in this review (see Figure 2.2).

Each of the 12 included articles was reviewed in-depth. In the workarounds articles (n = 9) causes of workarounds were coded as work system triggers to the

operational problems. In the adaptation articles (n = 3), triggers to the operational problems were identified by the research. Triggers then were categorized by the researcher using the 5 elements of the SEIPS work system. Relevant text was copied and pasted from the manuscripts to a table in a Word® document for review and analysis.

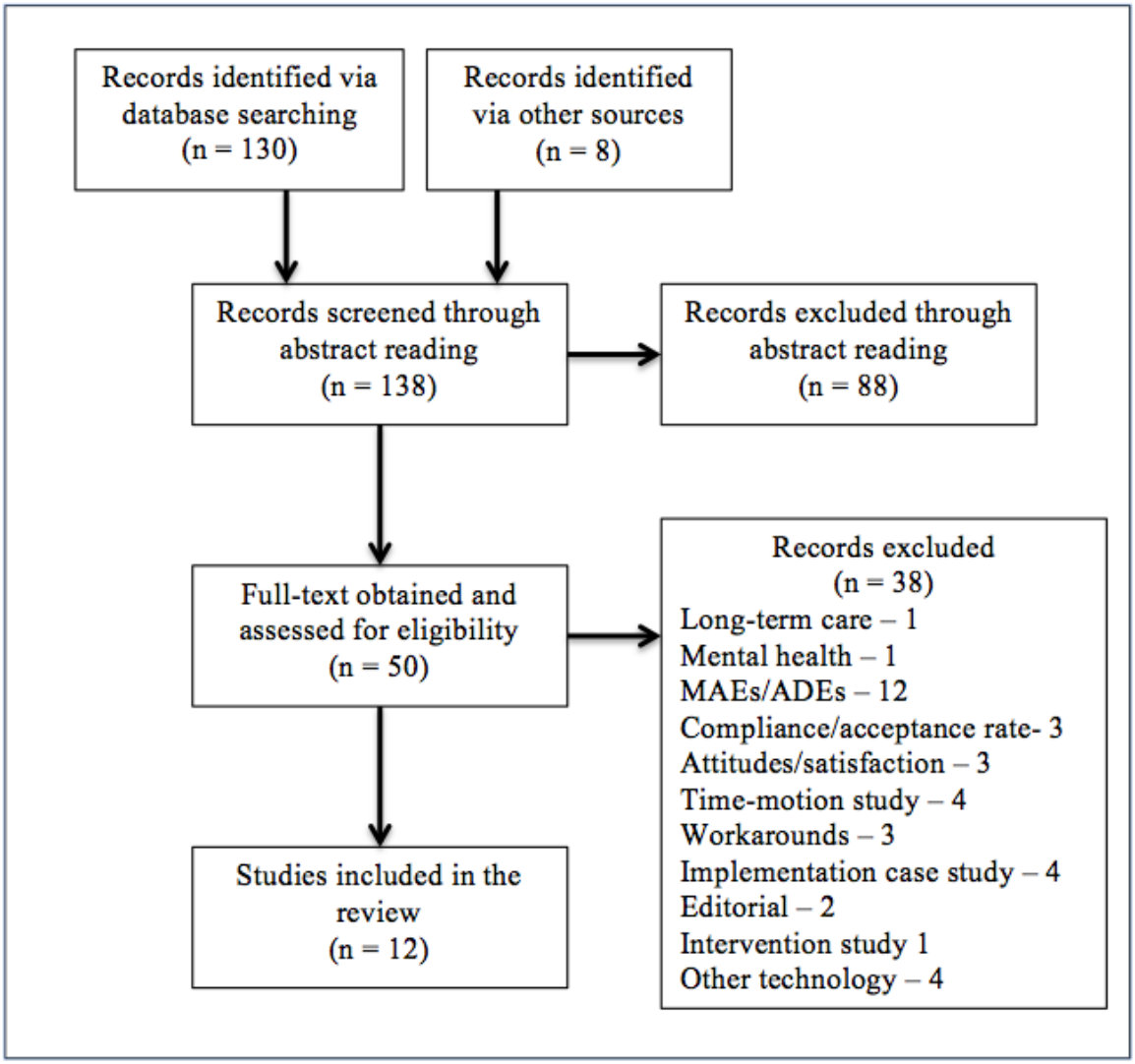

Figure 2.2. **Prisma Diagram.**

Results

The results of the literature review of the operational problems of BCMA were sorted into the components of the SEIPS work system: technology and tools, tasks, organization, environment, and person.

Technology and Tools Related Triggers of Operational Problems

Technology and tools related triggers of operational problems primarily include problems with BCMA software and/or hardware [10, 16], although eMAR may cause difficulties, too. Carayon et al. [12] introduced a concept "automation surprises" when described operational problems regarding technology, which were considered as unexpected or unpredictable responses by the technology [17].

The most frequently reported problem was multiple scan attempts needed until the barcode, attached on either patients' wristband, nurse ID badge, or the medication packaging, was read [10, 12, 18-20], due to the technology capability [10].

Some studies reported that the screens sometime were difficult to read or navigate [10, 12]. Nurses may have to switch between multiple screens to locate medication information, medication orders, and completing medication administration in different systems. Sometimes, one or more screens might not be allowed to operate, if needed field grayed out, which could be very frustrating for nurses. Gooder [21] reported in a case-control study that nurses had difficulties in determining what medication was due, or what medications the patient had already had.

Other technology related triggers to operational problems were abruptly frozen handheld scanner or computer [12, 18, 22], failing to connect to the network [12, 22], dead batteries, loss of power or failing to be charged [10, 11, 18, 20], or delays in response [19],

which could lead to a hard stop during medication administration. BCMA system times out nurses, if they do not confirm medication administration within a preset period of time [10, 12]. Scanners emit similar beep sound every time nurses scan, no matter if it is the correct move or wrong, which could be confused or ignored if the system is sending an alert. Computer on wheels (COW) is too large to fit into patient room, or it is charged through the outlets in the hall, and cannot be moved to the patient's bedside [10, 12]. If the scanner is too large, heavy, or bulky, nurses may be reluctant to carry it to patient's room [10].

Tasks Related Triggers of Operational Problems

Across the articles reviewed, issues related to scanning barcodes is the most frequently reported task-based trigger of operational problems [10-12, 18-26]. However, the understanding of the nature of the barcode issues is inconsistent across literature. Carayon [27] conducted an observational study, exploring the interaction between nurses and BCMA from a human factors viewpoint, in which administering medications that were not scanned or were not able to be scanned was considered as a task sequence that is not recommended. They also dug into the most common reasons for not scanning a barcode: 1) the barcode had not been inputted in the dataset due to nonformulary medication; 2) there was no barcode on medication; 3) the barcode on the package, especially for insulin and eye drops, was not able to be scanned by the nurses.

Barcode issues trigger operational problems in different ways. Barcode may exist inside different package, or one medication packaging had multiple barcodes, in which case nurses were not familiar with the variation from common situation [10]. If the medication is brought from a patients' home, or if the dispensing machine was out of

order, the medications may do not have a barcode [10, 22]. Some medications, e.g., insulin, eye drops, and ointment in particular, may have barcodes, which are difficulty to scan, and the labels may be damaged or compromised [12, 19, 20]. Wristband barcodes may not scan as reliably as medication barcode [11]. Sometimes, barcodes themselves could be wrong, which requires nurses must to do a visual check of the medication [24].

Novak and her colleagues conducted extensive research on BCMA operational problems and how nurses interact with those problems from a system perspective [23-25]. They observed the BCMA system's tenacity with respect to "right time". In a variety of situations, nurses would delay administering a scheduled medication for a number of reasons: 1) the previous dose of the medication had been administered later than scheduled due to a surgical procedure; 2) an incompatible medication was presently being administered; 3) the administration of many medications required prior blood pressure readings, blood glucose measurements or research as to contraindication, side effects or adverse reaction; and 4) patient was in rest or tripped off the unit for tests and procedures, and meals. In some other situations, medications, particularly PRN (as needed) medications, may needed to be administered ahead of schedule, but the standard interval assigned to the timing of it had not elapsed. In the era of paper MAR, when nurses found they needed to administer a medication outside the window of "on-time" administration, no matter early or delayed, or they thought this could affect the timing of downstream doses, they could documented a plan in the MAR to "stagger" the patient back onto the original schedule through a series of appropriately adjusted doses in terms of timing. But within the BCMA system, it does not allow this flexibility from nurses' perspective, rather than being documented as "late" or issued a warning against administration, which

may cause stigma of late doses. Nurses have the authority and ability to adapt the schedule as was clinically appropriate and within their scope of practice [14].

Another representation of "tenacity" of the system is that nurses were not autonomous regarding adjusting doses of medications [25]. Holden, Alper [28] believed BCMA system applied an exclusive interpretation of physicians' original order, despite nurses' capability of making a simple substitution between two clinically equivalent sets of doses, e.g. one 20 mg vs. two 10 mg. Koppel, Wetterneck [10] also reported that when less than a full dose was available at the time nurses administered medications, or syringe/medication tablet contained more than ordered dose, nurses were not allowed to change the prescribed order, but altered the automatic documented administration that was based on the dose on the scanned barcode. For example, pharmacy sent 10-mg tablet instead of a 20-mg, nurses either documented a partial dose being administered and asked the physician to create an order to administer the remainder when it arrived, or scanned the medication twice to document a complete medication administration, delivered the partial dose, and remembered to administer the remainder later.

Additionally, in urgent cases, in which medication needed to be administered before ordered and documented, nurses used a blank MAR to document medications administered, bypassing the BCMA. However, in order to charge administered medications on the blank MAR, they had to be entered into the CPOE, which generated a new order being transmitted to the BCMA. Pharmacists then had to discontinue the order immediately after entering it [25].

Individual Related Triggers of Operational Problems

In the model of this review, individuals involved in the medication administration process include patients, families, nurses, and other disciplines. If patients removed wristband by themselves, or the wristband did not fit the patients' limb because of, for example, a cast or bandaging, then patients may would not be wearing a wristband [20]. Nurses then would not have the barcode on the patients to scan for the purpose of verifying the "right" patient. Patients under special circumstances could compromise the process of medication administration, for example, patients refused medications or vomited medications, or patients were sleeping, agitated, receiving central lines, showering, breastfeeding, or in contact isolation [10, 12, 18, 20].

Nurses with inadequate BCMA training, may be not familiar with which of several barcodes on medications to scan, which screens had needed information, confirmation procedures, or how to respond to allergy notification [10, 19].

Environment Related Triggers of Operational Problems

Environment related triggers of operational problems were described straightforward in the literature and referred to the hospital's physical structure and locations of persons, medications, and related technologies [10]. Some studies reported that nurses perceived the general physical environment as messy and disorganized for both the patient room and the medication room [12]. Noise may be loud in the medication room, and the alarm sound from the BCMA system may not be noticeable [10, 12]. Some doorways and patient room configurations hinder bedside access of the COWs. Medications may be stored remotely from the scanner, which necessitates multiple trips to scan, dispense, and return the remaining dose [10].

Organization Related Triggers of Operational Problems

Organizational operational problems that trigger operational problems include the interruptions initiated by patients and families, providers, medications, or technologies. This category of problems also refers to the coordination, collaboration and communication between nurses and physicians, pharmacists, and nurse assistants.

An interruption has been defined as the occurrence of an event recognized by the nurses that disturbed the normal processing of the current task performed [29-31]. Carayon, Wetterneck [12] found during medication administration, patients and/or families may ask questions, request water or juice to go with the medication, be sleeping or in bathroom, get intravenous catheter infiltrated, or be changing dressing. Another party who often interrupted during medication administration was physicians, for instance, physicians examined and talked to the patient or the nurse at patient bedside, in the process of medication administration. Medication administrating process would also have to be interrupted when medication was missing, medication-related information was missing, new patient ID wristband was needed, components of tools of administering (e.g. needle or extension tubing) was required, or previous intravenous bag was still running. A range of equipment and technologies in hospital equip advanced medical services, as well as bring about interruptions, such as intravenous pump sounding alarm, programming of pump, and wrapping handheld device in plastic when entering patient's room in contact isolation.

Nurses collaborate with multiple disciplines in hospital, especially when patients are transferred between different departments. Therefore, maintaining the continuity of the medication administration routine remains challenging but critical, and necessitates

coordination, collaboration and communication between nurses and other relevant personnel. Novak [23] conducted a qualitative research study to understand the new cognitive and physical tasks that were required of nurses when BCMA was implemented using organizational routines theory. When a patient came from the Emergency Department (ED), he/she often had medications ordered, but not confirmed or administered in the eMAR since the ED was not using the BCMA system. It was reported frustrating and time consuming for nurses to address and confirm numerous unconfirmed medications that were given prior to arriving on unit. In order to administer a medication, the patient must be admitted to the unit with an active medical record account. However, sometimes, the unit secretary would discharge a patient before he/she was going out the door, when the patient still had medications to be taking, and the nurse was not able to administer any medication to a person who was technically not a patient any more. When patients were on pain medications, physicians would prescribe a "range order", so that physicians determined the doses according to a range of pain levels assessed by the nurses. But the dose in the pharmacy dispensing system remained the upper limit of the "range", therefore when nurses administered the dose lower than that, an incorrect amount warning displayed.

Table 2.2
Summary of Included Studies

Authors	Aim	Method	Participants	Setting	Operational Problem
Carayon, Wetterneck [12]	Explore nurses' use of BCMA technology from a human factors viewpoint.	Structured observation.	62 observations	A 472-bed Midwestern academic medical center, USA	Not scannable barcode, automation surprises, alarms, interruptions, unfavorable environment, and patient under special conditions.
Gooder [21]	Examine the perceived impact of BCMA system on nurses' ability to give medications, perceptions of medication errors, and nurses' satisfaction with the medication administration process.	Case-control study using questionnaire in one unit that was implementing the BCMA system and one unit that was not, before and 5 months after the implementation.	Prior to the implementation, 25 surveys on the experimental unit and 22 surveys on the control unit. After the implementation, 33 staff on the BCMA unit and 26 staff on the control unit.	A 28-bed medical unit and a 28-bed cardio-vascular step-down unit in a 280-bed acute care facility in the western USA.	System is hard to navigate and not user-friendly.
Huang and Lee [22]	Explore the impact on nursing activity patterns of using BCMA and understand the nurses' usage of BCMA.	Work sampling observation and interviews.	40 from the BCMA group and 46 from the paper group, 4940 observations.	A medical center in northern Taiwan	Network disconnection and breakdown, user inconvenience, and unavailable drug dispensing machine.
Koppel, Wetterneck [10]	Develop a typology of clinicians' workarounds when using BCMA systems; identify the causes and	Mixed method which combined 5 methods into a triangulated research effort:	62 structured observations, 31 shadowing of nurses, 29 nurse interviews	A 470-bed Midwestern academic tertiary-care hospital and a four-hospital, 929-	Technology: timeout, multiple screens and scans, unavailable information, bulky computer cart or

	possible consequences of each workaround.	observation of BCMA use and shadowing, interviews with staff and hospital leaders, participation in staff meetings, failure modes and effects analysis (FMEA), and analysis of BCMA override log data.		bed East Coast health care system, USA	scanner, connectivity, dead batteries, scanning failure; Tasks: not typical barcode, packaging discarded; Organizational: partial or too large dose, or different formulation, nonformulary medication, unavailable order, unavailable barcode, inadequate or incapable staff; Patient: unavailable barcode, interfered activities; Environment: remote scanner, loudness, unfavorable setting.
Novak [23]	Describe hidden work resulting from the implementation of BCMA.	Ethnographic study using triangulation of field notes from non-participant observation, meeting documentations and email communications.	Over 120 hours of observation and 170 emails.	Ten adult inpatient units in an academic medical center, USA	Orders were not confirmed when patients were transferred between different departments who use different systems; "range order"; changed schedules.
Novak, Anders [24]	Examine the work of a group of nurses who serve as mediators of the adoption and use of a BCMA system	Ethnographic methods, using field notes from observation, documents, and	Over 50 hours of observation, 170 email communications.	A multi-hospital, tertiary medical center, USA	No "staggering doses" feature, missed doses, and instructions specific to a particular dose of medication;

	using mediation framework.	email communications to enable a triangulation research method.			inappropriatedly documented doses stretching out across shifts.
Novak, Holden [25]	Describe how the nurses' orientation can collide with the orientation that is represented by the technology and its implementation, resulting in adaptations at the individual and organizational levels.	Qualitative study using observation and ethnographic fieldwork, content analysis of email communications, and interviews with healthcare professionals.	313 episodes of problem solving, over 50 hours of observation, and 170 email communications.	One 236-bed, academic, tertiary care, freestanding pediatric hospital in the Midwest and one multi-hospital, tertiary medical center, USA.	Hidden directions of medication administration; have to delay the administration; system "tenacity" for PRN medications; not autonomous to physicians' orders.
Patterson, Cook [11]	Identify side effects from a natural experiment, the implementation of BCMA, a technology designed to reduce ADEs.	Cross-sectional observational study of medication passes before and after BCMA implementation using detailed, handwritten field notes.	67 nurse-BCMA interactions/ mini-cases	Acute care and nursing home wards of 3 VA hospitals, USA	Degraded coordination between nurses and physicians; unscannable barcode; interruption and distraction; system shutdown; no "taper dose" feature.
Rack, Dudjak [20]	Analyze frequency and potential causes of workarounds in hospital using BCMA technology.	Mixed method of nurse focus group and staff nurse survey, which collected data related to the types and frequency of	220 respondents and 42 staff nurses in the focus group	An academic medical center, USA	Scanning failure; dysfunctional scanner and computer; patient under special situation; structure and location don't allow scanning.

		workarounds.			
van Onzenoort, van de Plas [19]	Study factors influencing the bar-code verification by nurses during medication administration.	Descriptive study by calculating the frequency of bar-code verification against the administering time, departments, availability of bar-code, number of drugs to be administered, and staffing	23,492 medication administrations	Five medical departments at the University Hospital Maastricht (UHM), Netherlands	Difficulties in scanning barcodes on the medication labels; lack of awareness of barcodes on medication labels; delays in responses from the EHR.
Voshall, Piscotty [26]	Present an overview of the literature regarding BCMA systems and best practices and suggest actions for nurse leaders to decrease workarounds in the process.	Literature review of empirical studies published between 2000-2010 using keywords *barcode* and *workarounds*.	14 empirical studies	Not applicable	Unfavorable design of hardware; unavailable barcode; interruptions.
Zadvinskis, Chipps [18]	Explore nurses' perceptions regarding EHRs and BCMA 4 months post implementation.	Qualitative study using phenomenological approach with semi-structured interviews.	10 staff nurses	One medical-surgical unit in an academic medical center, USA	Software issues, power loss, difficult logging on and scanning; missing medication; time restriction; interruption.

Conclusion

This integrative literature review focused on triggers to the operational problems of BCMA according to the work system perspective of the SEIPS model. To summarize, the triggers to operational problems of BCMA can be categorized according to the 5 elements of the work system of the SEIPS model, including tasks related, technology related, organization related, environment related, and individual related triggers to operational problems. The review suggests that the 5 elements of the work system of the SEIPS model may serve as a typology for categorizing triggers.

Clearly triggers to operational problems can be considered in different ways, depending on the perspective one takes. For example, a missing medication is a tasks related trigger to operational problem when number and type of medications are the major focus of tasks in medication administration. Others may classify a missing medication as an organizational problem when nurses go searching for the missing medication during medication administration.

Even with the most advanced system, the introduction of a new technology into a complex environment can bring unanticipated side effects on technical, social, organizational, economic, cultural, and political respects of work [32, 33]. Even the best-designed system will fail in an environment in which dysfunctional practices undermine the proper use of the system [34]. Therefore, an understanding of operational problems of BCMA implementation will help us better recognize how nurses adapt to the operational problems, and therefore optimize the effectiveness of the adoption of the BCMA system.

By examining the triggers to operational problems of BCMA from the perspective of work system components, this lays the foundation for the next two studies to understand nurse adaptations.

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Chapter III

Operational Problems of Barcode Medication Administration Systems: A Qualitative Study

Introduction

Bar-code medication administration (BCMA) systems were developed to prevent medication errors, in part, by verifying a patient's identity and the appropriate medication to be administered at the right time [1-3]. Although a number of studies reported that BCMA systems reduce MAEs in hospitals [4-9]. What has also been demonstrated is that BCMA has led to unanticipated consequences on nursing work and new, potentially predictable paths to MAEs [10-24].

Efforts to understand BCMA's impact on nursing work have largely focused on nursing "workarounds", which are generally considered as deviations from BCMA use protocols [13]. "Adaptation", on the other hand, reflects nurses' attempts to create a new route to achieving a goal such as safe and timely medication administration.

The operational problems nurses encounter that trigger adaptations is under-studied; there are no studies that have systematically explored the operational problems of BCMA in practice. Recently, there have been calls to conduct further research to identify the characteristics of the BCMA system nurses consider problematic and in need of modification, so that the system design can reflect on nurses' considerations with respect to system usability, functionality, and impact on nursing practice [25].

Conceptual Framework

The conceptual framework guiding this study is an integration of the SEIPS model and a sociotechnical perspective considering that operational problems occur because of the collision between the "System Frame" and the "Practice Frame". The system frame is represented as the way the system is considered functionalized and implemented by the cumulative assumptions, decisions, priorities and perceived problem-solving of the vendor, developers and implementation decision-makers [26]. The work system within the SEIPS model frames dimensions of the system frame relevant to BCMA. The practice frame that drives nurses medication administration practices includes safety, efficiency, and the "5Rs" (right patient, right medication, right time, right dose, and right route) of medication administration. The focus of this study is validation of the typology of work system triggers of operational problems of BCMA (see Figure 3.1).

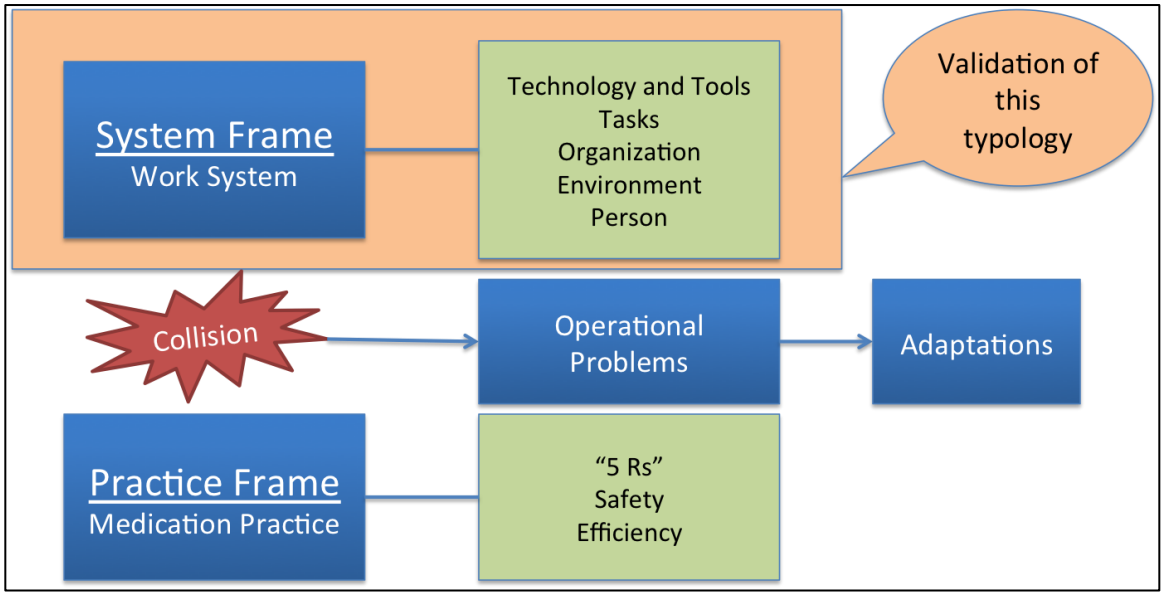

Figure 3.1. **BCMA and adaptation.**

Literature Review

The literature reported in Chapter II focused on components of the work system (see system frame) and is summarized as follows. The most frequently reported technology and tool related triggers of operational problem of BCMA was the repetitive scan attempts until the system could pick up the barcode [13, 17, 27-29], due to the technology capability [13]. The EHR system sometimes was hard to navigate [13, 27, 30], especially when nurses had to switch several screens between different systems, for example in some hospitals, the CPOE was isolated from the eMAR, or different services had their unique access to the system. Other technology difficulties could be contributed by the a abruptly frozen system [27, 28, 31], dead power supply or Internet connection [27, 31-35], time out by the system [13, 29], or an oversize or overweight computer or scanner [13, 27].

Tasks related triggers of operational problems were primarily addressed by the barcode issues. Barcodes could be wrong, [36], multiple available [13], not available [13, 31], or hard to scan [17, 27, 29]. Novak and her colleges described the system as "tenacious", as nurses were not autonomous to strategically adjust the doses of medications and the time of the administration for any reason [36-38]. Therefore, nurses were not able to stagger the schedule of medication administration as was clinically appropriate and within their scope of practice [15], or substitute with clinically equivalent sets of doses, when partial or extra doses were ordered [39].

Person related triggers involved in the medication administration could bring about operational problems. Patients in special situations impeded the performance of medication administration, i.e., patients refused or vomited medications, or patients were resting, agitated, in the restroom, or in contact isolation [13, 27-29]. Sometimes, patient

removed their wristband with or without any reason, and then nurses had to obtain another wristband barcode to scan [29].

Several environmental factors could interfere the procedure of medication delivery. Nurses could not access to the bedside or the computer, if the configuration of the patient's room is not user-friendly designed. Messy or disorganized patient room or medication room hindered efficient medication administration, especially when multiple trips to scan, dispense, and return of the remaining were needed [27, 32].

Organizational triggers of operational problems were addressed as interruptions and coordination, collaboration and communication between nurses and physicians and pharmacists. Interruptions happened when patients and families initiated special requests, physicians intervened in the process, medication or barcode was found missing during the process, or other medical equipment sounded alarms [27]. Interdisciplinary collaboration, coordination, and communication filled up the gap, to some extent, when patients were transferred with pending or active medication orders between different departments, where the BCMA was not applied [37].

The purpose of the study was to validate the findings of the work system triggers to operational problems of BCMA identified in the literature review in Chapter II. Given the fact that this study touched the sensitive issues of medication administration errors and workarounds, there was not a single approach that was able to uncover the truth.

Methods

The aims of the study were to explore what operational problems of BCMA nurses were having in their daily practice or expecting to happen in the future, and then

validate the findings in literature review reported in Chapter II. Approval of the Institutional Review Board from the study site was obtained.

Study Design

A prospective, exploratory design was conducted to meet the study aims.

Sample

Given that the compliance rate of BCMA across the hospital reached around 90% and considering operational problems of BCMA was a rare incidence, it was planned to enroll 30 nurses for observation and interviews about BCMA-related operational problems, until data saturation was reached. Multiple studies have identified a sample size of 30 nurses as a sample size required to reach saturation [27, 30, 32-34, 36, 38, 40-42].

Inclusion criteria were: 1) permanent full-time staff RNs; 2) working on one of four medical and surgical adult acute care units; 3) having worked on the unit for at least one year (including unit based temporary staff); 4) having been trained to use BCMA; and 5) having experience in using BCMA. Exclusion criteria were central staffing resource nurses (CSR temporary staff).

Setting

This study was conducted in a 1000 bed large academic medical center located in Michigan. Nurses were recruited from 4 adult medical-surgical units. The BCMA system used in the study site is a part of the EHR system, which provides with technology support for an integrative electronic medical records system used across different units, departments, and hospital sites within the health system.

Procedures

Data collection consisted of: (1) observations of BCMA use by shadowing of staff administering medication, (2) interviews with staff nurses involved in BCMA use. Observations and interviews respectively provided examples of BCMA-related operational problems. The integration of these data sources supplement each other to provide a more comprehensive perspective.

A semi-structured interview guide was developed with open-ended questions and probes (see Appendix I). The interview guide was modified after consulting with the hospital specialist who monitors and audits the BCMA scanning compliance condition within the entire system, and also conducts education and training with nurse staff about the BCMA usage.

1. Development of the observation form

The observation form developed for the on-site observation addressed the steps of the workflow of medication administration practice on the study site (see Figure 3.2). This form was reviewed by a nurse specialist of the study site, who persistently oversees and audits the compliance report of BCMA scanning across the entire medical system every month. Necessary modification to the observation form was made accordingly. Field notes were made when an operational problems was triggered at any key step.

2. Development of the interview guide

Nurses were asked to give examples of conditions that triggered operational problems with open-ended questions, framing their examples by the components of the work system of the SEIPS model: technology, tasks, environment, organization, and person. Besides the current operational problems the nurses had already encountered,

future difficulties that the nurses could think of were also addressed in the interview (see Appendix I).

BCMA Observation Form

Unit _____ Shift _____ Subject ID _____

Task	Time	Observation	Comments
Access MAR			
Obtain Meds		Meds, types, route, and preparation personel	Is the medication available?
Prepare Meds		Patient's level of consciouseness Surface for Med Admin Lighting in Pt Room Other Environl Factors	Is barcode scanning available?
Scan Wristband		Scaner Reaches	Is wristband barcode scanning available?
Scan Meds			Are the five rights accounted for? Does the medication require dual sign-off?
Admin Meds			Does the patient get ready for medication administration?
Document the Admin			
Warning	□ 'Medication not Scanned' warning □ Administration warning □ Other Nuisance warning		
Personnel Involved	□ Physician □ Pharmacist □ NP □ NA □ Families □ Other		
Other Comments			

Level of consciouseness □ Alert □ Vigilant □ Lethargic □ Stupor □ Coma □ Uncertain
Surface for Med Admin □ COW □ Patient Table □ Wall Tray □ Other
Lighting in Pt Room □ Overhead Lighting □ Spplemental Lighting □ Other
Other Environl Factors □ Noisy □ Crowded □ Organized □ Other
Scaner Reaches □ Without hitting objects □ Stretching over pt □ Other

Figure 3.2. **Observation form.**

3. On-site observation

After obtaining IRB and Nursing Administration Research Committee approvals at the study sites, a list of eligible unit sites (medical and surgical adult acute care units) was obtained. Three pilot observations (n=3, 10% of the targeted sample size) were conducted on one study unit to test the observation form.

Next, a list of potentially eligible nurses from the Nurse Manager or designee (e.g. charge nurse) was obtained, upon arrival at the eligible unit sites. Nurses were randomly selected from this list and validated with the Nurse Manager or designee about their eligibility against the inclusion criteria. Eligible nurses were approached to participate in the study by enrolled after obtaining a written informed consent. All the recruited nurses consented and participated in the observations and the follow-up interviews. The consented nurses then agreed on a time during that day when the nurse agreed to be observed and interviewed. The observation of each event was planned for 10 minutes.

Each nurse was observed for 1-3 medication administration events. One medication administration event was an event of one patient being given a set of doses of medications at a time. The observation of each medication administration event started when the nurse accessed the eMAR in the medication room. When the nurse obtained the medications from either patient's cabinet or the Omnicell, the amount and type of the medications that needed to be delivered, and their availability when the nurse accessed them were observed. Then, the nurse went into the patient's room and, if the medications were available, prepared medications at the patient's bedside. Data collected by the researcher: 1) patient's level of consciousness, 2) surface used for medication administration, 3) lighting sufficiency in patient room, 4) other environmental factors

(e.g., noisy, crowded, organized, etc.), and 5) barcode availability. The nurse would scan the patient's wristband, where the availability of the wristband and the verification of patient's identity were conducted by the nurse, followed by another scanning on the medications barcodes. Finally, the medications would be administered, and the administration would be automatically documented in the eMAR. In the course of the medication administration, other information which would be taken notes as well were: all the warnings triggered by the system, personnel involved in the process, and whether the scanner reached out without hitting objects.

4. Follow-up interviews

After the observation, a semi-structured interview with each nurse was conducted in a private room. The interview focused on the operational problems the nurses had encountered and expected could happen in the future. The interview was planned for no longer than 30 minutes. The interview was tape-recorded. Basic demographic information was also collected, including age, gender, and education.

Data Analysis

Quantitative and qualitative data were analyzed separately and collectively. Quantitative observation data were analyzed using descriptive statistics (minimum, maximum, mean and standard deviation; frequency and percent). The field notes on triggers of operational problems were coded into work system elements of SEIPS model: (1) tasks are number and type of medications, including pharmacy-prepared medications, which are known as ready-to-administered medications, and medications that have to be labeled on unit. Necessary care related to medication administration is also counted as a part of the task, such as glucose monitoring and blood pressure monitoring; (2)

technology primarily refers to BCMA although eMARs were included because they may introduce technology-based difficulties; (3) organizational factors could be coordination, collaboration and communication between nurse and physicians, pharmacists, or nurse assistants; (4) environment is described as lighting, noise, neatness, organization, crowdedness of the patient room and medication room, and interruptions introduced from environment and other individuals; and (5) person includes patient factors (e.g., isolation, rest, critical conditions) and disciplines. Both quantitative observation data and qualitative interview data were coded and classified into operational problems.

Interviews were fully transcribed. The responses to each question were summarized.

Results

Sample Characteristics

When data saturation was reached, twenty-two nurses were enrolled in the observation, with all of them completing the follow-up interviews (n = 22). Table 3.1 demonstrates that the majority of nurses were younger than 25 years old (n = 6, 27.3%), female (n = 20, 90.9%), working in unit A (n = 9, 40.9%), and professionally trained with a baccalaureate degree (n = 18, 81.8%).

Table 3.1
Characteristics of Sample (N=22)

Variables	*N (%)*	*Variables*	*N (%)*
Age		Unit	
<25	6 (27.3)	**A**	9 (40.9)
25-30	5 (22.7)	**B**	6 (27.3)
30-35	3 (13.6)	**C**	2 (9.10)
35-40	3 (13.6)	**D**	5 (22.7)
40-50	5 (22.7)	Education	
Gender		**Associate Degree**	2 (9.10)
Male	2 (9.10)	**Baccalaureate Degree**	18 (81.8)
Female	20 (90.9)	**Master's Degree**	2 (9.10)

Observation Data

There were 43 medication administration events observed and included in the study. One medication administration event was defined as one nurse passing medications with one patient at one point in time. The average duration of each medication administration event was 13.19 minutes, with a standard deviation of 9.34, and an average of 5.16 medications were delivered during that time (SD = 3.96). Most of the observations were conducted in the morning between 7 am to 9 am (n = 26, 60.5%). Table 3.2 summarizes the full results of the observations.

Table 3.2
Descriptive Data on Major Observation Variables (N = 43)

Variables	*N (%)*	*Mean ± SD*
Duration of Medication Administration (min)		13.19 ± 9.34
Number of Medications Passed		5.16 ± 3.96
Time of Observation		
7 am – 9 am	26 (60.5)	
2 pm – 3 pm	10 (23.3)	
9 pm – 11 pm	7 (16.3)	
Medication Availability		
Yes	37 (86.0)	
No	6 (14.0)	
Patient Level of Consciousness		
Alert	31 (72.1)	
Vigilant	7 (16.3)	
Lethargic	4 (9.30)	
Stupor	1 (2.30)	
Surface Used for Medication Administration		
Computer on Wheel (COW)	28 (65.1)	
Patient Table	7 (16.3)	
Wall Tray	1 (2.30)	
More Than One Platforms	7 (16.3)	
Lighting In Patient Room		
Overhead Lighting	27 (62.8)	
Supplemental Lighting	3 (7.00)	
Daylight	6 (14.0)	
Screen light	7 (16.3)	
Environmental Factors		
Noisy	1 (2.30)	
Crowded	17 (39.5)	
Organized	24 (55.8)	
Both Noisy and Crowded	1 (2.30)	
Medication Barcode Scanning Availability		
Yes	43 (100)	
No	0 (0.00)	
Scanner Reaches		
Without Hitting Objects	31 (72.1)	
Stretching Over Patient	11 (25.6)	
Other	1 (2.30)	
Wristband Barcode Scanning Availability		
Yes	36 (83.7)	
No	7 (16.3)	
Five Rights Accountability		
Yes	22 (51.2)	

No	21 (48.8)
Dual Sign Off Application	
Yes	0 (0.00)
No	43 (100)
Patient Readiness	
Yes	30 (69.8)
No	13 (30.2)
System Warning	
Medication Not Scanned Warning	1 (2.30)
Administration Warning	5 (11.6)
Both	2 (4.70)
No Warning	35 (81.4)
Personnel Involved Other than Nurses and Patients	
Physicians	6 (14.0)
NP/PA	1 (2.30)
Families	5 (11.6)
Pharmacists	15 (34.9)
More Than One Personnel	7 (16.3)
No Other Personnel	9 (20.9)

In the majority of the medication administration events, medications were available when they were due (n = 37, 86%). Most of patients involved were alert (n = 31, 72.1) or vigilant (n = 7, 16.3%). The computer keyboard attached beneath the monitor of the computer on the wheels (COWs) was the most frequent surface used by the nurses to place the medication (n = 28, 65.1%), followed by the patient bedside table (n = 7, 16.3%). In 7 events, nurses laid out the medications on the keyboard to scan the barcodes and then placed them on the table before they scanned patients' wristbands (16.3%). Nurses preferred to use the overhead lighting for medication administration (n = 27, 62.8%), whereas in some nighttime events, nurses passed the medications only under the faint light of the screen of the computer (n = 7, 16.3%). Some of the patients' rooms were crowded (n = 17, 39.5%) when the nurses passed the medications, and the nurses hit objects (n = 31, 72.1%) or stretched over the patients (n = 11, 25.6%) when extending the cord of the scanner to reach the patients. Medication barcode was available in all

observed events. There were a few observations when patients' wristbands were not available (n = 7, 16.3%), either because they were not attached on patients' wrists or the barcodes wore out. In many observations, patients were not ready for medication administration when the nurses approached them with medications (n = 13, 30.2%); for example, they were still eating meal, or getting ready for a trip off the floor.

Among the 8 cases when the nurses recorded a system warning when they scanned the medications, one warning occurred when the vial of the antibiotics was not scanned before or after the dilute solution bag was scanned (2.3%), and another five alerts occurred when the dose of the medications scanned did not match with the order (11.6%), because only a partial dose of a vial or a pack needed to be administered. There were always some personnel other than patients and nurses who were involved in medication administration (n = 34, 79.1%), and in most of those cases, more than one party (e.g. physicians and pharmacists) played a role (n = 22, 51.2%). For instance, pharmacists were called for delivering some medications that were STAT orders or new orders (n = 15, 34.9%), or physicians were paged for a clarification about a specific medication order (n = 6, 14%).

Qualitative Interviews

The qualitative interviews were focused on the triggers of the operational problems the nurses had encountered before, or they had heard or seen them happen to someone else, as well as the problems they believed could happen in the future. Qualitative data analysis was informed by the conceptual framework that guided this study: 1) overall perceived impact of the BCMA on medication administration, 2) perceived technology related triggers of operational problems, 3) perceived tasks related

triggers of operational problems, 4) perceived environment related triggers of operational problems, 5) perceived person related triggers of operational problems, and 6) perceived organization related operational problems. Multiple minor themes emerged to support this classification.

Overall Perceived Impact of BCMA on Medication Administration

Participating nurses shared their overall perceptions about the impact of the use of the BCMA on the medication administration practice on a daily basis at the beginning of the interviews.

Safety. The majority of the nurses perceived that the use of the BCMA could improve patient safety in terms of delivering the right medication to the right patient at the right time. Most nurses described the use of BCMA could prevent them from making mistakes when administering medications:

"... I mean I feel safer. You get tired at the end of your shift. It is nice to just have another verification for your meds..."

"...I'm very, very satisfied. I think it is a terrific tool for improving patient safety. Because we're only human beings… people are busy and you can very easily miss something or give something..."

Many nurses perceived that the use of BCMA made the medication administration more accurate. In a manner of speaking, it helped them better understand what the medications were they were delivering, when exactly the last dose was administered, and when the current dose should be giving:

"...They (medications) are in their little packages… one of the positives is the nurse is saying, well I have this, this, and this for you and so if the patient isn't taking one of those, they can say something and you know exactly what that pill cause it is still in its package…"

"...I guess it makes us more on time for that (medication administration)…and then it allows us to see like the exact minutes instead of (hours)…if you're giving a PRN medication, and it's only Q4… the last person gave it at the 5'o clock hour, but is it 5:15 or 5:50? It would make a big difference, whereas now with the scanner, it gives us an exact time…."

Efficiency. Majority of the nurses perceived that the use of BCMA improved their workflow, compared to the paper era, in terms of cutting off the multiple comparisons of the medications against the printed MAR and expediting the medication administration process:

"...I think it's definitely improved my patient care flow and the speed at which I can administer meds… where I first started working, we didn't even have computers in the room. So it was very cumbersome to pass medications because you had to print out their entire MAR. Double check it, make sure you had it all right… and then in that time, if a doctor changed the orders, you didn't know it until you got back on the computer… and that could have been a whole hour before you're on a computer again. So from that experience to now, it is so much better cause, if a doctor makes a change on a med, I'm gonna see it because I have to get on a computer before I can give it…"

Some nurses also pointed out that since the BCMA could pick up the order automatically when physicians prescribed or changed it, it benefited the patient care in an efficient manner:

"...It changes the efficiency of the patients getting precisely what the physicians want them to receive..."
"...And then if something that was ordered…the doses slightly got changed, the computer will pick up on it..."

Stress. Despite being considered as a tool that improved patient safety and work efficiency, the use of BCMA was believed as stressful by a few nurses because of the added steps they had to go through before the verification was checked out by the computer. Sometimes, stigma arose:

"...I mean it can be stressful when there are a lot of people in the room and you have to try and scan, and the wristband doesn't scan, you get a big red box on the computer you have to hit cancel before you can scan again, so you have to walk back and forth between the computer and the patient several times…"
"...I think there's that added stress a little bit when you get caught up doing stuff in the morning and your last patient doesn't get their meds until 10… things are documented at 10 and they were due at 8..."

Overdependence. It is noteworthy that a number of the nurses perceived overdependence on the use of BCMA. They believed nurses over relied on the

verification performed by the BCMA, instead of performing the "5 right" themselves. In a worse case, when nurses suspected it was not the right medication when the BCMA verified oppositely, they would trust the BCMA and proceeded with the medication administration, which would dramatically endanger patient safety:

"...I mean if we're scanning a med and it's not the med that we think it is. But it's telling us it's the right med, sometimes people tend to rely on the scanning more than they should... So making sure even though you're scanning, it gives you a safety blanket but you also have to check what you're giving..."

Some other nurses described that with the application of the BCMA, nurses nowadays just physically scanned what they needed to deliver, without critically thinking about the effects of these medications, or the plan of care of a specific patient in a holistic way:

"...I know that I still do my safety checks and everything, but I feel like it almost takes away thinking about the meds, nurses especially, like why are they getting the med? Do they need it? You're like go over here, get the med, scan, scan, scan, take these meds...Yeah, it kind of takes away some of the thought process..."

Even when the BCMA has some sort of functions to support nurses' decision making, it is still easy to be missed:

"...You have to be able to judge like if some one's heart rate is too low, am I going to give them this Lopressor? But some people don't, they just scan, scan, scan... and there is usually a note in there that will say, don't give if they're less than 60. What would be nice would be a little prompt or something, like our IV pumps do... so like next to the medication there's this little yellow thing that you have to hover over to see the directions..."

The majority of the nurses perceived that the use of BCMA indeed improved patient safety and work efficiency in a variety of forms, just as how it was designed and expected to function. However, simultaneously, some nurses identified that the BCMA could introduce stressfulness and overdependence, and these issues would jeopardize patient safety in a different, but more inattentive, way.

When the nurses moved on to the operational problems of BCMA they had encountered in real work environment, they described the operational problems as a result of 5 different contributors.

Perceived Technology Related Triggers of Operational Problems

The majority of the nurses perceived that operational problems of BCMA were due to the hardware and/or software of BCMA, some were expected or predictable and some others were not.

Frustration caused by the cord. The cord connecting the scanner to the computer was the most frequent issue reported by almost every nurse, which always frustrated nurses, especially when the cord could not reach the patient who was away from the computer or multiple scans were needed before the scanner could catch the barcode on the wristband.

"...The only thing I would say about that is the cord… like in bed 1, the computer is on this side and if they're on the chair on the other side of the bed, you've gotta walk around and stretch this thing way over there…"

"...I would say just the fact that it's on a cord and like having to maneuver... If the patient is in the hallway and going for a test and they get nauseous, and so you want to give them something real quick, before they leave and you can't scan it because the cord isn't going to reach into the hallway, so you just got to override it..."

System backstage glitches. Some nurses reported that sometimes, the system would not register the medication administration after all the medications were successfully scanned, verified, delivered, and documented in the eMAR. Nurses would not even know until the next time they logged into the system to deliver patient care.

"...Sometimes when you scan a barcode and you click accept, the machine won't register that you scanned it so when you go back in the MAR, even though you gave the med and there is no warning that says you didn't give it. It comes up as not given in the MAR, so you have to go back in and manually put in 'yes I gave this', so that's been a little bit annoying..."

"...So now my biggest problem that I have had is that I have scanned all the meds, clicked that I gave them, and then later in the day, I go back and find that none of

it was documented and I don't know why that happened. But then I have to go back and then individually…because of course I don't have the barcodes at that time because I have already dispensed the stuff, so that's for me, probably the biggest thing that sometimes it doesn't capture, and then you have to follow up and go back and fix it…"

Another trigger of operational problem reported by the nurse which is related to the glitches in the system is that after the nurses scanned the medication, the system alerted that the order did not exist, when the order was not actually discontinued at all.

"…The other day a patient had an order for an IV fluid. I think it was D5.45 with 20 of K. I double-checked it with her (another nurse) and it wouldn't scan. It kept saying 'patient doesn't have an order'. So we had to call the pharmacy and they had to discontinue the order and reput the order in, and then it worked. But things like that where it had the order, I have the right med. It's not working. So it's delaying my care. There's no reason for it..."

System delays or shutdown. The nurses reported that when experiencing system or computer shutdown, they would have to wait for it coming back or restored, and therefore their medication administration would be delayed.

"…I mean you could be giving your meds, and all of a sudden it's time for a windows update, it shuts the computer down..."

"…Our computers don't run on batteries. So when I tried to move the computer, it became unplugged, and then I had to wait for it to reboot…"

When a STAT order was made with an existing stand order, there could be a delay in the system for the new STAT order being transmitted to the Omnicell before the nurse could pull the medication out of it.

"…There are some meds like different electrolyte supplementations. If they have a standing BID order for certain electrolytes, and then they add another electrolyte for that day on top of it, it's sometimes complicated how you can retrieve those meds from the Omnicell and how you can scan them. Because there's some lag in the system that says that that med was already given, even if it's a separate order..."

The technology-related triggers of operational problems reported by the nurses are mostly unpredictable by nurses and always cause a hard stop during medication

administration. Nurses often feel frustrated when the reason contributing to the hard stop is unknown and they are even unable to override the system to proceed with the operation.

Perceived BCMA Tasks Related Triggers of Operational Problems

Specific task-related triggers of problems are discussed below.

Specific medication barcode is unavailable. Some medications may have multiple barcodes on manufacturer packaging with different functions, which could be confusing for nurses to scan.

"...The Lidoderm patches has two barcodes on it. It has one in the front and one in the back. One works, and one doesn't. So you have to grab the right barcode. It's a manufacturer thing..."

Some packaging or pills don't have a rip on them. When nurses have to deliver partial dose of a pack or a pill, the packaging often got damaged after the entire dose was separated, and the barcode on the packaging was hard to be caught because of that.

"...Sometimes, like the Colace pills, they don't rip. They come in these big packs. And they don't rip apart too well. So I've definitely had times where I've ripped the barcode. So then you have to leave the ripped one in there and get a different one. It depends on the medications that, just the ones that come in the big..."

The barcodes of some narcotics or other controlled substances, which nurses often had to waste a partial dose, were very easily to be ditched before the barcodes were scanned, because this operation happened before the nurses went to the patient room. Even for regular medications, it was not a rare case when nurses threw away the vial or the packaging before the barcode was scanned. In those scenarios, nurses would have to either override the system, or retrieve another intact dose and scan the barcode of it:

"...Like for Lasix, if I had gotten rid of that little vial before I had scanned it, you'll probably get a 50/50 split of answers on the unit. A lot of people will just say 'barcode unreadable', or 'barcode unavailable' because they got rid of it. If it's something that I can reproduce, then I'll try to go back to the Omnicell, pull out another vial of Lasix to be able to scan it and then return the extra one just so I can scan the correct medication because I know that they audit trails of barcodes being unreadable or

barcodes being unavailable and have suspicion of 'are you administering the right medication?' But it creates a lot of extra work to have to go back, pull out another one, take it to the patient's room, scan it, go back to the Omnicell and return that medication…"

"…One thing I've run into is we have to waste our medications if they are a narcotic or a controlled substance in the Omnicell before we give it cause a lot of times they're just partial doses, so if you forget to bring that vial with you, and you accidentally put it into the sharps already, then sometimes that causes a problem. We're used to the old way where we would waste and then dump the like a Dilaudid syringe. I know I've done that before, and I know that other nurses have done that, too, where they accidentally put it into the sharps after wasting..."

Medication barcode mismatches the medication. Sometimes, barcode can be wrong, which requires nurses to visual check of the medication. This is the time when nurses' past training and experiences become crucial for patient safety:

"…Sometimes, it (medication) doesn't always correlate to what the computer says it is. So it'll say this is past its expiration date, or this is inappropriate, so then you have to go 'okay, barcode not available', because sometimes, what pharmacy prints out and what the computer is seeing don't match..."

"…But I guess there's been issues where that barcode isn't matching what the med actually is. It's scanning and it's saying that it was the right med but it wasn't..."

Wristband barcode is unapproachable. A number of the nurses reported that the multiple barcodes or the outworn barcode on patients' wristband always impeded the process of medication administration and created extra work along with the difficulties the cord had brought about.

"…The patient wristband has multiple different scanning options, so there is one that is used for phlebotomy, there is one that is used for medication, and one that is used for to check a blood sugar, so you have to isolate the one that you need; otherwise it is going to pick up one of the other ones and then you have to redo it…"

"…If a patient has been here for a long time, their wristband gets worn out. So that's why it stops being able to scan..."

"…If it (the barcode) doesn't pick up the first time, you have to walk back and edit it and go back around, so a wireless system would be amazing…"

System's "Tenacity". It was reported by the nurses that the eMAR would not allow nurses to adjust the time of medication administration, when nurses delayed or brought forward administering a scheduled medication for a good reason:

"...When you get new orders for a medication, like you're supposed to give potassium 10 mEq once a day and they change it to 10 mEq twice a day. And they change it at like 10:00 and maybe you're a little bit late giving your medications because you are busy. It (the system) thinks that the first order was DC'ed (discontinued) and then, it doesn't populate the MAR with the BID order until a timing of 9:00. So you get caught in this. It asks you 'Do you want to administer this? This order is not set to start until the future. Do you want to administer it?' But it won't let you go back to the order. It's still the same order… then you'll end up having to document that you're administering the new dose early and then going back that you didn't give the other dose. So there's some overlap issues when there's some new orders..."

"...One of the issues with the EMAR is it, the minute that the physician writes an order, it populates onto the MAR. So if we are going to give heparin three times a day, it's 6, 2, and 10. So they write for a heparin shot, say now (10:00). Well, I'm not going to give it to them at 10, I am going to give it to them at 2, so then it gets on that schedule, but unfortunately everything populates the moment that it is written for..."

Another representation of "tenacity" of the system reported by the nurses was that nurses were not autonomous regarding adjusting doses of medications:

"...I have an extra order for potassium because they have a low K in the morning but they get a standing dose of 10 or 20 daily, you have to give them separately. Like you have to accept them and then you have to go back and scan everything again, even though both doses are there. It's the same with insulin. You're doing a lot of double clicking to give your entire dose of insulin, like if they have a sliding scale and meal coverage..."

Among the tasks related triggers of operational problems reported by the nurses, some are contributed by the manufacturer, which seem not hard to be fixed, while some other are generated by the computer system, which required interdisciplinary collaboration to optimize the system.

Perceived Environment Related Triggers of Operational Problems

The environment related triggers of operational problems were described consistently across nurses, and from two different perspectives: the limitation of the work platform and the limitation of the workspace.

Limitation of the work platform. Most nurses expressed that they were not satisfied with the design of the work platform for medication administration at patients'

bedside. There was a tray that nurses could pull out under the computer, but it was a little high for a lot of nurses and always occupied by supplies.

"...The platform you use to prepare the medications is not user friendly. You got the computer up here, you got the keyboard here, then you got the little thing here, and most of the computers are on an angle so sometimes stuff starts sliding, especially if you're short. If you're really short you can't get to the top of the computer..."

"...I'd open the meds and put the wrappers on the keyboard, and I wouldn't be able to type. I don't think there's enough room at all to prepare medications. There is a tray on the wall. Yeah it's usually occupied by other stuff and I'm like shorter. So sometimes, I'm like reaching my arms up, and I feel awkward opening my medications where I wish I had something more at chest level. So I could open them up downwards instead of upwards and have them fling everywhere..."

Limitation of the workspace. This type of operational problems was generally related to the layout of the patient room. It's very conspicuous nowadays is because nurses make much more movements at patients' beside during medication administration, compared to the era when nurses do not necessarily move around:

"...Like if there is a lot going on in the room, or if their room is really cluttered or the computer where I tend to lay out my meds before I scan them is really crowded, sometimes I get a little anxious because I want to make sure that I get all the meds, and I don't want something to slip under their blanket or a pillowcase..."

"...Just with how small the rooms are, like there's a bed and a chair and all the equipment… it's ergonomically (difficult), and then just frustrating taking the scanner walking around the room…"

Although there are several elements that compose the physical environment of patients' room, like light and noise, the nurses mostly considered the layout of the room and the design of the work platform could be improved to facilitate the medication administration practice.

Perceived Person Related Triggers of Operational Problems

Majority of the nurses agreed that it was challenging and cumbersome to deliver medications, when patients were under special circumstances: emergency and/or isolation.

Emergency situations. When patients are in emergency situations, the workflow of medication administration will be adjusted accordingly. The medication orders will primarily be oral orders prescribed by healthcare providers, which haven't been registered in the eMAR. Nurses will have to administer the medications before they are ordered or documented, but keep the corresponding vial or packaging for later documentation. However sometimes, the nurse who administered the medication doesn't even know the physicians who were involved in the rescue. The nurses reported that it could be hard for them to track physicians down and complete the whole documentation process afterwards:

"...I had a verbal order from the doctor to give 4 of morphine because my patient was having a heart attack. The CCMU fellow was there. I said, ' I'm giving 4 of morphine', and she said, 'okay'. And then I never got an order to link it. I needed them to place an order so I could link my override. When I reached out to that CCMU fellow, she said 'I never… I didn't tell you to give that… well you have to get the order from the physician who told you that'. But I don't know his name! He was a cardiologist; he was at the bedside with her. So I had to hunt him down and it was this long drawn out process for no reason when she was at the bedside. It shouldn't have been that difficult, especially when the patient was having a heart attack..."

Patients in isolation. When delivering medications to the patient who is in isolation, nurses will have to take necessary precaution before they enter the isolated patient room. The nurses described that they had to come up with some strategies to avoid violating policies or the repeated dressing when making multiple trips in and out.

"...I find isolation to be annoying, and that's why things have to be done very systematically because it's kind of annoying to be putting on the gown, taking off the gown. It's time consuming, too. So you have to make sure that you've got everything you need. And I will always take more into the room, like maybe they want this PRN, maybe they don't want their Tums, not narcotics of course, but I will take some Mylicon for example, so that you're amply prepared. But isolation rooms are time consuming..."

"...In contact rooms, it's more of a nuisance because you have to think, but you can't take the whole insulin syringe in there because it's a contact room, so you really have to prepare that in the med room. So you have to be cognizant of what you're taking in there and what you need. We had an issue with a multi-dose vial, so the patient was requiring PRN Labetalol frequently, and somebody had left the Labetalol at the bedside

because they took it into the room. It's not a medication that can be left at the bedside, but it's a multi-dose vial, and they don't want you to prepare it in the (medication room). So they have come up with some of those things can get multiple stickers, but still you're preparing it in the med room then..."

Although there are other individuals who always present on the scene when nurses deliver medications at patients' bedside, like families or other disciplines, the nurses did not consider these individuals as distraction or obstacles. Only when patients who are in emergency or isolation did the nurses realize operational problems were generated.

Perceived Organization Related Triggers of Operational Problems

Nurses collaborate with multiple disciplines in hospital when passing medications, where most of the collaboration takes place with pharmacists. After physicians place medication orders in the eMAR, the orders will be transferred to the pharmacy for pharmacists to verify, prepare, and deliver the medications on to the floor. The nurses recognized that pharmacy often delay with the verification and the delivery of medications.

Delayed verification of medications. The nurses indicated that it always took a lot more time than they expected to get the medication verified by the pharmacy, which could dramatically endanger patient safety. Sometimes, whey would have to override the system or workaround the policy to obtain or pass the medications.

"...Sometimes what will happen is that pharmacy will take forever to verify something and you're like, 'Does pharmacy have not verify this? Do you want to override it?' Yes, I want to override it! Because it's like they just changed one Motrin to a new Motrin and it's like they changed 400 to 600 milligrams. Same medication…"

"...You call pharmacy and ask them to verify it. One time I had a big safety issue, like they started him on Sotalol because he was doing lots of VTac (ventricular tachycardia) and I called pharmacy and was waiting like an hour. I called them 3 times to verify the medication so I could get it from pharmacy. Still wasn't verified. My patient went into sustained VTac for like 2 minutes while he was in the bathroom, so the service calls the pharmacy to try to get the Sotalol and it still takes an hour to get it down here.

So issues like that happen a lot. You got to do what you got to do…Yeah, because of patient safety. They need the medications..."

Delayed delivery of medications. The nurses also reported that, after the pharmacy verified medications, there still could be a delay with the delivery of the medications, especially when patients were transferred between different departments.

"…One of the biggest problems is there's only one pharmacy for the hospital now. So let's say they make their runs on the half hour. So they start on 6. They do 5, they go down to Med-ops, they go to surg-ops, and then they come back up here. So theoretically, they can order a medication at 7:30, and you might not get it until 9, or even the 10:00 run. So there's a delay sometimes when they verify it, when it gets delivered…"

"…Like scheduled meds, that should be there. They have been on these meds for a few days. Yeah and they are not there, and they are due, and they have still not been delivered. Especially when you have transplant medications, stuff that is really important. We have more difficulty when they come from the ICU; I think it takes a little bit for our pharmacy to catch up with them, and that can be a real difficulty…"

The nurses described that physicians always responded to their request in a timely manner, whereas pharmacy often impeded the efficient implementation of medication administration. It was reported frustrating and time consuming for nurses to address unverified or undelivered medications with the pharmacists.

Discussion

The results of this study mostly validate the findings of the triggers of operational problems yielded in the literature review in the Chapter II, although there are some differences noted.

Technology and Tools Related Triggers of Operational Problems

Firstly, the cord of the scanner, which always got intertwined between the computer and patient, was the most frequently reported technology-related operational problems by nurses in this study. Koppel, Wetterneck [32] reported the same finding in their study. Multiple scan attempts were needed until the scanner could pick up the barcode. This was a common finding across this study and the literature [13, 17, 27-29], due to

the technology capability [13]. But in this paper, this type of operational problem will be considered as task related operational problems, rather than technology issues, because the reason why this has been happening is either because the quality of the barcodes is imperfect, or the barcode is just missing, whereas the barcode scanning is the tasks nurses are trying to accomplish. Technology related operational problems owing to system delays or shutdown were overwhelmingly found in the literature [27, 32-35, 41, 43]. Another significant outcome of this study is that sometimes the medication order was not in the system by the time it was due because of backstage glitches. Koppel, Wetterneck [32] described the same finding, but it's as a consequence of a stat, verbal, or not yet entered order. When talking about different BCMA systems utilized in different hospitals, technology related operational problems could perform in different ways.

Tasks Related Triggers of Operational Problems

It is readily apparent that barcode issues are the most common operational problems encountered by nurses in this study, as well as throughout the literature [13, 17, 20, 27-31, 36-38, 44]. As discussed above, this type of difficulties are considered as task related. Barcodes on medication packages or patient wristband could be missing, broken, or blurred. Novak, Anders [36] reported the barcode could be wrong, which required nurses must to visual check of the medication, which was also uncovered in this study. Some medications, take narcotics for example, need to be wasted a partial dose before nurses come to patient room, and it is easily to dispose the vial with the barcode on it before it is scanned, which has not been reported in the literature. The system does not allow nurses to adjust the time of medication administration or the dose of the medication to be delivered. These issues also found in this study were defined as "system tenacity" by

other researchers [36, 38, 42]. Without this delegation, nurses have to go through several unnecessary steps and spend extra time to accomplish medication administration.

Organization Related Triggers of Operational Problems

Organization related triggers to operational problems primarily refer to the collaboration between nurses and other disciplines, specifically physicians and pharmacists. Physicians are always responsive for medication related questions, whereas pharmacists are a different story. Due to the nature of pharmacists' work, there is often a delay for medication verification and/or delivery onto the floor, especially when there is patient who is transferred from the emergency room (ER) or has a stat order. In the literature, this challenge was not heavily reported. Only Novak [42] narrated a similar situation in her qualitative study that when a patient came from the ER, it was frustrating for nurses to administer carried medications, because the BCMA was not applied in the ER, and the medications were not verified by the pharmacy. Carayon, Wetterneck [27] also introduced interruption, commonly initiated by families, patients, and physicians, as an organization related operational problems. However, in this study, nurses considered an interruption from families or patients as a valuable opportunity for communication, education, and assessment. The way that nurses dealt with physicians' interruption was a little tricky. During the observation, some nurses were very confident to tell the physicians that they need to finish medication administration before then could talk, if this was not an emergency, while some others were hesitate about what should do.

Environment Related Triggers of Operational Problems

Regarding the environment of the medication room and patient room, nurses perceived that it was always not enough space for them to perform the medication

administration. The room configuration is not user-friendly. Some nurses even did not turn on the light to verify medications during the night shift. These issues were commonly seen through the literature [27, 32].

Person Related Triggers of Operational Problems

It is demonstrated in this study that, when patients are under special circumstances, like emergency or isolation, it is challenging for nurses to conduct medication administration using BCMA. This was approved by several studies [27, 32, 34, 35]. It was also reported in a couple of studies that nurses with inadequate BCMA training may not be familiar with BCMA usage [32, 43]. This situation was not counted in this study, probably because nurses who had not been working on the floor over a year were excluded from the study.

The findings of this study indicate that while nurses addressed that the BCMA made the medication administration practice safer and more efficient, it also brought nurses about extra stress and overdependence on the technology. These findings are partially consistent with the work of Morriss Jr, Abramowitz [45] and Hurley, Bane [46], which reported that nurses considered BCMA as an assistance in performing the 5 rights of medication administration and felt safer when medication orders were not required to transcribed to paper medication sheets any more. Although they thought that using BCMA was more time consuming, nurses believed that the extra time they spent to assure verification was worth it [45, 46]. Nurses reported that stress that resulted from computer breakdowns was greater than that resulted from other situations [45]; whereas in this study, nurses' stress primarily came from the time pressure when a medication administration was passed due, or the distraction impeding nurses from concentrating on

medication administration at patient's bedside. Sandelowski [47] showed in the study that operational problems of BCMA could actually be created when users did not rely on their own clinical judgment as a result of the availability of the technology, which is also demonstrated in this study and another one [32]. The results of this study demonstrate that BCMA will function and serve in the way it was designed and expected, as long as it is used properly; otherwise, it could bring about side effects, which could undermine patient safety and nurse job satisfaction.

This study has several limitations. A convenience sample was used. The majority of nurses had a baccalaureate degree, which is not nationally representative. There was only one study site with 4 medical/surgical units recruited in the study. Even within this study site, the BCMA system is used differently across units, and therefore the workflow is inconsistent. Importantly, only one person (the study PI) analyzed and classified the data thus investigator bias may be present. Finally, Hawthorne effect may interfere with the findings of this study. However, several studies have shown a negligible effect on the results through the direct observation [4, 48-50].

Conclusion

In conclusion, despite the existing limitations, the results of this study largely support the literature review on the triggers to operational problems of BCMA as analyzed by work system factors as categorized by the SEIPS model. The researcher was able to categorize all observations into the 5 elements of the SEIPS work system. When nurses were asked what types of work system triggers contributed to the operational problems, all of their responses could be classified by the 5 elements of the SEIPS works

system. The study extends the literature review by providing extensive detail on nurses' perceptions about BCMA operational problems.

Next steps are to explore the adaptations of nurses in the face of operational problems. The adaptation strategies nurses come up with these operational problems could inform future practice or system design.

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Appendix I Interview Guide

Hello, Subject ID. My name is: Interviewer's name. I am conducting a research study on nurses' performance with bar-code technology, and I would like to ask you to consider participating. I have IRB approved for this project, and I have a consent form. Would you be interested? If yes, I will go over the consent form with you. If no, thank you for your time.

Interviewer completes consent process. ONCE consented observation is conducted, proceed with the following:

Interviewer to start audio recorder and state the following before interview begins:

A. *Subject ID*
B. *Site ID*
C. *Date*
D. *Time*

I am going to be asking you some questions about your experience of medication administration using bar-code medication administration system, hereinafter referred as BCMA.

1. How long have you been working on the unit? How long have you been using BCMA to administer medications?
   Probe: How long have you been trained before it was implemented on the floor?

2. Overall, how satisfied are you with the BCMA?
   Probe: If not satisfied, in what way?

3. How do you think the BCMA has impacted your work experience in the hospital?
   Probe: The impact could be reflected in modified workflow, work efficiency, pattern of prioritization, the way of managing patient care, stressfulness, etc.

4. Are there any difficulties/problems you have encountered in the past with the BCMA since it has been implemented in the hospital?
   Probe: Are there any difficulties you encountered that were related to the BCMA itself, including software and hardware?

   Are there any difficulties you encountered that were related to the tasks that you were trying to accomplish (e.g., a number of medications, medications that needed to be checked out on the unit, bulk of medication were used)?

Are there any difficulties you encountered that were related to the environment (e.g., light, noise, people around, crowdedness)?

Are there any difficulties you encountered that were related to the communication or collaboration between you and staff you work with (e.g., physicians, pharmacists, nurse assistants)?

Are there any difficulties you encountered that were related to the condition of the patient (e.g., isolation, rest, critical or emergency conditions)?

Do you think these difficulties you described could jeopardize patient safety?

5. Are there any difficulties/problems you think will continue to happen with the BCMA in the future?
   Probe: Are there any difficulties you encountered that were related to the BCMA itself, including software and hardware?

   Are there any difficulties you encountered that were related to the tasks that you were trying to accomplish (e.g., a number of medications, medications that needed to be checked out on the unit, bulk of medication were used)?

   Are there any difficulties you encountered that were related to the environment (e.g., light, noise, people around, crowdedness)?

   Are there any difficulties you encountered that were related to the communication or collaboration between you and staff you work with (e.g., physicians, pharmacists, nurse assistants)?

   Are there any difficulties you encountered that were related to the condition of the patient (e.g., isolation, rest, critical or emergency conditions)?

   Do you think these difficulties you described could jeopardize patient safety?

6. When you found it was hard to strictly follow the protocol when you encountered difficulties/ problems with the BCMA, could you briefly describe how you handled that?
   Probe: What were you thinking about when you handled it, or what factors determined the way you handled it?

Thank you for your participation.

Appendix II Themes of Qualitaitve Interviews

Major Themes	Minor Themes
1. Overall Perceived Impact of the use of BCMA On Medication Administration	1) Safety
	2) Efficiency
	3) Stress
	4) Overdependence
2. Perceived Technology Related Triggers of Operational Problems	1) Frustration caused by the cord
	2) System backstage glitches
	3) System delays or shutdown
3. Perceived Tasks Related Triggers of Operational Problems	1) Medication barcode is unavailable
	2) Medication barcode mismatches the medication
	3) Wristband barcode is unapproachable
	4) System's "Tenacity"
4. Perceived Environment Related Triggers of Operational Problems	1) Limitation of the work platform
	2) Limitation of the workspace
5. Perceived Person Related Triggers of Operational Problems	1) Emergency situations
	2) Patients in isolation
6. Perceived Organization Related Triggers of Operational Problems	1) Delayed verification of medications
	2) Delayed delivery of medications

Chapter IV

Bar-Code Medication Administration System and Nurse Adaptations

Introduction

Medication administration errors (MAEs) are a common issue that threatens patient safety and quality of care in hospitals. Despite accreditation standards, public policies and the availability of evidence for reducing MAEs during hospitalization, MAEs continue to be national patient safety issue [1-3]. This may be, in part, because the process of medication administration is complex, and a number of opportunities exist for MAEs to occur [4]. In order to mitigate the risk to patient safety, the use of barcode medication administration (BCMA) system to verify a patient's identity and the medication to be administered is a promising strategy for preventing MAEs.

In the computer technology field, it is well accepted that "no technology is exception-free and no simple technology is available to remove exceptions from workflow" [5]. It is known that the implementation of health IT may introduce additional risks into the environment of care as a result of either design or implementation failures [6, 7] or unintended consequences [8]. The reason why this happens is likely because the health care environment is complex, which may create operational problems [9, 10].

Operational problems are defined as "any occurrence or state that makes goal accomplishment impossible, difficult, or unsatisfying in light of standards for timely and effective performance." [11] Adaptation, known as "problem solving", is any type of responses performed by the nurses to their perceived problems, in order to accomplish

some pre-established goals, which is already set by standards for timely and effective performance within the context of a system or process." [11] The definitions of "operational problems" and "adaptations" clearly explicate that adaptations are goal-oriented behavior. When operational problems are considered as necessary consequences of complex work or environment, nurses are unavoidably engaged in "adaptations" [12, 13].

However, efforts to understand BCMA's impact on nursing work have largely focused on nursing workarounds, which are a specific type of adaptations [11, 14]. Workarounds are generally considered as deviations from BCMA use protocols [7], while adaptations are a broader category of changes to the work practices or the technology. In addition, workarounds are often studied under the assumption that workarounds are inherently dangerous and a threat to patient safety [7, 15-17]; whereas, adaptations do not have to be negative; they could be neutral or even positive (see Table 4.1). In fact, some of today's best practices were yesterday's adaptations; some of today's adaptations could also be tomorrow's best practices [18]. Adaptations are dynamic responses by people to the operational problems and altering of work practices to accommodate the technology [19]. In the context of health IT, adaptations can be situational, but they can also become institutionalized in formal and informal ways.

Table 4.1
Contrast Between Workarounds and Adaptations

Workarounds	Adaptations
Performed at individual level	Performed at individual or institutional level
Typically only one single step in the process	Could be multiple steps in the process, multiple decisions
Interpreted as negative behaviors because not compliant with the practice protocol	Interpreted as neutral or positive behaviors even though not compliant with the practice protocol
Involving action at single point in time to deliver the medication	Involving deliberate decisions to accommodate the work system

Conceptual Framework

The conceptual framework guiding this study is an integration of the SEIPS model and a sociotechnical perspective considering that operational problems occur because of collisions between the "System Frame" and the "Practice Frame". The system frame is the way the work and operational system is functionalized and implemented, based on the cumulative assumptions, decisions, priorities, and problem-solving of the vendor, developers and implementation decision-makers [20]. In this study, the work system within the SEIPS model was adopted to characterize dimensions of the system frame relevant to BCMA.

The practice frame that drives nurses medication administration practices includes safety, efficiency, and the "5Rs" (right patient, right medication, right time, right dose, and right route) of medication administration. The highlighted area is the purpose of this study, in terms of understanding the process of nurse adaptations to operational problems of BCMA (see Figure 4.1).

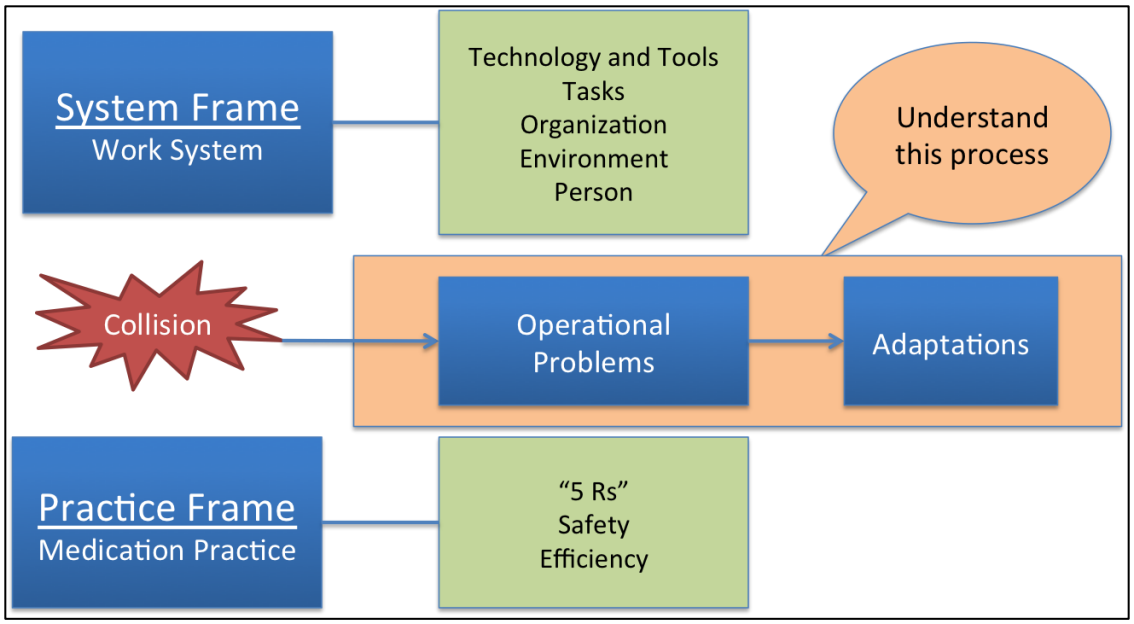

Figure 4.1. **BCMA and adaptation.**

Problem Statement and Purpose of this study

Research studies that attempt to understand BCMA's impact on nursing work have largely focused on nursing workarounds [11, 14]. Whereas, adaptations, as a broader dynamic process involving nurses' behaviors of the accommodation to the operational problems of BCMA, has been understudied [11, 14]. No studies have explored the rationale of adaptive behaviors of nurses in response to the operational problems of BCMA. There has been a call for further research to better understand how an increase in emphasis on timely medication administration affects decision tradeoffs during goal conflicts [26]. Factors that may contribute to this are unavailable methods in hospital for conducting a comprehensive assessment [18], complexity of studying the entwined processes of adaptations [7], BCMA's evolving nature and evolving work rules [7], and nurses' negative impression and resistance about workarounds. It is believed that when there are large gaps between intended practice, as recommended or mandated in policies and procedures, and actual practice, predictable problems emerges [27].

Thus, the purpose of this study was to understand existing operational problems that are hindering efficient nursing work, how nurses respond to operational problems, and nurses' perception about the adaptations they made to effectively prevent MAEs and improve patient safety by better functioning BCMA. The research questions are: 1) can nurse adaptations to the operational problems of BCMA be interpreted in a scientific way? and 2) can the perceptions of nurses about the adaptations to the operational problems of BCMA be interpreted through interviews?

Methods

Aims and Design

The aims of this study were to: 1) investigate nurses' adaptations when encountering operational problems of BCMA, and 2) explore nurses' perceptions about adaptations of BCMA.

To better understand the process of adaptation when nurses encounter operational problems of BCMA, a prospective exploratory research design was applied in the study to collect, synthesize, and interpret the data. Scenario interviews with follow-up were the approaches used to explore nurses' perceptions of adaptations to operational problems of BCMA. It is critical to collect data by combining scenario interview and follow-up interviews, since either of them could reveal only one face of the coin, while the two approaches can cross complement each other with the missed information.

Sample

A purposive sampling method was employed. The target enrollment was 30 nurses for scenarios and interviews about BCMA adaptive behaviors, with plans to enroll nurse participants only until data saturation was reached. Inclusion criteria were: 1)

permanent staff RNs; 2) working on identified medical and surgical adult acute care units; 3) having been working on the unit for at least one year (including unit based temporary staff); 4) having been trained to use BCMA; and 5) having experience in using BCMA. Exclusion criteria were nurses from central staffing resource (i.e., CSR temporary staff on a specific unit).

Setting

This study was conducted in 4 medical-surgical units (labeled as A, B, C, D in this study) of a large academic medical center located in the Mid West of the United States. The scenario interviews and follow-up interviews were both conducted in the conference room of each designated unit. The Institutional Review Board of the study site approved the study.

Data Collection Methods

1. Development of the interview guide for scenario interviews

The operational problems synthesized and validated in the previous studies were used as resources to create scenarios, which addressed one or more of the 5 dimensions of the work system (individuals, technology, organization, environment, and tasks) (see Table 4.3). The operational problems that were reported in the literature, but not identified in the study site were excluded from the scenario development. The scenarios were reviewed by a nurse specialist of the study site, who persistently oversees and audits the compliance report of BCMA scanning across the entire medical system. Modifications were made accordingly. Two cases studies with 4 scenarios each (operational problems) were generated. Case studies provide the clinical context of a hospital patient who needs to receive medications administered by a nurse. Scenarios are

examples of medication management events within the context of the case studies that demonstrate one or more work system triggers to operational problems. Open-ended questions were asked to the nurses to describe what they would do within specific scenarios.

Table 4.2
Characteristics of Scenarios

	Scenarios	System Frame				
		Person	Technology	Organization	Tasks	Environment
	Case 1: Patient John Doe, male, 82 years old, admitted 4 days ago, diagnosed with heart failure, pneumonia, type II diabetes, and urinary tract infection. Patient is receiving Digoxin® tablets 125 mg po QD, Rocephin® 2g ivpb QD, Penicillin 250 mg po q.8h, and Humulin R® 3-6 units SQ PRN with meals, amount based on POC glucose.					
Operational Problems	**Scenario A**: **Missing label on medication. At 8 am, when the nurse prepares the medication, she finds the label of the par stock insulin has run out.**			X	X	
	Scenario B: **Oral dosage changes prior to order verification. The physician just orally changed the dosage of the Digoxin from 125 mg daily to 250 mg daily, and it has not been verified by the pharmacy yet, so the nurse is unable to remove the dose from the Omnicell without preforming an override.**			X	X	
	Scenario C: **System alert. When the nurse scans the vial of the antibiotic, an alert pops up, and stating "missing component".**				X	
	Scenario D: **Dosage change prior to medication delivery. The physician just changed the dosage of Penicillin from 250 mg q.8h to 500 mg q.8h, but the medication has not been delivered yet.**			X	X	

Operational Problems	Scenarios	System Frame				
		Person	Technology	Organization	Tasks	Environment
	Case 2: Patient Jane Doe, female, 24 years old, admitted 2 days ago, diagnosed with upper respiratory tract infection. Patient is receiving Ceclor 500mg PO BID.					
	Scenario A: **Unfavorable environment. At 9 pm, when the nurse comes to the patient room with the medication, she finds the patient is resting in a chair in front of the computer and the room is very dark, so she asks the patient if she can turn on the headlight briefly for the medication pass, but the patient refuses. The nurse is also unable to reach the computer.**	X				X
	Scenario B: **Backstage glitches. Order and label both match, but computer alert indicates no active order.**		X			
	Scenario C: **Medication administration interruption. The nurse is in the patient's room passing the medication, while in the process of scanning the medication the physician comes in to speak with the nurse about the patient.**					X
	Scenario D: **Missing wristband. The patient wristband is found on the bedside table and not affixed to the patient.**	X			X	

2. Development of the interview guide for follow-up interviews

The factors that contributing to the adaptations nurses decide to take was addressed in the interviews. The development of the interview questions was guided by the Rational Model of Decision Making, which is a multi-step process for making choices between alternatives [28]. The process of rational decision-making favors logic, objectivity, and analysis over subjectivity and insight.

The interview questions focused on nurses' perceptions of their adaptive behaviors, including the operational problems they identified in the scenarios, the objectives they had when they had the operational problems, the alternatives they had besides the strategies they took, the evaluation of their performance (see Appendix I). By answering these questions, nurses reflected the factors that determined what they did in the scenarios interviews. The content validity was tested by sending the questions to three nurse specialists of the study sites. The content validity of the interview questions was 0.65.

Procedures

1. On-site scenario interviews

After obtaining IRB and Nursing Administration Research Committee approvals at the study site, a list of potentially eligible nurses from the Nurse Manager or designee (e.g. charge nurse) was obtained, upon arrival at the eligible unit sites. Nurses were randomly selected from this list and validated with the nurse manager or designee about their eligibility against the inclusion criteria. Eligible nurses were approached to participate in the study by obtaining a written informed consent. All the nurses who were recruited consented and participated in both the scenario interviews and the follow-up

interviews. The consented nurses then agreed on a time during that day to participate the scenario interviews.

Scenario interviews were conducted in the conference room on the units. The researcher first introduced the purpose of the study and provided an initial instruction to the nurse, stating "please tell me what you are going to do step by step and what you are thinking, when you have these operational problems". Then, the nurse was given a copy of the scenario description, and the scenario interview started. It is important to note that only the description of the scenarios was given to the nurses.

The nurses were asked to constantly "think aloud" what they would do step by step during the scenario interviews, and if they paused for longer than a few seconds the research quietly reminded them to "keep thinking aloud." *Think aloud* approach provide rich verbal data about reasoning during a problem solving process [29]. Using *think aloud* and protocol analysis, information that is concentrated on during problem solving and how that information is used to facilitate adaptation were identified. Aside from this talk, all interaction between the nurses and researcher was kept to a minimum so as not to interfere with the nurses' flow of thoughts. The scenario interview was tape-recorded, and the researcher took field notes.

2. Follow-up interviews

At the end of each scenario interview session, a semi-structured follow-up interview was conducted in the same room with the nurses as a debriefing about why they took the adaptive strategies as recorded. All follow-up interviews were tape-recorded and documented as a supplement to the scenario interviews recording and field notes, which, as a whole, form an integrated portrait of a nurse's adaptation process. Basic

demographic information was also collected, including age, gender, education, working experiences, and experiences of using BCMA.

Data Analysis

Both scenario interviews and follow-up interviews were transcribed, with responses sorted into the following categories: Protocol describes the desired response by the nurse to the triggers, represents the practice frame from the perspective of the organization. Operational problems are the collision between the triggers (system frame) and the protocol (practice frame). Actions of adaptations were what nurses actually reported what they would do. The reported actions were fully transcribed, categorized, and compared to the protocol.

The follow-up interviews were analyzed using a content analysis approach. Relevant statements were sorted under each step of the Rational Model of Decision Making model. The researcher generated common themes by synthesizing the meaning units. Themes reflected a general description of the nurses' experiences with the BCMA operational problems.

Results

Sample Characteristics

Twenty-one nurses were enrolled in the scenario interview and the interviews (n = 21). Table 4.4 demonstrates that the majority of nurses were younger than 35 years old (n = 14, 66.6%), female (n = 20, 95.2%), having a Baccalaureate Degree (n = 16, 76.2), working on unit A (n = 12, 57.1%), having less than 5 years working experience (n = 13, 61.9%), and having been using BCMA over 10 months (n = 21, 100%).

Table 4.3
Characteristics of Sample (N=21)

Demographics	*N (%)*	*Demographics*	*N (%)*
Age		Unit	
<25	2 (9.50)	**A**	12 (57.1)
25-30	8 (38.1)	**B**	1 (4.80)
30-35	4 (19.0)	**C**	3 (14.3)
35-40	1 (4.80)	**D**	5 (23.8)
40-50	6 (28.6)	**Total**	**21 (100)**
Total	**21 (100)**	Working Experiences On the Unit	
Gender		**<1 Year**	1 (4.80)
Male	1 (4.80)	**1-5 Years**	12 (57.1)
Female	20 (95.2)	**>5 Years**	8 (38.1)
Total	**21 (100)**	**Total**	**21 (100)**
Education		Experiences of Using the BCMA	
Associate Degree	4 (19.0)	**17 months (Since July 6, 2014)**	19 (90.5)
Baccalaureate Degree	16 (76.2)	**10-17 months**	2 (9.50)
Master's Degree	1 (4.8)	**<10 months**	0 (0.00)
Total	**21 (100)**	**Total**	**21 (100)**

Reported Actions of Adaptations

During the scenario interviews, every nurse was given 2 case studies of medication administration with 4 scenarios (operational problems) to solve in each case (see Table 4.5). Actions reported by the nurses are presented in the table. For each scenario, the actions are reported as consistent with the protocol, or not.

In most scenarios, the actions reported by the majority of the nurses were consistent with the recommended protocols. The only exception was scenario C in case 2. This suggests that when the system frame collides with the practice frame, most nurses tend to follow the protocol. But there still were a considerable of nurses who did not follow the protocol and adapted to the operational problems in their ways.

Table 4.4

Reported Actions To the Collision Between the Practice Frame and the Triggers of the System Frame (N = 21)

Scenarios **Triggers of the System Frame**	***Protocol*** **Practice Frame**	***Operational Problems*** **Collision**	***Reported Actions***	**N (%)**
Case 1: Patient John Doe, male, 82 years old, admitted 4 days ago, diagnosed with heart failure, pneumonia, type II diabetes, and urinary tract infection. Patient is receiving Digoxin® tablets 125 mg po QD, Rocephin® 2g ivpb QD, Penicillin 250 mg po q.8h, and Humulin R® 3-6 units SQ PRN with meals, amount based on POC glucose.				
Scenario A: Missing label on medication. At 8 am, when the nurse prepares the medication, she finds the label of the par stock insulin has run out.	The nurse should contact pharmacy to send out a new bottle with additional labels and discard the existing vial. Once the new bottle and labels arrive, the nurse should verify the vial and label against the order, attach the label to the syringe, draw up the prescribed dosage of the insulin into the syringe, put the vial back into the fridge, and then take the syringe to the bedside.	Although the insulin is available, the nurse would have to reach out to the pharmacist and hold the medication passing, until a new bottle and additional labels delivered.	i. The nurse gives the insulin with a dosage indicated in the system, but without a label on the syringe, and overrides the BCMA.	4 (19.0)
			ii. The nurse waits for labels prior to administering dose and uses the current vial. ***Protocol***	17 (81.0)

Scenarios **Triggers of the System Frame**	***Protocol*** **Practice Frame**	***Operational Problems*** **Collision**	***Reported Actions of Adaptation***	**N (%)**
Case 1: Patient John Doe, male, 82 years old, admitted 4 days ago, diagnosed with heart failure, pneumonia, type II diabetes, and urinary tract infection. Patient is receiving Digoxin® tablets 125 mg po QD, Rocephin® 2g ivpb QD, Penicillin 250 mg po q.8h, and Humulin R® 3-6 units SQ PRN with meals, amount based on POC glucose.				
Scenario B: Oral dosage changes prior to order verification. The physician just orally changed the dosage of the Digoxin from 125 mg daily to 250 mg daily, and it has not been verified by the pharmacy yet.	The nurse should hold the medication administration, wait for the pharmacy verification. At the meantime, the nurse could pass all other medication. Once the new dose is delivered, the nurse should verify against the order and then remove it from the Omnicell.	Since the new order has been verified yet, so the nurse is unable to remove the dose from the Omnicell without performing an override. The nurse would have to wait for the pharmacy verification before he/she can perform the medication administration.	i. The nurse overrides the new dose, removes the medication from the Omnicell cabinet, and overrides the BCMA.	2 (9.50)
			ii. The nurse holds the medication administration, wait for the pharmacy verification. At the meantime, the nurse passes all other medication. ***Protocol***	18 (85.7)
			iii. The nurse holds the medication administration, and asks the physician whether she should wait or give the medication, and which dosage should be given.	1 (4.80)

Scenarios **Triggers of the System Frame**	***Protocol*** **Practice Frame**	***Operational Problems*** **Collision**	***Reported Actions of Adaptation***	**N (%)**
Case 1: Patient John Doe, male, 82 years old, admitted 4 days ago, diagnosed with heart failure, pneumonia, type II diabetes, and urinary tract infection. Patient is receiving Digoxin® tablets 125 mg po QD, Rocephin® 2g ivpb QD, Penicillin 250 mg po q.8h, and Humulin R® 3-6 units SQ PRN with meals, amount based on POC glucose.				
Scenario C: System alert. When the nurse scans the vial of the antibiotic, an alert pops up, and stating "missing component".	The nurse should cancel this action, and try to scan the solution bag first than scan the medication vial.	The nurse would have to cancel the current action, and try to scan in a different sequence, although the solution and the antibiotic are the correct medications.	i. The nurse overrides the system, and continues to scan the solution bag.	1 (4.80)
			ii. The nurse cancels this action, and tries to scan the solution bag first than scans the medication vial. ***Protocol***	17 (81.0)
			iii. The nurse contacts the pharmacy to update the order.	3 (14.3)
Scenario D: Dosage change prior to medication delivery. The physician just changed the dosage of Penicillin from 250 mg q.8h to 500 mg q.8h, but the medication has not been delivered yet.	The nurse should hold the administration of Penicillin and wait for the delivery of the 500 mg. Once it is delivered, the nurse should take the 500 mg to the bedside and scan it before deliver it.	The nurse would have to wait for the delivery of the 500 mg, although there are 2 doses of the 250 mg available in the patient's medication drawer.	i. The nurse obtains the 2*250 mg Penicillin from patient's medication cassette and administers it. When alert pops up, she overrides the BCMA.	1 (4.8)
			ii. The nurse holds the administration of Penicillin and waits for the delivery of the 500 mg. ***Protocol***	20 (95.2)

Scenarios **Triggers of the System Frame**	***Protocol*** **Practice Frame**	***Operational Problems*** **Collision**	***Reported Actions of Adaptation***	**N (%)**
Case 2: Patient Jane Doe, female, 24 years old, admitted 2 days ago, diagnosed with upper respiratory tract infection. Patient is receiving Ceclor 500mg PO BID.				
Scenario A: Unfavorable environment. At 9 pm, when the nurse comes to the patient room with the medication, she finds the patient is resting in a chair in front of the computer and the room is very dark.	The nurse should ask the patient if she could turn on the headlight briefly for the medication pass and persuade the patient to allow her to access the computer.	The nurse would not have enough light to verify the medications against the order. He/she also would not able to reach the computer to access the order or the BCMA.	i. The nurse gives the medication without turning the light on and documents the administration outside of the room.	5 (23.8)
			ii. The nurse persuades the patient to allow her to access the computer and turn on the light. ***Protocol***	16 (76.2)
Scenario B: Backstage glitches. Order and label both match, but a computer alert indicates no active order.	Nurse should hold the medication delivery and contact the pharmacy to understand why medication label is not scanning when active order and label match. The pharmacy should be able to fix the backstage glitch.	The nurse may be confused when active order and label match but the medication can't be scanned. He/she could either verify with the physician to see if the order has been deactivated, or ask the pharmacy to see how to proceed.	i. Nurse administers the medication as ordered and overrides the BCMA.	5 (23.8)
			ii. Nurse contacts pharmacy to understand why medication label is not scanning when active order and label match. ***Protocol***	10 (47.6)
			iii. Nurse contacts pharmacy for a new dose.	1 (4.8)
			iv. Nurse contacts physician for verification.	5 (23.8)

Scenarios **Triggers of the System Frame**	***Protocol*** **Practice Frame**	***Operational Problems*** **Collision**	***Reported Actions of Adaptation***	**N (%)**
Case 2: Patient Jane Doe, female, 24 years old, admitted 2 days ago, diagnosed with upper respiratory tract infection. Patient is receiving Ceclor 500mg PO BID.				
Scenario C: Medication administration interruption. The nurse is in the patient's room passing the medication, while in the process of scanning the medication the physician comes in to speak with the nurse about the patient.	The nurse should tell the physician he/she is in the middle of administering these patient medications and will come out and speak with them when he/she is finished with this task.	The nurse may be interrupted or distracted in the middle of medication administration by healthcare providers or patient families.	i. The nurse stops the medication administration to speak with the physician.	11 (52.4)
			ii. The nurse tells the physician he/she is in the middle of administering these patient medications and will come out and speak with them when he/she is finished with this task. ***Protocol***	9 (42.9)
			iii. The nurse talks with the physician and continues to administer the patient medications.	1 (4.8)

Scenarios **Triggers of the System Frame**	***Protocol*** **Practice Frame**	***Operational Problems*** **Collision**	***Reported Actions of Adaptation***	**N (%)**
Case 2: Patient Jane Doe, female, 24 years old, admitted 2 days ago, diagnosed with upper respiratory tract infection. Patient is receiving Ceclor 500mg PO BID.				
Scenario D: Missing wristband. The patient wristband is found on the bedside table and not affixed to the patient.	The nurse should ask the patient the name and DOB to verify the identity of the patient, and affix the wristband back to the patient. Or, he/she could go to the clerk, print a new wristband, and affix to the patient after performing identification verification, and then, administer medications.	The nurse probably would assume this is the same patient indicated on the wristband, so he/she probably would not take further action to verify identification before affix the wristband back to the patient.	i. The nurse asks the patient to put on the wristband without asking patient's DOB and scans it.	4 (19.0)
			ii. The nurse asks the patient patient's name and DOB to verify the identity of the patient, and affix the wristband back to the patient. ***Protocol***	9 (42.9)
			iii. The nurse goes to the clerk, prints a new wristband, and affix to the patient just prior to administering meds. Performing identification verification prior to affixing the wristband. ***Protocol***	8 (38.1)

Within the 21 scenario interviews, nurses suggested pharmacists would be called for help in addressing 9 of the operational problems (42.9%). Physicians would be involved in addressing 4 operational problems (19.0%), while pharmacist and physicians were both engaged in addressing 8 operational problems (38.1%). None of the operational problems could be accomplished by the nurses themselves alone.

Follow Up Interviews

Qualitative data analysis is summarized along the steps of rational judgment, with several themes emerged under them (see Table 4.6): 1) identifying operational problems, 2) identifying ultimate goal, 3) determining situation, 4) strategies for adaptation, and 5) consequences of the alternative actions. Examples from multiple selected transcripts are presented go demonstrate these themes.

1. Identifying Operational Problems

In the follow-up interviews, nurses verified that the operational problems delineated in the scenarios happed frequently in their daily work situations. They described that these operational problems happened every single day and were the issues that bothered their delivery of care in an efficient and safe way.

Table 4.5
Themes Emerged From the Qualitative Interviews

Steps of Rational Model of Decision Making	*Themes*
1. Identifying Operational Problems	1) Operational problems triggered by technology 2) Operational problems triggered by task 3) Operational problems triggered by environment 4) Operational problems triggered by person 5) Operational problems triggered by organization
2. Identifying Ultimate Goal	1) Safety 2) Accuracy
3. Determining Situation	1) Medication characteristics 2) Patient situation
4. Strategies for Adaptation	1) Jump-in 2) Skip and come back 3) Equalize 4) Be proactive 5) Override upon scrutiny 6) Communicate patiently 7) Collaborate with other disciplines
5. Consequences of the Alternative Actions	1) Sabotage patient safety 2) Delay of care 3) Dissatisfy patient

Besides the difficulties portrayed within the scenarios, nurses also provided other examples that were similar to examples in the scenario interview. These operational problems could be triggered by task, which involves medication and barcodes, technology, i.e., technology difficulties, environment, which could be limited space or distractions/interruptions, organization, which primarily refers to the delays resulted by the pharmacy.

"Whenever pharmacy sends us multiple dose vials, they never send us stickers, like labetalol. They always send you one packet of stickers, and that's not enough."

"I mean things like that have happened where you have the right medication and everything and you don't have an active order and you're like, 'wait what happened?' The doctor said to give this, and so I have it. It's usually just a matter of like, they're in the computer tinkering around with it so you need to wait for it to actually be an active order and you need to wait for the pharmacy to verify it so. I feel like all those are real life situations that happen frequently."

"I feel like we get interrupted a lot during our med pass times. Whether or not it is respiratory therapy, or physical therapy, that they wouldn't even acknowledge that we're in the middle of passing medications. They might start talking to the patient. One time, respiratory therapist just out of habit I think, like logging me off the computer during the middle of my med pass. So I feel like the interruptions is a major thing."

"The problem with pharmacy is we are the last stop on their run. So sometimes it's like the doc might come in and write an order for something. They may put in an order at let's say 10:30. They send their run out at 10:30. So if we don't go get it, we're not going to get it until noon. And depending on what the drug is, you can't wait."

The operational problems they delivered in the interviews verified the results of the literature review, the observation and the interviews conducted beforehand, which proves that BCMA-related operational problems do exist within the process of medication administration and impede nurses from strictly following the established protocol.

2. Identifying Ultimate Goal

After the nurses identifying the operational problems when they were trying to accomplish the medication administration, they then realized they had to pause their performance and thought about the ultimate goal before they could make the next move.

Safety. The majority of the nurses set patient safety as their priority at that moment, which was also the ultimate goal of what they were trying to accomplish. When they could not strictly follow the protocol with the operational problems kept in the middle of the way, they aimed to deliver the right medication to the right patient, at the right time, in the right way, with the right dosage.

"For the most part, I just want to make sure that I give my patients the meds they need, I give them the correct meds, and obviously that they're safe, and I'm doing as ordered to do. If I ever have a question, I'll page the doctor, or the pharmacy, just to clarify if something doesn't sound right. A lot of times, if I'm reading off the medication I'm giving, and the patients are like "I don't take that" or "why am I on that?" and then I'll page the doctor just to have them explain to me why they're on that or prescribed that. Sometimes, you've caught meds that shouldn't be given that way."

"It's definitely hard because nursing is a balance. You want to be able to get things done so you're not dilly-dallying. But you obviously need to be able to do that, but at the same time, I mean the goal should be patient safety and making sure that we're keeping the patient safe regardless. I mean computers are computers. Technology is not always 100%, so when something fails, we need to rely on ourselves to make sure we're providing the best care possible and promoting safety. And yeah, it might take ten more minutes but it could be someone's life in the end so."

When operational problems happen, these nurses often consult with another nurse, or even other disciplines, to verify the "5 right". It not only requires critical thinking, clinical judgment, but also collaboration to adapt to those problems.

Accuracy. Besides safety concerns, several nurses also worry about the accuracy of their performance adjustment. When the path the nurses took had to deviate from the normal way, they wanted to make sure that it was still accurate and would not interfere with the future care.

"Make sure it is accurate, and it is all recorded because that is how people can look up if they last took it a certain time, so just accuracy and safety."

"I want to complete my tasks on time because I don't want to just sit around, and wait two hours for something to come from pharmacy. That's why I will always call them and make sure that 'are you guys making this? Did you see the change?'"

The nurses set a clear goal in their mind, when they encountered the operational problems, if they probably could not accomplish the tasks in an ideal way. This goal would enlighten their action plan for the next step. Guided by the ultimate goal, the nurses then gathered the information and analyzed the situation, followed by a decision made on the next move.

3. Determining situation

When facing operational problems, nurses were exposed in a complicated situation with a number of factors entangled with each other. The nurses would have to gather data and information and apply their knowledge, experiences, and critical thinking to make a clinical judgment about the patient's conditions, and then to decide the next move they should take by determining the current situation.

Medication Characteristics. When they came across the problem that the medication was not delivered at the time medication was due, or the dosage was changed before the pharmacy verified, some nurses would take the characteristics of the medications they were delivering into consideration to determine if the medication could or not wait to be delivered.

"Depending on what the medication is, some of them are more critical than others. Like if it's 9 AM and it's a multivitamin and stool softener, and they only take once a day, I can wait until noon on those meds."

"Um, well, I guess I would go ahead and probably just give it that way the patient gets the medication when they need it, instead of having to wait for the pharmacy to send a new tablet. I am going to want to give it to the patient as soon as possible, especially if it, depending on the medication, if it is a blood pressure medication or something like that, I want to give it to the patient in a timely manner."

Patient situation. Some other nurses, on the other hand, would consider patient's situation as a more critical factor, when they determined if they should wait for the pharmacy to deliver the medication by tubing or on their next trip, instead of taking alternative actions themselves, such as overriding the BCMA, picking up the medications themselves, or delivering the same medication but with different, equalized doses.

"If that was a regular scheduled medication, the patient was in no obvious distress, and an oral medication would take an hour to work anyways, I'm less concerned with the patient's need for an on-time medication. I would wait for pharmacy to deliver the meds. I will not override the system. I am more concerned with safety and making sure that it's recorded properly."

"For instance with the insulin, I know that's what they need. Yes, I could wait for more labels. If the blood sugar was high, I would give the medication, but I would bring the vial with me, and I would check it and make sure that this is what they're getting. In that situation, I would override it because that's what they needed. But for other things like their antibiotic dose doubled or something like, I would wait for that, because half an hour, an hour, is not going to make a big difference for that."

"So, by waiting for the pharmacist to make sure that it was correct and that it was verified, the patient is now waiting, so I mean there could be some potential consequences there. So that is where it is always making sure that they are safe. So obviously, any point in time if they seem like they were deteriorating, then I might have made a different decision. But if it seems like they are completely stable, and it is just a simple waiting for the verification, then I

think, I made the right choice by choosing what I did. But if they started to deteriorate, then I would do something different in that moment."

"It's a med they've already been given, and I know they're not going to react to that medication. If I have the dose that I need in a different form I have given, if they really need that medicine because their heart rate's sky high or something like that, I'll usually ask the doctor for permission. I'll say, "I have these two tablets. They equal whatever dose. Do I have to wait or can I give this?" and they usually give it, "it's fine". I'll just write, "okay per MD" in the comment."

Nurses collected the information, analyzed the situation, and then made the decision by balancing patient safety, their comfortableness, and work efficiency. This process costs their knowledge, professional skills, and clinical experiences. Different people may see situation differently, but in the end, the skill sets they get from their experience will lead them to make the right decision to the best of their knowledge.

4. Strategies for Adaptation

To accomplish their ultimate goal, the nurses developed their own strategies to adapt to the operational problems, after they analyzed the situation with the information they gathered on site. These strategies are appropriate or effective with some operational problems, but may not be appropriate or effective with other operational problems.

Jump-In. When the nurses had the operational problem that the medication was not delivered yet, the majority of the nurses chose to jump in and execute immediately.

"I would say, just to get the medications here in a timely manner, whether it be me going up to pharmacy or asking if somebody else can go up to pharmacy, calling them either to get them verified, so I can pull it out of the Omnicell, or just running up there to get the actual physical medication."

"We spend a lot of time going upstairs to pharmacy to get things because we don't want to wait for stuff to be delivered, because it can take a considerable amount of time. We have to leave all the patients, and somebody else has to keep an eye out for our patients. We have to leave the floor. It's just an additional step; it takes a lot of time out of our day if I have to do it. So that's the biggest problem with that."

Skip and come back. When the nurses had an uncooperative patient, or the patient was in rest/sleep, when they were trying to deliver medications, one nurse described that she would skip that patient and come back later at a better timing.

"Cause I can usually work around the patient. Sometimes if they're sleeping or something, and I have 3 sets of people to give meds to, I'll leave that one and go to the next person. Sometimes by the time you get back to them, they're awake, and they're more cooperative and more willing to let you do what you need to do."

Equalize. Nurses are not autonomous on dosage adjustment of medications. But when bigger dosage had not been delivered yet, some nurses matched the smaller ones to the bigger one to ensure the medication would be passed in a timely manner.

"Digoxin is in the Omnicell, the smaller dose. So what you could do is just take two small pills and scan them to make the big dose. That's probably what I would do. Cause if I'm already giving them pills, and they have a hard time swallowing or I have to crush them, I'm going to cluster my care. I'm not going to wait for that new dose to be delivered. Cause you're not bothering the patient as much and it's clustering care. On this unit, you give so many meds and there's so much going on. Each patient might have like 20 something meds just at 9 AM. Yeah. And you have your noon's, your 2's, your 5's, and your 6's."

Be proactive. Some nurses mentioned that as a nurse, they needed to act proactively, especially when physicians modified orders in the system. They would notify pharmacy right after the order had been adjusted, instead of waiting for the pharmacy to verify the order in hours.

"You need to be proactive and call pharmacy. Say "hey they've changed this dose, um, can I use the ones that I have the one on the floor or can you send me one as soon as you can? Can you prepare it for me?" Like I said, pharmacy's always been great, getting me meds as soon as they can."

Override upon scrutiny. The nurses viewed override in different ways. Some of them expressed that they would rather not to override the system whenever they had an operational problem, as they believed overriding the alert would endanger patient safety. However, other nurses relied more on their own visual check, when they viewed delivering medication as it was scheduled equally important as patient safety is.

"I have had it happen a few times, when the barcode won't scan, when I know I have the right medication. I have the med in my hand, and I am checking the order. I know it is the right medication, right patient, and the barcode just won't scan, whether it is because the barcode is ripped or it's water damaged or sometimes. The barcode looks perfect, but it just won't scan. I think that is usually when I end up overriding, because I know I have the right medication. I know it's appropriate for the patient. Especially if it is something more time sensitive, like an antibiotic or a pain med, where the delay of me getting the pharmacist to send me a new barcode or new one of the medication, just seems completely unnecessary."

"I override like every shift at least once. I know some nurses don't do that, but I'm not going to let my nursing care suffer because of technical difficulties. I think as long as you're not relying on just the barcoding for everything to be accurate, and you still looking at the package and looking at everything, even with the barcoding working perfectly, I think you're not necessarily going to run into safety issues."

Communicate patiently. In a work system, multiple disciplines play roles in the process of medication administration, as well as patients and their families. To make the work system function effectively, nurses are unavoidably required to communicate with different parties. Interruptions coming from either patients or physicians were impeding the nurses to deliver medications in a safe and efficient way. The majority of them were able to negotiate with physicians, but a few admitted that in the real life, they would probably let the physician finish their talking before they could proceed with their medication administration.

"I have had times like where patients are not or refusing to wear the wristband for whatever reason and taking the time to have that conversation with them, why it is important that they wear it. Also, if a doctor interrupts me while I am passing medications, have that conversation with them. Once you tell people it is for safety, they get it. I think a lot of times we, in health care, have so many things going on in our heads and a million different to do lists, that we kind of skip over the easy explanations to our patients. So they just think they are being told to do something, but don't understand the reason."

Collaborate with other disciplines. To accomplish medication administration, when there was an operational problem, nurses would have to collaborate with other disciplines. It is noticeable that nurses expressed they would always go to the advanced practice team or the pharmacists first when they had a medication issue. Physicians would be their last stop, if the

other two disciplines could not help, because physicians were probably too busy to be able to help.

"We have a pretty good rapport with our advance practice team, who is the one writing our orders. So I feel comfortable to go in and talk to them, if I have a question about a med."

"I think a lot of times with any type of barcode error or scanning error, your first instinct is to go to pharmacy. However there are certain instances where you need to let the physician know, so that they can reorder the medication. I feel like physicians are pretty distant from this issue. Because it's like they just want to make sure the meds are being given. It's probably a little more difficult for them to understand our frustration with it or our issues. So pharmacy first and foremost is probably your best choice. They can help with ensuring that you can scan appropriately and how to resolve issues if there's any."

When operational problems happened, the nurses came up with different strategies to adapt to the correspondent problems. No matter what strategies the nurses chose to apply, they were generally created by a good intention, ample experiences, cautious analysis, and appropriate judgment. Behind diverse coping strategies, patient safety is always put as the priority by the nurses.

5. Consequences of the Alternative Actions

When the nurses had strategies in their mind to address the operational problems, they also described the consequences of the alternative actions to approve their strategies were the most appropriate. They believed if they did not do the way that they performed, they could sabotage patient safety, delay the nursing care, or dissatisfy patients.

"I mean there could be minor to major consequences. You could give a wrong medication, you could give the wrong dose, or you could give it to the wrong patient. You could end up killing someone and not even mean to because you didn't critically think. I mean obviously those are very serious questions."

"If I didn't wait, there could be a drug interaction. It could not be safe for the patient, so I am always waiting for verification. I always want to make sure the pharmacy verifies it first, because there could be several reasons why they don't okay it. Because that is why we go through the pharmacy first is to make sure it is safe for the patient. Make sure there isn't any other drug interaction. There are other people that you work with that can see that you're doing that, and that's not promoting the best practice. You eventually end up getting in trouble for not

following protocol. I always think it is worth the hassle to go and do the extra step even if it's not something my patient or someone else thinks is right."

"Just like delay of care. I mean especially with time sensitive medications, with antibiotics, you want to try to stay as closely on schedule as you can. If that gets messed up, that throws it all off. So that is an issue, same with like a pain medication, and that could lead to the patient getting upset, because they feel like you are not giving them the care they want. If the pharmacists are really busy doing something else, and then they might take longer than the hour, which could be an issue. So that is why it would be necessary to call them and have a discussion with them, and why you need it verified sooner than some of the other meds that are on their to do list."

"I would be backed up on my work probably. Patients probably would not be very happy, because they'd be waiting and waiting. For instance if I didn't give the other meds and just held that one med that I didn't get yet, the patient would probably think I'm ignoring them. They'd probably think, "Well, why am I not getting my other meds? I know this dose changed but…" They feel like you're not taking care of them if you're not showing up and being active in there. So if it's just one pill I'm waiting for, I can give them all their other pills and come back for that other one."

The nurses described that patient safety and how patient would feel about their performance were critical for them when they were dealing with the scenarios. With that priority in their minds, although operational problems happen, patients will not be jeopardized when the problems hinder nurses from delivering medications in the way as they were ordered.

Discussion

The findings indicate that in hypothetical, scenario-based practice examples, the practice frame collides with the system frame, which leads to a series of operational problems, requiring adaptation from the nurses' end. The operational problems identified by the nurses of this study were consistent with the existing literature. For example, the medication order was not in the system when nurse scan the medication by the time it was due because of backstage glitches, which required the nurse to discover the source of the barricade. Ross Koppel et al. [30] described the similar finding in their work, but in a different way, i.e., it's the consequence of a stat, verbal, or not yet entered order. The physical environment was not always favorable for nurses to

perform the medication administration, which was always reported in the literature [10, 30]. The "tenacity" of the system was shown in cases such as when nurses were not autonomous regarding adjusting doses of medications was reported in precious literature [14, 31]. An operational problem rarely occurred as an independent event with singular cause; it was more likely to be associated with multiple components of the work system [30, 32, 33]. Nurse leadership must take the collective impact of these components into consideration, in order to make sure the policies, workflow, and processes and structures are consistent with best practice and meet the demands of bedside nurse practice [34].

The strategies nurses came up with in this study, when encountering medication administration operational problems were partially reported in the literature. In this study, nurses were reported that they would first contact with the pharmacy or the advanced nursing service before they had to reach out to the physicians [35, 36]. This pattern of behavior could introduce new paths to adverse events, in terms of failing to detect automatically renewed or discontinued medication orders [35]. Some literature reported that when goal conflict, timeliness of medication administration was the priority set by the nurses because they were concerned about the analyses of timeliness of medication administration and the stigma of late doses automatically documented in the system [14, 35]. However, in this study, the timeliness of medication administration is less prioritized than patient safety, when nurses determine the ultimate goal during goal conflicts. Nurses describe their work in holistic terms. They examine medication management amid various clinical and logistic dependencies, such as patient comfortableness, their trips off the floor for test and therapies, and patient's needs for sleep and rest [14].

The results of this study have a couple of implications for system redesign. Nurses reported the characteristics of the medications they were delivering and patient situations were

crucial factors determining their strategies of adaptation. Other literature also described that nurses placed transplant patients at a high priority for on-time administrations, in terms of paying special attention to the deliver of antibiotics and drawing at peak and trout blood levels of the drugs. Other medications, which were of lower priority, could be delayed as a result of patient's resting, such as Tylenol or stool softener [14]. While the traditional classification of medication was the active ingredients, the characteristics of medication and patient situation could be introduced into decision support of the BCMA. For example, after nurse collect patient's blood pressure before delivering the Digoxin, the BCMA could indicate the nurse if the Digoxin is needed to be given immediately or not. So when the Digoxin delays to be delivered or is missing on the unit, the nurse can determine if he/she needs to take actions at this moment, either go pick it up or borrow from other patients. The personal-level of decision support should address both the characteristics of the medication and patent situation to collectively analyze the necessity of a specific medication and provide the nurses with the correct suggestions of the next move.

In this study, it was noteworthy that some nurses were more inclined to override the BCMA than other nurses. They reported that as long as they conducted the visual check and followed the protocol, they were confident to override the BCMA and proceed with the medication administration, when an alert popped up. In addition to that, some nurses would take a series of actions to understand the nature of an operational problem, while others only reached out to the pharmacy, when there was an alert indicating no active order in the system after a medication was scanned. This type of behavioral pattern could be included in the continuous and iterative assessment of nurses' interaction with the computer system [37] and operational failure that impede task accomplishment [38] to provide personalized support according to various characteristics of nurses. For example, for those nurses who frequently overrided the BCMA, the

system may automatically reduce the frequency of the alerts of the performance they didn't usually override, but increase the frequency of the alerts of the performance they often override, in order to decrease their level of the comfortableness of overriding. This type of analysis and audit should also be delivered by the technical support from health IT professionals.

There are several limitations to this study that limit he generalization of findings. There were only one hospital's 4 units recruited in the study. The findings from this study could be hard to generalize to other sites with different type of medical services, patient population, and BCMA system. The scenarios may not able to cover all the types of operational problems nurses usually encounter in real nursing practice. Finally, only the investigator analyzed the qualitative data, and the identification of themes was not confirmed with study nurses.

Conclusion

This study presented an initial but crucial step to understand the adaptation to the operational problems of BCMA, taking the various components of the work system into consideration when understanding nurses' adaptive behavior to the operational problems of a new health IT. Different nurses would respond differently when they are facing the same operational problems of BCMA, which requires us to view the process of adaptation within a context of the work system. By understanding the pattern and rationale of the adaptive behaviors of nurses to the operational problems of BCMA, it is helpful for us to improve the quality of care by optimizing the work processes, workloads, training and education, and policies. Given the fact that the operational problems of BCMA are unavoidable, it is critical to understand how nurses can better adapt to them before they endanger patient safety. This research provides suggested paths to reveal the nature of the adaptive process, when BCMA operational problems occur.

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Appendix III Interview Guide

Interview Guide for Aim 3

Hello, Subject ID. My name is: Interviewer's name. I am conducting a research study on nurses' performance with bar-code technology, and I would like to ask you to consider participating. I have IRB approval for this project, and I have a consent form. Would you be interested? If yes, I will go over the consent form with you. If no, thank you for your time.

Interviewer completes consent process. ONCE consented observation is conducted, proceed with the following:

Interviewer to start audio recorder and state the following before interview begins:

A. *Subject ID*
B. *Site ID*
C. *Date*
D. *Time*

I am going to be asking you some questions about the medication administration you just performed with the bar-code medication administration system, hereinafter referred as BCMA.

1. What operational problems have you encountered?

   Probe: The operational problems could be consistent of the BCMA itself, the tasks (medication), the physical environment, the collaboration with other staff, and the patient.

2. When you have encountered these operational problems, what were your objectives? How did you prioritize objectives?

   Probe: The objectives could be patient-oriented, i.e., keep patient safe and comfortable and obey protocol, or task-oriented, i.e., complete the medication administration and work efficiency.

3. Did you have alternative actions other than what you performed?

   Probe: Why you chose to do what you did other than other alternative actions?

4. How do you evaluate your performance?

   Probe: Did you achieve your objectives? What consequences would be if you did the alternatives? What other potential consequences could be after you did what you did?

Thank you for your participation.

Chapter V

Conclusion

The specific aims of the study were to: 1) conduct an integrative literature review about operational problems of BCMA, 2) validate a typology of operational problems of BCAM yielded in the integrative literature review, and 3) assess nurses' adaptations to BCMA operational problems and describe their perceptions about the adaptations. This dissertation adds to the growing knowledge base of the understanding of BCMA operational problems and nurses' adaptations. This chapter provides a summary of the findings, strengths and limitations of the study, and implications for future research and nursing practice.

In chapter one, a conceptual framework guiding this dissertation was described. From a sociotechnical perspective, operational problems are the occurrences that are perceived to make goal accomplishment difficult, unsatisfying, or impossible in accordance with standards or protocol for timely and effective performance [1]. When operational problems occur in the BCMA process, nurses are respond to the perceived problems in order to accomplish some pre-established goal relative to standards for timely and effective performance; this process is known as "adaptations" [1]. Based on the literature, a conceptual framework was developed to describe the relationship between the "system frame", "practice frame", collisions between the system frame and practice frame that cause operational problems, and adaptations to operational problems (see Figure 5.1). "System frame" describes the functionality or implementation of a system as the representative of the cumulative resources within a system to operate and problem-

solve [2]. In this framework, the five factors of the SEIPS work system compose the system frame, and often are triggers for the collisions that occur between system frames and practice frames. The "practice frame" is an aggregation of the bedside nurses' perspectives gained through observations and interviews [2]. In the context of medication administration practice, practice frame is represented as the standards and protocols, which known as the "5Rs" (right patient, right medication, right time, right dose, and right route), safety and efficiency. When the "system frame" can't meet the needs of the "practice frame", the two frames collide, and operational problems occur, which require nurses to adapt.

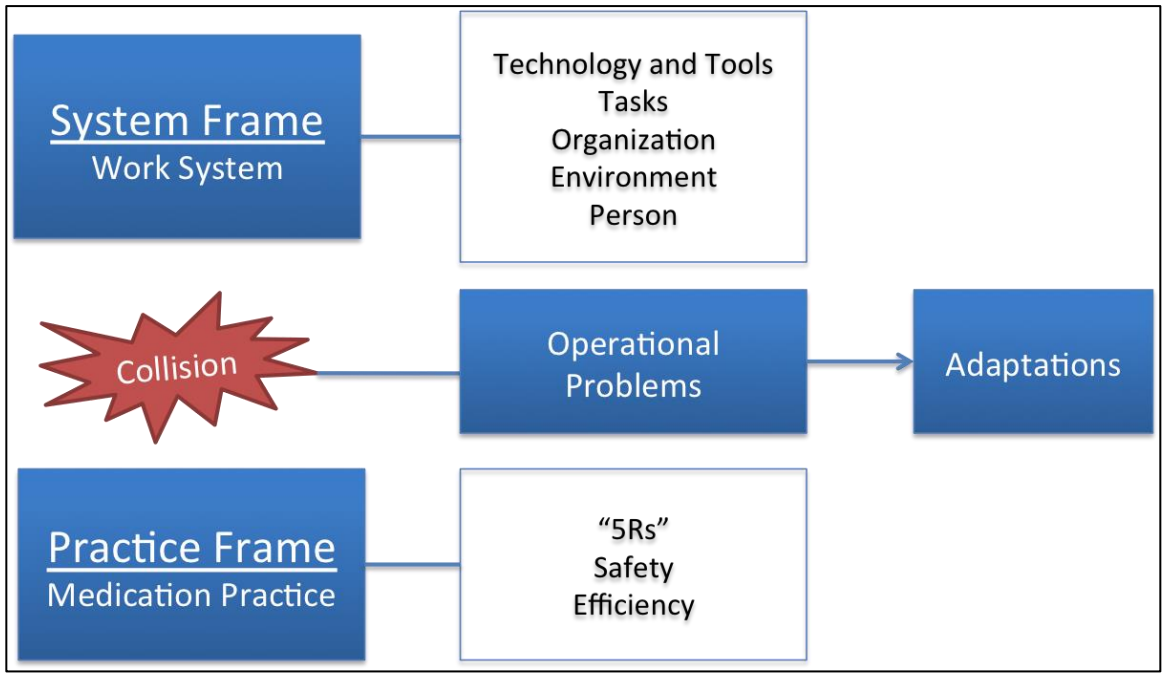

Figure 5.1. **BCMA and adaptation.**

However, efforts to understand BCMA's impact on nursing work have primarily concentrated on workarounds [1-17], which is a type of adaptation [2]. Workarounds are defined as "informal temporary practices for handling exceptions to normal workflow" [8], or "staff deviation actions that do not follow explicit or implicit rules, assumptions, workflow regulations, or intentions of system designers" [18]. In contrast to "adaptations" which emphasize goal-

oriented behaviors, the "workarounds" literature emphasizes behaviors as a consequence of the processes within a work system. Furthermore, "adaptation" emphasizes the process of operational problem solving as a dynamic process, in which the communication between nurses and the environment has the potential to inform pathways to design or redesign the work system. Workarounds are often studied under the assumption that workarounds are inherently dangerous and a threat to patient safety [9, 19-21]; whereas, adaptations are beneficial attempts, reflecting the reactions and decisions in difficult situations. It has been noted that some of today's best practices were yesterday's adaptations; some of today's adaptations could also be tomorrow's best practices [22].

In chapter two, an integrative literature review was conducted to summarize the existing state of knowledge about the triggers of the operational problems of BCMA. The main findings of a review of 12 publications were: 1) the triggers of the operational problems of BCMA reported in the selected literature can be sorted into the 5 categories of the SEIPS model (person, technology, environment, organization, and tasks), 2) operational problems triggered in medication administration practice are not only a result of imperfect design of hardware and software, but also derived from the barriers developed by how the technology is used and responded to by its users, 3) across the 5 categories of triggers to the operational problems, we noted that each category does not exist exclusively; and 4) the medication administration practice is viewed by nurses in a holistic way, rather than being unique "5Rs".

Chapter three validated the findings of operational problems of BCMA yielded in the integrative literature review in Chapter two. The study used a combined research method that involved on-site observations of medication administration and follow-up semi-structured interviews to better unveil the triggers to the operational problems of BCMA that nurses are

currently facing or anticipate may occur. First, there were 43 medication administration events conducted by the 22 nurses on 4 medical/surgical units.

Major findings gained through the on-site observations are reported as follows. The computer keyboard, instead of the patient table, was the most frequent surface (n = 28, 65.1%) used by the nurses to organize the medications. Most of the nurses used the overhead lighting to deliver medications (n = 27, 62.8%). The majority of the nurses hit objects (n = 31, 72.1%) or stretched the cord over the patients (n = 11, 25.6%) when delivering medications. Other disciplines (i.e., physicians and pharmacists), besides nurses, were always involved in the medication administration (n = 34, 79.1%).

During the follow-up interviews, the nurses described that they could deliver medications in a safer and more efficient way by using BCMA, but they also felt more stressful in the manner of adding more steps. A number of nurses noticed they were overdependent on the BCMA, without critical thinking about the necessity of a medication to a patient. The cord issues, system backstage glitches, and system delays or shutdown were identified by the nurses as the operational problems triggered by the technology itself. Missing or dysfunctional medication barcode and wristband barcode were the nurses' biggest concerns related to the tasks the nurses had. It was reported that the system's "tenacity" did not allow the nurses to adjust the time of the medication delivery or the dose of the medications. There was always limited space on the platform and in the patient room, which was the most frequently reported operational problem caused by the environment. Patients under special conditions (i.e. emergency or isolation) were perceived by the nurses as barriers for delivering medications in an efficient way. Nurses portrayed that pharmacy could delay the verification and delivery of the medications after physicians prescribe them in the EHR. The results described above mostly validated the findings

of the literature review. The trigger of the operational problems of BCMA fell into the five components of the work system [23]. The majority of the operational problems reported in this study were also described in the literature.

Chapter four explored patterns of how nurses responded to the operational problems of BCMA and their perceptions about the adaptive behaviors they conducted. To better understand the process of adaptation, a prospective, exploratory research design was utilized, including both scenario-based interviews and follow-up interviews. The scenarios were developed using the triggers to the operational problems of BCMA synthesized and validated in the first two studies. During the scenario interviews, all of the 22 nurses completed 2 cases with 4 scenarios (i.e., operational problems) of medication administration.

It demonstrated in the scenario interviews that overall, across the scenarios, the majority responses to the scenarios were consistent with the practice protocol. This finding suggests that when the system frame collides with the practice frame, most nurses tend to follow the protocol. But there is still a number of nurses who adapt their behaviors to the operational problems in different ways.

In the follow-up interviews, the nurses explained the rationale for their adaptive behaviors. Firstly, the nurses verified that the scenarios described during the interviews did happen frequently in their daily practice and intervene with the safe and efficient nursing care. After identifying the operational problems, most nurses set patient safety as their priority, when they were having the operational problems. Then, nurses made a clinical judgment about the patient's conditions to determine the next move they should take. Factors affecting their decision-making were medication characteristics and patient situation. Following that, to accomplish their goals, nurses developed their own strategies to adapt to the operational

problems. When the medication was not delivered yet, the majority of the nurses would jump in immediately, in terms of picking up the medication themselves. If the patient was not ready for medication administration, nurses skipped that patient and came back to that patient later. If the bigger dose of a medication had not been delivered yet, some nurses picked the smaller doses to match the bigger dose to make sure they would be administered on time. A number of the nurses reported they would be proactive, when physician adjusted orders, by notifying pharmacy to verify the updated orders. Although the majority of the nurses expressed that they would try not to override the system for safety issues, some nurses would rather override the system with a visual check to deliver the medication in a timely manner. Generally, the nurses stated that physicians' interruptions during medication administration could be eliminated, if they communicated patiently. It was noteworthy that nurses showed their willingness of collaborating with the advanced practice team or the pharmacists over the physicians, if they had a medication problem. Finally, nurses evaluated the consequences of the alternative actions. They believed that, if they did not adapt to the operational problems, they could put patient in danger, delay the medication delivery, or dissatisfy patients.

Overall, a key contribution of this dissertation research is the indication that the conceptual framework provides a new way to examine the nature of the operational problems of BCMA and the adaptations to those problems. This one of the first studies that investigated nurses' perceptions about their adaptation process when operational problems of BCMA occurred.

Limitations

Limitations of the study are recognized. Overall limitation of this dissertation study is that there is only one rater across all three studies. The inter-rater reliability of the findings is not

established. Different reviewers may have classified the results of the literature and observations differently.

One of the limitations of the study reported in Chapter 4 is that scenarios were delivered as interviews, not actual observations of adaptations. A combined qualitative research method with on-site observations and interviews was recommended in the literature to better understand the full-scale of the phenomenon [9, 24-30]. Direct observation with patients in the natural environment can better imply the need for process and technology redesign [27].

Implications for Clinical Practice

This dissertation study demonstrated that operational problems of BCMA prevalently occurred during medication administration practice. The triggers of the operational problems could be categorized into the five elements of the SEIPS work system. An operational problem was more like to be caused by several triggers, which are contributed by upstream and downstream glitches [9, 31]. The scenarios designed in Chapter IV showed that an operational problem could be triggered by multiple elements of the SEIPS work system. This finding could help leadership and management to consider the collective causes and sources of the operational problems to ensure that BCMA policies, processes, and protocols are consistent with best practice and the demands of bedside nursing care [31]. Operational problems may be able to be mitigated by controlling and adjusting the triggers of the system frame. The recommended practice protocol of the practice frame may evolve over time by learning from nurses' adaptations. The process of nurses' adaptations is a dynamic process; the adaptations affect the adjustment of the triggers of the system frame and the protocols of the practice frame.

The triggers of the operational problems of BCMA reported by the nurses in Chapter III may provide system designers and developers with evidence of opportunities for improvement.

The majority of the participating nurses reported issues with cord between the hand scanner and the computer. A cordless scanner with a reset button could dramatically facilitate the medication administration process, especially when the patient is away from the computer with objects in the way, and the barcode on patient's wristband is hard to scan; nurses would not have to make multiple trips between the computer and the patient, when the cord does not easily stretch over the patient and other objects.

Given that adaptation is understudied, it is very possible to label adaptation as undesirable side effects committed by "resistors" or "bad apples" [2, 32]. Actually, adaptations are probably unavoidable and necessary to accomplish the pre-established goals of safe medication administration [1]. Adaptations could be tomorrow's "best practice" and consequently, be promoted and facilitated [1]. Sometimes, nurses attempt to adjust the dosage of medication and the time of administration for good reasons. For example, when the schedule of a regular sleep medication needs to be staggered after a surgical procedure, or a nurse wants to administer two smaller doses of an antibiotic after the bigger dose has not been delivered for an hour. The system design and practice protocol should allow nurses to make that adjustment by documenting a comment, instead of stamping a "late dose" or "wrong dosage" in the system. Management and leadership could take several actions to remove the stigma of some adaptations that actually promote safe and timely medication administration [2].

Directions for Future Research

Future research should more rigorously investigate nurses' adaptive behaviors to operational problems. Client simulation has been used extensively in studies for clinical problem solving because it allows researchers to mimic the clinical environment while controlling for other variables possibly existing in real-life situations [33, 34]. High fidelity simulation is

considered especially useful for identifying variations in workflows that are rooted in implementation of a new system, and then predicting potential use problems and errors[35]. In simulated scenarios, relevant information can be teased out with details using predetermined and standardized scenarios within a relatively short period of time.

The model of this dissertation study demonstrated that when the components of the system frame and practice frame collide, operational problems occur, which trigger nurses to adapt their behaviors to accommodate the problems and accomplish the medication administration (see Figure 5.1). The study results reported in Chapter IV showed nurses came up with various strategies when adapting. Some of the strategies would affect the functioning of the system frame and the practice frame. For example, nurses would communicate patiently with physicians when being interrupted during medication administration, or nurses would perform proactively when an updated order had not been verified by the pharmacy in a timely manner. These behaviors would affect the functioning of "organization" of the system frame and the "efficiency" of the practice frame. From this point of view, adaptations should be considered as a dynamic process of performance. Future studies could take longitudinal perspective to discover the evolution of the system frame and practice frame, and then explore how nurses' adaptation impacts on planned changes of the two systems.

The study site of this dissertation consistently audits nurses' BCMA compliance report. It is a real time database with the BCMA compliance rate of all in-hospital units. It also shows the top reasons identified by nurses for overriding the system when scanning the medications and the patients' barcodes. The goal of the compliance rate of order scanning and patient scanning are both above 95%. The top reason for non-compliant order scanning has been barcode of the medication was not available. The top reason for non-compliant patient scanning was that the

barcode of the wristband was not readable. But based on the results of the observations and interviews with the nurses in the hospital, there is information missing, if researchers only look at the compliance numbers. For example, is this top reason picked up by nurses only because this was the first reason popped up on the screen when nurses had to override and there was no other reason better applied, or this is the actual reason for them to override? Although nurses didn't override, did they go through operational problems during medication administration? Why was the non-compliant rate of this specific nurse on this specific unit always higher than others? It will be very innovative to conduct observations and interviews about medication administration and compare to the contemporary non-compliant rate of scanning to piece together the picture of medication administration practice. The results can shed lights on professional development and work education, in terms of how to override appropriately.

In summary, this study presented a new conceptualization of adaptation to operational problems of BCMA, a conceptualization that moves beyond the negative connotations of workarounds. Future studies are needed to validate this conceptualization, and to address BCMA system design issues that introduce collisions when work systems do not correspond to the practice goals of safe and effective medication administration.

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