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What Are the Causes of Noncompliance Behaviors in Bar Code Medication Administration System Processes?

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Healthcare information systems (e.g., Bar Code Medication Administration [BCMA] system) have been adopted to deliver efficient healthcare services recently. However, though it is seemingly simple to use (scanning barcodes before medication), users of the BCMA system (e.g., nurses and pharmacists) often show *noncompliance behaviors*. Therefore, the goal of this study is to comprehensively understand why such noncompliance behaviors occur with BCMA system. Through comprehensive literature review, 128 instances of causes were identified, which were categorized into five categories: Poor Visual and Audio Interface, Poor Physical Ergonomic Design, Poor Information Integrity, Abnormal Situation for System Use, and User Reluctance and Negligence. The results show that successful use of a BCMA system requires supportive systems and environments, so it is more like an issue of the system rather than that of an individual user or a device. It is believed that the proposed categories could be applicable in investigating noncompliance behaviors in other healthcare information systems as well.

1. INTRODUCTION

Medical errors and adverse drug events, which are the two largest sources of healthcare accidents, contribute to between 44,000 and 98,000 deaths per year (Alvarado, Ntaimo, Banerjee, & Kianfar, 2012; Kohn, Corrigan, & Donaldson, 2000). The Centers for Disease Control and Prevention announced that healthcare-associated infections cause more than 100,000 deaths, and unnecessary harm from their care processes occur in one fourth of Medicare patients admitted to a hospital (Klevens et al., 2007). In addition, Lewis et al. (2009) found that an average medication error rate in all prescribing orders is estimated at 7%, and every two admissions experience an error. To solve these issues, various types of healthcare information systems (HIS) such as Electronic Medical Record, Computerized Provider Order Entry (CPOE), and Bar Code Medication Administration (BCMA) have been suggested (Medicare Payment Advisory Commission [US], 2004).

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The successful contributions of the HIS greatly depend on the system users' attitude toward the system implementation. The complex and dynamic nature of care processes and diverse types of system users easily trigger the gap between the system-intended process and the actual work process, and negative perceptions about technology (André et al., 2008; Karsh et al., 2009; Silow-Carroll, Edwards, & Rodin, 2012). The user workflow should be gradually modified to decrease the user reluctance, and users also should accept some extent of change in work processes and job responsibilities (Kuperman & Gibson, 2003). Newly implemented systems without consideration of existing workflows and user adaptation can provoke unfavorable perceptions of and reluctance about the systems, and these can be major causes for noncompliance behaviors and workarounds (Holden et al., 2011; Yang, Ng, Kankanhalli, & Yip, 2012). Miller and Sim (2004) showed that positive attitudes were critical to successful adoption of the systems.

Particularly, previous studies report that the BCMA system becomes useless when users do not follow the predefined procedure of the BCMA system (Bargren & Lu, 2009; Koppel, Wetterneck, Telles, & Karsh, 2008; Patterson, Cook, & Render, 2002). To prevent errors in the medication administration process, the BCMA system has been widely adopted in the medication management process. Using the BCMA system, a nurse can scan one bar code on a patient's wristband and another on a medicine package to ensure that the dispensation matches the patient's prescription. However, nurses sometimes do not verify or update medication orders displayed in the BCMA system (Bargren & Lu, 2009). Such noncompliance behaviors are harmful because they disrupt workflows (Kobayashi, Fussell, Xiao, & Seagull, 2005), confuse communication (Koppel et al., 2008), potentially increase the risk of errors (Vogelsmeier, Halbesleben, & Scott-Cawiezell, 2008), negate the safety features provided by the system, and create additional unexpected problems (Ferneley & Sobreperez, 2006).

Noncompliance behaviors in the BCMA system process have been a long-lasting conundrum: Users often do not comply with the simple process (e.g., scanning bar codes). Thus, previous studies attempted to identify the causes of noncompliance behaviors. However, the previous research studies tended to be narrow and specific process oriented, so they failed to provide comprehensive and generalizable results; identified causes seem to be for temporary and local issues (Bargren & Lu, 2009; Koppel et al., 2008; Patterson, Rogers, Chapman, & Render, 2006). In other words, there is no clear understanding of what causes the noncompliance behaviors and how they can be resolved (Agrawal & Glasser, 2009; Miller, Fortier, & Garrison, 2011; Yang et al., 2012).

Thus, the goal of this article is to understand noncompliance behaviors in the BCMA system process by surveying previous studies. We did not conduct an observation study with a specific group of users—specifically, nurses—because such observations cannot comprehensively collect causes of noncompliance behaviors. Instead, we decided to comprehensively review existing literature reporting the underlying causes of noncompliance behaviors in the BCMA system processes between 2000 and 2012. After analyzing and classifying the collected causes, we found some interesting patterns among them. The patterns not only shed light on the complexity of this issue but also suggest future direction of research.

This article consists of the following sections. The Background section introduces the BCMA system processes, noncompliance behaviors, and prior studies. The Methods section details how we collected and reviewed previous literature. The Results section presents the five categories identified from our analysis. Finally, the Discussion and Conclusions sections provide the implications and potential applications of the proposed categories, contributions, limitations, and future work.

2. BACKGROUND

2.1. Definition of Noncompliance Behavior

The *American Heritage Dictionary* defines noncompliance as "failure or refusal to comply" ("Non-compliance," n.d.). However, there exist many definitions of *noncompliance* in the domain of healthcare and human–computer interaction. Furthermore, they do not seem to converge into one (Halbesleben, Wakefield, & Wakefield, 2008). Although some considered noncompliance behaviors as a creative and clever method to increase work efficiency (Ash, Berg, & Coiera, 2004; Lalley & Malloch, 2010), others treated them as a detour that workers take in order to avoid additional workloads because they perceive the original process as unrealistic or harmful (Saleem et al., 2011; Schoville, 2009). Furthermore, other terms, such as deviation, deviance, workarounds, violations, and shortcuts, are often used interchangeably to describe noncompliance. Even though each variant has its own characteristic (Kaplan, 1975), we decided to use all the terms (i.e., noncompliance, deviation, deviance, workarounds, violation, and shortcuts) for this study because our goal is to review noncompliance behaviors comprehensively.

2.2. Bar Code Medication Administration

Bar code systems have been implemented to reduce errors in the medication administration process. The medication administration process is as important as other medication processes such as prescribing, transcription, dispensing, or monitoring because it is the final chance to prevent actual harm to patients. However, according to Shane (2009), 38% of preventable medication errors occurred in the medication administration process.

The BCMA system process consists of four steps that nurses should follow: preparation, scan, match, and follow-up. In the preparation step, a nurse obtains medications and administering supplies from dispensary, logs on to the BCMA system, and sets up the scanner. In the scan process, a nurse scans one bar code on the patient's wristband and another bar code on the medication. The two scans retrieve patient information and medication information from electronic medical record systems and present the information on a display. In the match process, a nurse ensures that the patient information matches the right patient, that the medication information matches the right medication, and that dispensation matches the patient's prescription. In the follow-up process, a nurse returns the scanner to the system, logs out of the system, and prepares and administers medications to the patient (Bargren & Lu, 2009).

Many peripheral systems support the BCMA system process. Such systems interactively exchange patient and medication information between other HIS. Some peripheral systems include (a) Electronic Medical Administration Record (eMAR), (b) Pharmacy Dispensing Systems, (c) Pharmacy Information Systems, and (d) CPOE. The eMAR contains patients' prescription information and works as a central point to all information technology systems, the CPOE system provides order information, the pharmacy information and dispensing systems provides medication information and schedule, and the laboratory information system and radiology information technology system provides supplementary patient and medication information.

2.3. Noncompliance Behaviors in the BCMA System Process

Many studies have investigated noncompliance behaviors in the BCMA system process and other forms of medication administration process (Carayon et al., 2007; Koppel et al., 2008; Schoville, 2009; Vogelsmeier et al., 2008). They identified diverse cases of noncompliance behaviors and their causes. Most of the studies simply listed cases and causes of noncompliance behaviors, but only a few attempted to classify them to find meaningful patterns in the list. However, even the studies that reported classification failed to provide comprehensive categories.

On one hand, some studies provided abstract categories on the cases of noncompliance behaviors. For example, Carayon et al. (2007) observed nurses' use of the BCMA technology and categorized flexible task sequences by five elements of the work system model: tasks, technology, organization factors, physical environment, and individual factors related to patient and nurses. Because the categories simply indicate several factors to influence noncompliance behaviors, such factors often fall short to identify underlying issues and repeating patterns. In another example, Vogelsmeier et al. (2008) suggested two categories of noncompliance behaviors: blocks introduced by technology and organizational processes, respectively. Due to rough categorization, this classification cannot distinguish the specific aspects of noncompliance behaviors. For example, the categories make it difficult to distinguish noncompliance behaviors that originated from system software or hardware issues from those stemming from users' dissatisfaction of the system or work environmental issues such as emergencies or poor system layout.

On the other hand, some categories of noncompliance behaviors are specific and process oriented. Koppel et al. (2008) classified noncompliance behaviors by three categories: omission of process, out of sequence process, and unauthorized process. These categories are developed around the task sequences, but they do not present other important factors like environment that can affect noncompliance behaviors. Schoville (2009) also organized nurses' noncompliance behaviors in five categories: workflow timing of events, communication changes, system problems, learning curve of system use, and patient safety. However, the categories do not seem to be mutually exclusive or to provide comprehensive factors. Table 1 shows the summary of studies on the cases of noncompliance behaviors.

Some studies classified the causes of noncompliance behaviors by abstract categories (see Table 2). Koppel et al. (2008) proposed technology, task, organizational, and patient-related issues and environmental factors as main categories of causes. Halbesleben et al. (2008) also indicated policies/laws/regulations, protocols, process/design/flow, technology, and people as categories of the causes of noncompliance behaviors. Although such high-level categories provide the holistic view of causes, it is difficult to apply the categorization results to reduce noncompliance behaviors.

In contrast, some other studies categorized causes based on a small set of specific categories of noncompliance behaviors. Carayon et al. (2007), using processing the mapping approach, analyzed medication administration task sequences to classify influencing factors on nurses' use of and interaction with the BCMA system into three phases: technology design, technology implementation, and technology use. However, this classification mostly focused on system adoption and adaptation issues and is not enough to describe comprehensive causes of barriers. Halbesleben, Savage, Wakefield, and Wakefield (2010) also grouped 12 barriers of nurses' tasks in intensive care units by the perspectives of information-processing stages. They suggested information entry, information exchange, and internal supply chain as main causes for noncompliance behaviors. However, the categories are mostly based on the scope of patient information and medication flow.

Despite the high volume of studies on noncompliance behavior cases and their causes, we failed to find an answer to the following question: What are the causes of noncompliance behaviors? Different studies suggested some potential causes of noncompliance behaviors, but they tend to be detailed or not comprehensive. To answer this question and to construct a comprehensive cause of noncompliance behaviors, we decided to conduct systematic reviews on previous studies. We believe that answering this question will provide some hints to resolving this long-lasting conundrum of minimizing noncompliance behaviors.

3. METHODS

3.1. Study Scope

This study aims to investigate noncompliance behaviors of healthcare practitioners while administrating medicines using the BCMA system. Because medication administration processes are continuous and multidirectional, it is difficult to find a clear line between the BCMA system and other systems. In our study, we defined the boundary between the two as follows: The BCMA system includes only systems that help healthcare practitioners to check patient and medication information and to dispense medicines to patients, whereas other systems include systems providing patient and medication information to the BCMA system. For example, other systems include the eMAR system, automatic medication dispensing system, and CPOE system.

3.2. Selection of Papers

We comprehensively collected relevant articles published between 2000 and 2012. The initial search of relevant literature was performed using three sets of keywords. The first keywords set included "non-compliance," "workaround (work-around)," "violation," "shortcut (short-cut)," "deviation," and "deviance." The second set included "healthcare (hospital) information system," "bar-code (bar code, bar-coded, bar-coding)," "electronic (computerized) medication," "bar-code scanning," "clinical decision support," and "nursing informatics." The third set included "medication (medicine, drug) administration," "nursing practice (process)," "medication management," "patient identification," "medication identification," "medication process," and "medication monitoring." Using comprehensive combinations of three keywords, each of which came from one of three keyword sets (e.g., "non-compliance" AND "bar-code scanning" AND "medication administration"), we searched for all the papers that contain the search keywords in either their abstract or title using the following databases: PubMed, Cumulative Index Allied Health Literature (CINAHL), Health Source: Nursing academic edition, PsycINFO, PsycARTICLES, and Social Sciences Full Text. We included only articles published in peer-reviewed journals or presented in academic conferences. This process resulted in 418 papers.

TABLE 1
Noncompliance Behavior Classification in Healthcare System Environment

Paper	Setting	Method	Result	Category
Abstract categorization				
Carayon et al., 2007	BCMA system in academic medical center	Structured observation of medical administration process	5 categories (from Balance theory of job design) based on 18 different task sequences and very large variability in the order steps of medication administration process	• Task (e.g., task sequence, potentially unsafe medication administration) • Technology (e.g., automation surprise, alarms) • Organizational factors (e.g., interruptions) • Physical environment • Individual (e.g., patient factors)
Vogelsmeier et al., 2008	Electronic medication administration record system in nursing home	Direct observations, process mapping, interviews, and review of medication field notes	No quantitative results or cases are reported.	• Blocks introduced by technology • Organizational processes that had not been reengineered to integrate effectively
Lawler et al., 2011	General healthcare information technology	Reviewing prior studies	No quantitative results or cases are reported.	• Ad hoc solutions to poor work process and sociotechnical design • Product of resolving competing demands
Specific categorization				
Koppel et al., 2009	BCMA system in two hospitals	Structured observations, unstructured and semi structured interviews, participating staff meetings, FMEA of the medication use process and BCMA use processes and reviewing BCMA override log data	3 categories from 15 types of workarounds	• Omission of process steps • Steps performed out of sequence • Unauthorized BCMA process steps
Schoville, 2009	Institutional CPOE system	Observations on nurses daily work, emails to key leaders and participants, follow-up interviews and reviewing the internal CPOE web site	5 categories based on 40 workarounds and 18 artifacts	• Workflow timing of events • Communication changes • System problems • Learning curve of system use • Patient safety

(*Continued*)

TABLE 1
(Continued)

Paper	Setting	Method	Result	Category
Miller et al., 2011	BCMA system in adult medical/surgical units	Reviewing override reports and alert messages	3 categories based on 7 types of workarounds from 121 cases	• Omitted step • Unauthorized step • Incorrect sequence
Patterson et al., 2002	BCMA implementation process in 3 hospitals	Observation on nurses' BCMA use, CPOE and order verification process by pharmacists	5 negative side effects from 12 types based on 67 BCMA interactions	• Nurses confused by automated removal of medications by BCMA • Degraded coordination between nurses and physicians • Nurses dropping activities to reduce workload during busy periods • Increased prioritization of monitored activities during goal conflicts • Decreased ability to deviate from routine sequences
Yang et al., 2012	Electronic medication administration system, which is combined functions of BCMA, CPOE and eMAR	Qualitative case study based on interviews with the users of EMAS	15 categories of workarounds performed by physicians and nurses	• Physician used paper IMR to order instead of EMAS. • Physician used COW outside cubicle instead of bedside. • Physician did not fill up columns fully during ordering. • Physician edited dosage forms suggested by the system. • Physicians shared log in account. • Physicians requested to reorder medication by nurses. • Nurse used COW instead of PDA. • Nurse used PDA to scan clinical board instead of wrist tag. • Nurse picked next time slot to serve because current used. • Nurse served medication outside of expected timing. • Nurse cleared omission for PRN medicine in batches. • Nurse clicked medicine to be administered on COW before • serving. • Nurse did not serve medication ac cording to order in EMAS. • Nurse cosigned for another nurse during serving. • Nurse served medication before it was ordered.

Note. BCMA = Bar Code Medication Administration; FMEA = Failure Mode and Effect Analysis; CPOE = Computerized Provider Order Entry; IMR = Inpatient Medication Records; EMAS = Electronic Medication Administration System; COW = Cart On Wheels; PDA = Personal Digital Assistant; eMAR = Electronic Medical Administration Record; PRN = *Pro Re Nata* (Latin, meaning 'necessary')

TABLE 2
Noncompliance Causes Classification in Healthcare System Environment

Paper	Setting	Method	Result	Category
Abstract categorization				
Koppel et al., 2009	BCMA system in 2 hospitals	Structured observations, unstructured and semistructured interviews, participating staff meetings, FMEA of the medication use process and BCMA use processes and reviewing BCMA override log data	Identified 31 types of probable causes of workarounds	• Technology • Task • Organizational • Patient related • Environmental
Halbesleben et al., 2008	General healthcare	Literature review (not systematic)	5 categories of workaround causes	• Policies/laws/regulations • Protocols • Process/design/flow • Technology • People
Bargren & Lu, 2009	BCMA system in acute care hospital	Direct staff observation, process mapping, and informal group discussions	3 categories from 13 gap's source and consequences within the step of the medication process	• Technical gap (e.g., computer capacity, system downtime) • Human interaction gap (e.g., human mistakes and inefficiencies) • Content workflow gap (e.g., need for information)
Specific categorization				
Carayon et al., 2007	BCMA system in academic medical center	Structured observation of medical administration process	Identified work system factors that affects nurses' use and interaction with BCMA process	• Technology design (e.g., screen size) • Technology implementation (e.g., nonbarcoded medications) • Technology use (e.g., interruption)
Halbesleben et al., 2010	Intensive care units of four hospitals	Observation and structured interviews	3 categories of causes by 12 barriers to nurses' task	• Information exchange • Information entry • Internal supply chain
Niazkhani et al., 2010	CPOE system	Qualitative study in medication-use process. Data are collected from transcripts of interviews with clinical end-users, artifacts used in daily work, and educational materials to train physicians and nurses to use the CPOE system.	Details of the problems encountered, their probable root causes, and the resulting workarounds that emerged to address them.	• Prescribing • Communication of order • Dispensing • Administration • Monitoring

Note. BCMA = Bar Code Medication Administration; FMEA = Failure Mode and Effect Analysis; CPOE = Computerized Provider Order Entry.

We reviewed abstracts and keywords of all the 418 resulting papers to determine their eligibility for further review using the following criteria. First, the end users of the BCMA system should be healthcare practitioners. We excluded studies of the BCMA system used by patients or nonprofessional healthcare providers such as social workers (Exclusion 1). Second, we excluded papers that deal with other care processes only, such as prescribing or dispensing (Exclusion 2). Furthermore, we excluded papers that do not address the causes of noncompliance behaviors (Exclusion 3). Last, we also

TABLE 3
Paper Exclusion Criteria and Resulting Numbers of Papers

Exclusion Criteria	No. of Papers
Search results from databases	418
Exclusion 1: No care practitioners' behaviors	−337
Exclusion 2: Not relevant to medication administration	−27
Exclusion 3: Irrelevant topics or scopes	−26
Exclusion 4: Not accessible	−4
Final paper pool	24

excluded papers if we had no access to their full manuscripts (Exclusion 4). Eventually, 24 papers were selected for the review, referred to henceforth as the paper pool. In the paper pool, we collected 128 causes of noncompliance behaviors (see Table 3).

3.3. Code Schemes and Codification Process

We used the open coding approach to develop the codes. The open coding approach collects the quotes from the referenced papers to clarify the causes of noncompliance behaviors and delineates characteristics to represent raw data (Corbin & Strauss, 2008). In the coding process, we ensured that the codes should be independent to each other and be placed in the same abstraction level. We iteratively constructed and destructed codes to obtain reliable and consistent results in the following procedure. First, we randomly selected 21 causes and abstracting core concepts. The extracted codes were adjusted and refined to group similar causes. Then, we independently coded the rest of 107 causes using the initial causes. The researchers compared the outcomes of the codification with each other. When we had significant discrepancies between coders, we discussed and adjusted the code scheme. This process repeated until we stabilized categories of causes of noncompliance behaviors. In the final process, we categorized quotes using the five categories. Interrater reliability measures show substantial agreement levels: Fleiss's Kappa value was 0.618 and Conger's exact Kappa value was 0.619.

4. RESULTS

We found the five categories of causes of noncompliance behaviors in the BCMA system process:

- Poor Visual and Audio Interface (11)
- Poor Physical Ergonomic Design (10)
- Poor Information Integrity (40)
- Abnormal Situation for System Use (23)
- User Reluctance and Negligence (9)

Each category represents a common cause that leads to noncompliance behaviors in the BCMA system process. The numbers in parentheses represents how many causes belong to each category. However, these numbers should not be used to infer the seriousness of each category. In this section, we describe definitions and common characteristics of the five categories one by one. In addition, we also show some examples of causes that fall within each category.

4.1. Poor Visual and Audio Interface

Poor Visual and Audio Interface refers to problems from suboptimal user interfaces used in the BCMA system. Some of them are very typical, and they are often identified through a discounted usability inspection method (Nielsen & Levy, 1994). For example, information required for medication administration is not readily available [3],[1] a text field does not allow additional information to be entered (e.g., additional notes from a physician and documents for the next shift nurses; [4][9]), and the system does not allow users to update incorrect information (e.g., medication administration time; [8]).

However, issues in this category are not limited to a visual user interface. Some issues in an auditory interface were also found. For example, a scanner uses identical beeps for both acceptable and wrong scanning, which might make nurses confused or lead them to ignore the auditory feedback [2]. Some additional problems come from multiple systems. For example, due to the lack of integration among multiple information systems, nurses might encounter difficulties while processing information from multiple screens [1].

Issues in Poor Visual and Audio Interface are technically easier to fix than other issues (e.g., Poor Physical Ergonomic Design) because some of them are very specific to certain elements of user interface (e.g., a text field for additional note) and could be fixed through software update (e.g., software patch or version upgrade). However, it does not mean that all issues in Poor Visual and Audio Interface are easy to fix. When user interface developers are not readily reachable or the BCMA system is part of the enterprise-scale software, changing such minor aspects can take a substantial period of time. Furthermore, radical changes in interface may frustrate users and lead to noncompliance behaviors due to the novel design.

4.2. Poor Physical Ergonomic Design

Poor Physical Ergonomic Design refers to problems due to incompatible designs of hardware. Generally, Poor Visual and Audio Interface negatively affects users' cognitive behaviors such as perception and cognition, but Poor Physical Ergonomic Design interferes with physical behaviors. Some physical specifications of HIS are designed without enough consideration of actual work processes and environments; mobile workstations

[1]A number in brackets represents the cause identification number; a corresponding quote can be found in Appendix A.

or medication carts are heavy, bulky, or inconvenient to take into the patient's room [12][16]; a poor system layout such as inaccessible workstations also can prevent nurses from performing the scanning task [15]. Due to such misfit system specifications, nurses tend to find workarounds or shortcuts.

Issues in Poor Physical Ergonomic Design are difficult to fix because they originate from the initial design of system specifications. Modifying the system specifications after implementation usually requires significant efforts and costs. To minimize such issues, the real work environments and conditions should be considered at the very beginning stage of system design process.

4.3. Poor Information Integrity

Poor Information Integrity refers to problems caused by poor information transfer or incorrect and/or missing information. Poor Information Integrity is often found in the midst of communicating information through electronic medium (e.g., communication between the eMAR and BCMA systems), but it should be noted that physical forms of information media (e.g., bar code) also cause the Poor Information Integrity issues.

First, incorrect or missing information from peripheral systems, such as eMAR, computerized prescribing system, and automated medication dispensing system, could be causes of noncompliance behaviors. For example, eMAR often fails to send medication orders on time, so nurses try to complete the medication administration process without the medication order [26]; actual administration information did not correspond to the information from the eMAR [37]. The dose of medication stocked by the hospital did not match that of the typical medication order [58][59]. Sometimes, due to strict information entry requirement, peripheral systems cannot transmit the information to the BCMA system on time; the eMAR requires all fields to be completed or there will be difficulty in documenting information [34].

Second, bar codes are another cause of noncompliance behaviors. Bar codes are an important information delivery medium in the BCMA system because patient identification information and medication information can be entered through them. In general, there are three commonly observed issues in the bar codes: missing bar codes, damaged bar codes, and inaccessible bar codes. Some medications may not have bar codes to scan on their bottles; the bar codes may be on the box containing the bottles [27][50][53]. Some nonformulary medications, which are not in the list of brand name and generic medications, usually do not have proper bar codes for the BCMA system, so it requires nurses to take additional steps to manually register such medications. To avoid the burden, nurses sometimes skip the scanning process [51][56]. Damaged bar codes, such as dirty, twisted, or torn bar codes, are difficult to scan and delay the medication administration process [23][49][52][55]. Some bar codes are inaccessible to the scanner because the code is located on cringed or banded areas [32]. In particular, intravenous drips or other liquid medications have customized bar codes and are delivered via unconventional containers, which may prevent nurses from scanning them [47].

Issues in Poor Information Integrity mainly stem from lack of understanding on interactive and connected working environments. Stand-alone systems are hard to find in modern working environments, and communication and interoperability between systems are much more important. Especially, the designers should consider highly responsive task settings of care process at an early system design stage.

4.4. Abnormal Situation for System Use

Abnormal Situation for System Use refers to the problems due to uncontrollable or unpredictable situation of the BCMA system users. One of the major cases in this category is an emergency or uncontrollable situation. When patients arrive at a hospital in serious condition, nurses are likely to skip the scanning medication bar codes or patient identification steps [69][81]. In addition, patients are often taken off wards to have operations or diagnoses, which makes it impossible for nurses to proceed with the BCMA system process [67][71]. Some patients may have medical conditions that do not allow them to wear wristbands with bar codes [70][74][79][82]. Even though this is an issue of the bar code, this issue cannot be categorized as Poor Information Integrity because the issue stems from the patient's health condition, not from the role of information transfer.

Heavy workload on nurses is also included in this category. Heavy workload can result from insufficient staffing, busy periods, or time constraints to complete the tasks [65][76]. Surprisingly, compared to a paper-based system, the BCMA system adds seven to 24 more steps to administer medication, requires some level of change in the nurse's role, and requires more responsibility from care practitioners. Such changes can frequently cause breakdowns, interruptions, and over-workloads, so care practitioners understandably deviate from the work process required by the systems (Bargren & Lu, 2009; Cheng, Goldstein, Geller, & Levitt, 2003; Niazkhani, Pirnejad, van der Sijs, de Bont, & Aarts, 2010).

In addition, nurses intentionally bypass the BCMA system process to care for patients. Nurses do not want to disturb sleeping patients [72] and try to avoid interrupting discussions between patients, family, and other healthcare practitioners [73]. As another example, a nurse may skip scanning a patient wristband to avoid endangering patient care while waiting for a new wristband to be issued [80].

The causes in this category may not have specific solutions, at least from the user perspective, due to the unexpected and unavoidable characteristics of such events (Carayon et al., 2007; Tucker & Edmondson, 2003). However, heavy workload issues can be resolved by optimizing schedules and by increasing workforce (e.g., hiring more nurses).

4.5. User Reluctance and Negligence

User Reluctance and Negligence refers to the problems due to unclear understanding of work procedures or underestimation of associated risks. Whereas other categories of causes are based on poor system features, this category represents users' inappropriate attitudes toward the system (Rivera-Rodriguez et al., 2012).

First, this antagonism may occur because nurses are unfamiliar with how to use the system. Because nurses are unaware of how to retrieve patient and medication information, medication administration may be delayed, so they skip the BCMA system process [94]. Some cases show lack of understanding of bar codes of medication labels (e.g., fail to find the location of bar codes; [93]).

Second, nurses may underestimate the risk of noncompliance behaviors while using the BCMA system, or they may not fully appreciate the system's benefits [89]. In some cases, nurses think that they are familiar enough with the patients through long-term care, so they may skip confirming patient identification because they underestimate the risk of misidentification [95]. In addition, the lack of awareness of general hospital policies can be another issue in this category [90].

Obviously, training would be a solution for the issues in this category, but methods and contents of training are required to be more specific. For example, training programs need to be different based on specific system usages, benefits and risk of the system, or general policies.

5. DISCUSSION

5.1. Implications on Codified Categories

Table 4 shows the comparison between the five categories in this study and other categories from previous literature. Carayon et al. (2007) narrowed down the causes by technology implementation processes. In particular, their categories highlight the causes of noncompliance behaviors that occur in the design, implementation, and use stages of the BCMA technology. Halbesleben et al. (2010) classified causes into three categories: information exchange, information entry, and internal supply chain. These categories respectively indicate communication issues, information input issues, and medication issues. Niazkani et al. (2010) projected causes to the medication administration process. These categories are not comprehensive for a wide range of causes and explain only particular aspects of noncompliance behaviors.

Some studies used abstract and conceptual classification criteria to categorize the causes of noncompliance behaviors. Halbesleben et al. (2008) and Koppel et al. (2008) similarly categorized the causes of noncompliance behaviors by technology, task or process, people or patient related, policies or organizational, and environmental issues. Even though their categories are based on prior research and log data, some categories are not independent to each other and they did not use any systematic approach to define the categories. Because each of these categories points to a broad area (e.g., policy), it is difficult to derive solutions to resolve specific noncompliance behaviors.

In contrast, our five categories have three clear advantages over other categories. First, the categories have appropriate levels of criteria, and they are independent to each other. They cover comprehensive aspects of the BCMA system including software, hardware, users, and environment, and each category clearly explains the repeating pattern of the causes of noncompliance behaviors. Second, the categories have clear definitions. Halbesleben et al. (2008) insisted that many previous literatures have tended to classify the causes of noncompliance behaviors but have not provided clear definitions. Meanwhile, we define each category and easily classify the causes by the definitions. Third, our categories are based on qualitative data analysis. Through a repeating codification process, our categories can consistently and reliably explain the noncompliance behaviors. Also, such an analytic approach helps to maintain neutral perspective on developing the categories. With these three advantages, the categories can be applied into other HIS environments.

5.2. Potential Solutions to Reduce Non-compliance Behaviors

According to the codification results, the five categories identify three areas to reduce the chances of noncompliance behaviors.

Issues in Poor Visual and Audio Interface and Poor Physical Ergonomic Design indicate that system design deficiencies should be resolved to diminish noncompliance behaviors. The first way to resolve the deficiencies effectively is to build or modify the interface and system dimension with human factors design principles. A well-designed user interface and system dimension not only reduce noncompliance behaviors but also are easy to use and manageable, helping users to complete their work efficiently and feel satisfied. Many principles of effective human interface design have been published in a wide range of human–computer interaction research, cognitive psychology, and design best practices domains (Constantine & Lockwood, 1999; Cooper & Reimann, 2003; Gerhardt-Powals, 1996; Lidwell, Holden, & Butler, 2003; Nielsen & Levy, 1994; Shneiderman, 1998; Tognazzini, 2003). The following principles that are consolidated from several human interface design principles are necessary to improve the usability of HIS.

First, simplicity reduces confusion and removes any unnecessary or irrelevant elements (Nielsen & Levy, 1994; Norman, 2002; Rams, n.d.; Tognazzini, 2003). It improves the visibility and accessibility of the most commonly used task options. It also makes the system usable without detailed instructions and help data display in a manner that is clear and obvious to the target users. Second, usefulness provides basic value and utilities of the system and addresses the real needs of users

TABLE 4
Comparison With the Categories of Noncompliance Causes

Reference	Category	Codified Category				
		Poor Visual and Audio Interface	Poor Physical Ergonomic Design	Poor Information Integration	Abnormal Situation for System Use	User Reluctance and Negligence
Specific						
Carayon et al., 2007	Technology design (e.g., screen size)	✓				
	Technology implementation (e.g., non-bar-coded medications)			✓		
	Technology use (e.g., interruption)				✓	
Halbesleben et al., 2010	Information entry			✓		
	Information exchange	✓				
	Internal supply chain			✓		
Niazkhani et al., 2010	Prescribing	Too task oriented				
	Communication of order					
	Dispensing					
	Administration					
	Monitoring					
Halbesleben et al., 2008	Policies/Law/Regulations	Simple list of causing actors				
	Protocols					
	Process/Design/Flow					
	Technology					
	People					
Abstract						
Bargren & Lu, 2009	Technical gap	✓	✓			
	Human interaction gap			✓		
	Content workflow gap					
Koppel et al., 2009	Technology	✓	✓			
	Task			✓		
	Organizational				✓	✓
	Patient related				✓	
	Environmental				✓	

(Rams, n.d.; Shneiderman, 1998). The information and functions provided to the user should be relevant to the user's task and context. Third, efficiency encourages users' continuous progress in knowledge and skill (Nielsen & Levy, 1994; Tognazzini, 2003). It allows experienced users to work more quickly by customization or modifying of frequent procedures. Fourth, consistency follows appropriate standards or conventions for the system platform (Nielsen & Levy, 1994; Norman, 2002; Tognazzini, 2003). Actions, terminology, and commands should be used consistently, and information needs to be presented in a natural and logical order. Fifth, communication and feedback sequentially organizes the groups of processes so that users recognize the results of actions and what is going on with the system (Nielsen, 1994; Norman, 2002). Concise and focused help and documentation in the system support the user's task. Sixth, error prevention and handling includes the functions of forgiveness, error recovery, "undo," and "redo" (Nielsen & Levy, 1994; Norman, 2002). Forgiveness allows reasonable variations in input. Error recovery offers clear, plain-language messages about an error or a mistake on system use and suggests a solution. Finally, supportive automation and less memory load reduce the user's workload (Nielsen, 1994; Rams, n.d.). Supportive automation makes the user's work faster, simpler, and easier. Information and data in a brief, combined, and summarized form allow recognition rather than recall.

User Reluctance and Negligence issues underline the importance of users' understanding of system procedures and guidelines. To solve the issues in the lack of user awareness, training can be a principal solution. Although the improved care quality by the systems is mainly advantageous to patients, productivity or efficiency of the system is associated with nurses or other care practitioners who operate the system (Carayon et al., 2011; Lee & Duffy, 2009). Training also requires acknowledging the different characteristics of tasks that system users perform. In case of the medication administration process in the BCMA system, nurses' tasks can be divided into two different types. On one hand, most of preparation and follow-up tasks consist of simple tasks in straightforward sequence such as obtaining medications or bring medications to patients. On the other hand, scanning and matching tasks contain cognitive activities such as comparing, choosing, or analyzing. This may be one potential reason that scanning and matching tasks have more diverse causes of noncompliance behaviors than preparation and follow-up tasks. Thus, training should be designed to incorporate the unique user-beneficiary structure and to be tailored to support the different kinds of tasks in order to reduce noncompliance behaviors. Finally, poor system operating environments is another area that needs to be addressed to prevent noncompliance behaviors. System operating environments include not only uncontrollable environmental issues such as noise, lack of space, interruptions, and emergency situations but also controllable issues such as lack of workstations, poor wristband designs, and inaccessibility to bar codes. Unlike these uncontrollable environmental issues, simple fixes on controllable issues can significantly reduce the chances for noncompliance. Such uncontrollable environmental issues impede smooth transfer of the information from medications and patients. Furthermore, incorrect and missing information is easily ended in blocks to further work process (Halbesleben et al., 2008). Although we cannot prevent uncontrollable environmental issues, we may prevent controllable issues by applying participatory ergonomics to redesign the operating environment. Participatory ergonomics involve the main worker—nurses, in our case—in the design process so that the system can improve workers' efficiency and productivity. Implementing participatory ergonomics teams in hospitals can improve work efficiency and safety measures in the long run (Rivilis et al., 2008). Using participatory ergonomics, the BCMA system can rearrange its physical components and update user interface to prevent nurses from skipping necessary steps.

5.3. Relative Importance of Categories

Because our study is based on qualitative research method, the significance of the categories cannot be judged by the number of samples of noncompliance behaviors. Instead, we determine the relative importance among the categories by the availability of the possible solutions. The categories can be grouped into user oriented and system oriented. A user-oriented category is User Reluctance and Negligence, and this issue can be relatively easily solved by user training programs. As system-oriented categories, the issues of Poor Visual and Audio Interface and Poor Information Integrity can be solved by software modification approach such as interface redesign or communication protocol adjustment. The issues of Poor Physical Ergonomic Design can be fixed by the alteration of hardware specification, which is quite challenging in existing systems. Finally, Abnormal Situation for System Use issues can be amended by revamping whole system function and developing new task scenarios. Practically, it is not possible to include all uncontrollable and atypical situations of system use. Thus, based on the availability of the solutions, the issues of the user-oriented category are easier to solve than those of the system oriented, and the issues of Poor Visual and Audio Interface and Poor Information Integrity need relatively fewer efforts and costs than those of Poor Physical Ergonomic Design. The most problematic category is Abnormal Situation for System Use.

5.4. Challenges in Categorizing the Quotes of Noncompliance Behaviors

It is innately challenging to develop a comprehensive and mutually exclusive set of categories from diverse causes of noncompliance behaviors collected from diverse sources. We found that some causes do not fit into our five categories due to insufficient information. In addition, we struggled to settle the final five categories in order to provide more succinct and comprehensive categories for noncompliance behaviors.

There are three miscellaneous categories that are not matched to our codification criteria. First, we ruled out the causes that are insufficiently described. Because they are unable to specify the underlying causes of any noncompliance behaviors, it was difficult to assign them into certain categories. For example, one study roughly mentioned inconvenience of using a system for checking patient and medication information as the cause of noncompliance behaviors (van Onzenoort et al., 2008). Another study (van Onzenoort et al., 2008) showed that it is difficult to identify the specific causes of bar code scanning malfunctions in BCMA systems. Simply, a shortage of time and faulty equipment are discussed as the causes, but they seem to be too broad to determine the kind of problem (Morriss et al., 2009; Agrawal & Glasser, 2009). In addition, some studies argued the noncompliance behaviors as the causes. Missing the scan of patient identification bar codes and exceeding preset medication administration time are consequences of the causes, not causes themselves (Carayon et al., 2007). Thus, we ruled them out from our classification.

Second, we excluded the causes of overall inefficiency because they were a higher or broader level of problems than other categories we defined. For example, the delay in response from the BCMA system is grouped in this category, but this issue is also overlapped with Poor Visual and Audio Interface or Poor Physical Ergonomic Design (Yang et al., 2012). User perception issues such as dissatisfaction with the system and incompatibility of the system with actual workflow can be examples as well (Peace, 2011). We also considered workload issues and mismatched practice problems as separate categories, but we discarded them because these issues are commonly triggered by most of the causes of noncompliance behaviors. In addition, a lower and too detailed level was not included in our categories. For example, patient-related causes such as patient disturbance to the BCMA procedure (Patterson et al., 2002) or bar code contamination by patient (Patterson et al., 2002) were considered as a category, but we merged them into the Abnormal Situation for System Use category.

Third, some hardware function issues and accessory components issues are not included in our categories. Some nurses complained about the malfunction of scanners, reluctance to charge or replace batteries, and poor wireless connection (Koppel et al., 2008; Yang et al., 2012; McNulty et al., 2009; Peace, 2011; Lawler et al., 2011; Carayon et al., 2007). These issues directly cause noncompliance behaviors because further BCMA system processes cannot proceed with them. However, we consider these issues extraordinary cases that cannot occur in a normal work condition. Thus, we excluded them as simply miscellaneous issues.

5.5. Contribution and Limitation

We believe that this study contributes to HIS engineering domains. We discovered the diverse patterns of causes of noncompliance behaviors in the HIS. Previous research tends to focus specifically on work processes of care practitioners or broadly on concepts of the HIS. Thus, they defined the cause of noncompliance behaviors by taking a microscopic or abstract approach. However, we highlight the structural aspects of the HIS. Our five categories of the causes capture from interactions with the peripheral systems and environments as well as with the system structure itself. For this reason, our approach to categorize the causes of noncompliance behaviors is applicable to other HIS. This application could be able to provide a system-oriented view of noncompliance behaviors in HIS. Using these categories, it would be useful and meaningful to understand what type of system structure-based causes of noncompliance behaviors is in other HIS, such as CPOE systems or electronic prescribing systems.

Along with this contribution, there are some limitations in this study. We conducted this study with an assumption that noncompliance behaviors negatively affect work performance. However, some studies argue that noncompliance behaviors have positive aspects, such as improving work efficiency, providing alternative solutions in emergencies, and decreasing workloads (Ash et al., 2004; Lalley & Malloch, 2010). Although there may be positive outcomes, each occurrence of noncompliance behaviors indicates that users encounter unnecessary problems. Thus, noncompliance behaviors should be systematically captured to improve the quality of HIS regardless of their outcomes.

Another potential concern about this study is that some causes of noncompliance behaviors are difficult to uncover. Even though we reviewed relevant literature in a limited time range, the causes are not fully described or do not meet our codification criteria depending on the authors' scope and methodologies that were applied to previous studies. For this reason, the codification process with limited resources was inevitable. We believe that the results of this study are helpful in understanding system structure-based causes of noncompliance behaviors in HIS. Before applying and generalizing the five categories to other HIS, empirical evaluations must be studied.

6. CONCLUSIONS

In this study, we comprehensively investigated the causes of noncompliance behaviors in HIS, specifically the BCMA system. We found patterns of causes of noncompliance behaviors in the BCMA system from the existing literature reviewed.

The causes that disrupt interactions between users and the system are grouped into the five categories: Poor Visual and Audio Interface, Poor Physical Ergonomic Design, Poor Information Integrity, Abnormal Situation for System Use, and User Reluctance and Negligence. One of key lessons we learned while categorizing underlying issues is that the noncompliance behaviors in the BCMA system are caused by various reasons. More explicitly, many of them cannot be easily resolved by individual users (e.g., nurses and pharmacists). Even though the required behaviors of using the BCMA system are deceptively simple (e.g., scanning bar codes on medications and the associated patient before medication), many systematic and environmental supports should be provided to the users in order for the users to accomplish the simple behaviors.

Therefore, it is strongly recommended to approach this problem from an ecological perspective, rather than focusing on individual problems. If the administrators in a hospital look only at a summarized number of compliance ratio (i.e., what percentage of the medication was administrated with bar code scanning) and believe that scanning bar codes is a simple behavior, it is easy to blame the users of the BCMA system. In addition, people simply focus on educating and training the users in order to resolve the issues. However, according to this study, it is not a simple issue of an individual user. The BCMA system is tightly linked with other HIS, and surrounding environments are very influencing. The ones who would like to solve this problem should be aware that this is a complex problem, though the surface behaviors of scanning bar codes are deceptively simple.

In addition, we believe that these categories are meaningful in understanding types of system structure-based causes of noncompliance behaviors in other HIS. Although we have not thoroughly investigated whether these categories could be applicable to noncompliance behaviors in other HIS, we believe that the causes are not unique to the BCMA systems. Environmental factors are common to all other HIS and they are highly interlinked in a whole system. Thus, it would be interesting future research to investigate how well these five categories could be extended to other types of noncompliance behaviors.

Certainly, simply having the five categories is far from our lofty goal of providing solutions to prevent noncompliance behaviors in HIS. However, these categories can be an initial step in this direction. We believe that these five categories better describe the ways in which noncompliance behaviors occur while providing more useful common factors for further discussion and application in the research of noncompliance behaviors. Furthermore, we believe that the results of this study provide further knowledge to reduce barriers between users and HIS.

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APPENDIX A

TABLE A1
Codes and Their Definitions

Code	Category	Definition
1	Poor Visual and Audio Interface	Problems from suboptimal user interfaces used in the BCMA system
2	Poor Physical Ergonomic Design	Problems due to incompatible designs of hardware
3	Poor Information Integrity	Problems caused by poor information transfer or incorrect and/or missing information
4	Abnormal Situation for System Use	Problems due to uncontrollable or unpredictable situation occurred to the BCMA system users
5	User Reluctance and Negligence	Problems due to unclear understandings of work procedures or the underestimation of associated risks
Miscellaneous categories		
6	Insufficient Description	Unable to specify what the underlying causes of any non-compliance behaviors or make it possible to assign them into several categories
7	Overall Inefficiency	Higher or broader level than other categories we defined
8	Hardware Function and Accessory Component Issues	Malfunctions of components and accessory problems

Note. BCMA = Bar Code Medication Administration.

APPENDIX B

TABLE B1
Codification Results for the Causes of Noncompliance

No.	Quote	Reference	Page	Code
1	Finding medication information, orders on eMAR, or completing administration may necessitate clicking on multiple screens, especially if user needs to change medication order, etc. User may perceive time requirements onerous. One or more screens might not be allowed (e.g., required field grayed out).	Koppel et al., 2008	413	1
2	Scanners may emit beeps for each completed function, or beeps for acceptable vs. wrong scans may be confused or ignored.	Koppel et al., 2008	413	
3	Users do not know how to retrieve information, e.g., allergies, and parameters for administration.	Koppel et al., 2008	413	
4	How system limitations in how much information can be entered into a text field led physicians to enter additional discharge notes in a text field dedicated to dietary information because the diet field was not limited in text capacity.	Ash et al., 2004	195	
5	Some older staff members might not be able to see the screen. It's too small because when we actually see it from the COW it's much clearer. The font size is too small.	Yang et al., 2012	52	
6	It's a little bit tedious in the sense that you need to scroll the long list of medication and you need to go back to another screen to click medication that you want to serve. Click and scroll, click and scroll.	Yang et al., 2012	52	
7	The reliance of the physician on BCMA to communicate a new, high-priority order for imminent administration could be viewed as a poor strategy, even though there was no adverse outcome due to the nurse's anticipation of the order, because the software was not designed to actively highlight priority or new medication orders	Patterson et al., 2002	547	
8	In addition, the difficulty in correcting the difference between the actual and documented medication administration time could enable physicians, pharmacists, or other nurses to make incorrect inferences based on the data.	Patterson et al., 2002	547	
9	For example, a nurse on the next shift could delay medication administration. Similarly, the inability to document administration of medications not displayed creates the potential for coordination breakdowns between multiple nurses and physicians.	Patterson et al., 2002	547	
10	Although a taper order is a specific example of an issue that can be resolved through software enhancements, it illustrates the observed pattern of decreased flexibility when machine algorithms critique human actions, because the "vocabulary" used in communicating with a machine is restricted.	Patterson et al., 2002	550	
11	The handheld device screen alignment was a problem in two observations.	Carayon et al., 2007	38	

(*Continued*)

TABLE B1
(Continued)

No.	Quote	Reference	Page	Code
12	COW does not fit into patients' rooms. Computers remain plugged into hall outlets, and cannot be moved near patients' beds. Also, reluctance to carry scanning equipment back and forth from storage areas to patient rooms.	Koppel et al., 2008	413	2
13	The PDA is useful because you can scan the nametag but the sensor isn't very good.	Yang et al., 2012	52	
14	In addition, nurses uniformly believed that typing in a 7-digit number took less time than wheeling a large medication cart into a room and scanning a wristband.	Patterson et al., 2002	548	2
15	Inaccessible or inconveniently located hardware is a common cause of work-arounds.	Peace, 2011	318	
16	Other work-arounds related to hardware problems include those related to mobile workstations that are too heavy, bulky, or unwieldy to take into patient rooms	Peace, 2011	319	
17	Workstations placed in inconvenient locations	Peace, 2011	319	
18	Task-related causes of workarounds identified by nurses in the study included bar code scanning failures on certain medication packages such as ointments and eye drops and labels that were damaged or compromised.	Rack et al., 2012	237	
19	The medication cart size and drawer configuration varied based on unit type: medical and surgical units typically had 10 to 12 drawers per cart, critical care and ER typically had two to four drawers per cart and behavioral health had 24 to 36 drawers per cart.	Agrawal & Glasser, 2009	28	
20	Accommodating physical limitation of a COW	Lawler et al., 2011	341	
21	Nurses would usually plugin laptops rather than rely on batteries, adding an extra step to move a medication cart of changing electrical outlets.	Patterson et al., 2006	18	
22	Less than a full dose is available when nurse administers medications, or syringe/medication tablet contains more than the ordered dose. Nurse must alter the automatic documented administration that is based on the dose on the scanned barcode.	Koppel et al., 2008	414	3
23	Unfamiliar with variation from common procedure, e.g., barcode inside different package, medication packaging has multiple barcodes, medications from patient's home without barcodes.	Koppel et al., 2008	413	
24	Medications or medications' identifying numbers are not yet cataloged in the hospital computer formulary, or a unique barcode has not been created by the hospital as the medication is not expected to be prescribed. Therefore, medication does not have a readable barcode.	Koppel et al., 2008	414	

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TABLE B1
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No.	Quote	Reference	Page	Code
25	The medication order is not in the eMAR (often orders that are stat, verbal, or not yet entered by pharmacy), and thus not in the eMAR. Nurse, however, desires to administer medication promptly.	Koppel et al., 2008	414	
26	Barcodes often crinkled, smudged, torn, missing, or covered by another label—the latter reminding staff to scan barcode. Some medications are patients' own from home without barcodes.	Koppel et al., 2008	414	
27	Size of tablet or syringe stocked by hospital is larger than needed for typical medication order (e.g., morphine 10-mg syringes stocked, and typical dose is 2 mg). Also, information on medications may not yet be programmed into system. (This differs from no. 13, above, because it reflects hospital buying/stocking policies and programming workflow, rather than difficulty with an individual order.)	Koppel et al., 2008	414	
28	Medication was administered without being scanned and the packaging was discarded, preventing confirmation scan.	Koppel et al., 2008	414	
29	When using a COW for administration, medications requiring refrigeration are not on cart. Medication barcode scanning requires carrying medication package to scanner, scanning medication, returning remaining medication to refrigerator (e.g., insulin vial), and then back to patient to administer.	Koppel et al., 2008	415	
30	Nurses believe pharmacy should create orders for medications in BCMA systems when needed order is not available, should prepare medications for scanning, and should provide the exact medication dose needed for the order to avoid multiple scans for same operation.	Koppel et al., 2008	415	
31	Patient ID band torn, wet, chewed, or not on patient. Patient's ID band is covered (e.g., covered with sterile dressing for procedure or by blankets) and cannot be easily accessed.	Koppel et al., 2008	415	
32	Patients' wristbands are cut, smudged, chewed, deteriorated by fluids, never provided, or removed. Also, patient has non-valid ID wristband barcode from prior admission or from another hospital within the same health care system.	Koppel et al., 2008	414	
33	Sometimes during input of orders, certain columns need to be filled before EMAS can recognize the orders. That is a problem we have because in paper IMR we will just write 'N.A' and just skip, but sometimes when it's not applicable EMAS will still want us to fill in the columns.	Yang et al., 2012	54	

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TABLE B1
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No.	Quote	Reference	Page	Code
34	EMAS recommends dosage depending on medication selected however physicians may need to make adjustments due to patient demographic.	Yang et al., 2012	54	
35	The way of giving intravenous medicine is different from the way portrayed in the computer. This is because certain kids we cannot give too much water, but for computer it's already fixed to give that amount so we can't change that so we verbally tell each other to not give that kind of fluids.	Yang et al., 2012	55	
36	The nurse, anticipating that these medications would be ordered, looked in BCMA but found no cardiac medications (note that pending and discontinued medications are not displayed). He then looked in the order entry system and found two "pending" medications. The nurse borrowed and administered one of the two medications (taken from another patient's medication drawer) and waited for a less critical medication to arrive from pharmacy.	Patterson et al., 2002	546	
37	When there was difficulty in documenting information, either because the automatically generated data was incorrect or because medications were not displayed, the nurses moved on rather than take the time to ensure accurate documentation at that moment.	Patterson et al., 2002	547	
38	Degraded coordination between nurses and physicians can lead to predictable new paths to adverse events, including failing to detect erroneous medication orders, verifications, or administrations, failing to renew automatically discontinued medications, failing to prioritize a STAT medication order over other activities, or failing to explain why laboratory values are unusually high or low for an at-risk patient.	Patterson et al., 2002	547	
39	User log-in ID not functioning	Bargren and Lu, 2009	364	3
40	Electronic due time for medication entered incorrectly or follows a preexisting dose times in BCMA system set by pharmacy	Bargren and Lu, 2009	364	
41	Medication bar code cannot be scanned	Bargren and Lu, 2009	364	
42	Many reasons were discovered for not scanning medications before each administration, most related to the labeling technology and processes for overcoming glitches.	McNulty et al., 2009	31	
43	BCMA work-arounds may also be related to problems with environmental factors (e.g., the medication bar code is in a location inaccessible to the scanner, such as a refrigerator).	Peace, 2011	318	

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No.	Quote	Reference	Page	Code
44	To address the issue of UD bar coding, in 2006, the FDA-mandated drug manufacturers to include a bar code label on drug packages. However, it has only partially addressed the issue because the FDA's standard 10-digit National Drug Code code is not always the same as the UD bar code.	Agrawal & Glasser, 2009	26	
45	About 10 percent of KCHC's formulary is only available in bulk, and is repackaged by an automated robot into UD form with a barcode.	Agrawal & Glasser, 2009	27	
46	In-pharmacy intravenous mixing requires customized barcode labels based on compound mixtures, and are generated at the time of mixing. Ointments and liquids also require special considerations, as they are not typically in UD packages. Nurses need to retain the box packaging of the ointment or liquid to scan at administration time.	Agrawal & Glasser, 2009	27	
47	Continuous updating of medication configuration is necessary. We estimated that about 225 new product IDs need to be configured monthly.	Agrawal & Glasser, 2009	27	
48	Attention must be paid to the process of reprinting of wristbands, in the event that a wristband is lost or damaged. After considering the pros and cons, we determined that calling on admitting to re-print wristbands in these instances was not practical and would delay medication administration.	Agrawal & Glasser, 2009	28	
49	Missing of medication barcode to scan	Lawler et al., 2011	341	
50	Medication not in the formulary	Lawler et al., 2011	341	
51	Medication or wristband barcode integrity compromised (smudged, wrinkled, faded)	Lawler et al., 2011	341	
52	Lack or incorrect barcode on medication or wristband	Lawler et al., 2011	341	
53	Wristbands that were worn longer were less reliable to scan because they were dirtier; they were more likely to be twisted, torn, or removed by the patients and their ink quality had been affected by more patient baths.	Patterson et al., 2006	18	
54	The medication was nonformulary; therefore, the bar code had not been entered into database.	Carayon et al., 2007	37	3
55	At least 1 medication being administered was given "nonbarcoded," meaning that a medication bar code was not scanned or able to be scanned for correct medication verification before administration.	Carayon et al., 2007	37	
56	The available dose of the as needed medication was higher than what was ordered, and the nurse proceeded to give the dose.	Carayon et al., 2007	37	

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TABLE B1
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No.	Quote	Reference	Page	Code
57	Another potentially unsafe act occurred when a nurse intended to administer a medication dose despite an alarm sounding that indicated that the total dose scanned for 2 tablets exceeded the ordered dose.	Carayon et al., 2007	37	
58	Another issue included the following: not recognizing the nurse ID badge during the first scanning attempt.	Carayon et al., 2007	38	
59	Physician not available for clarification	Halbesleben et al., 2010	129	
60	Waiting pharmacy to deliver order	Halbesleben et al., 2010	129	
61	Medication is not where expectation, not in drawer or not in Pyxis.	Halbesleben et al., 2010	129	
62	BCMA use may slow rapid medication administration in emergency situations, especially when equipment faulty (e.g., battery dies, screen out of alignment). Also, with patients in contact isolation for infection control, bringing scanning equipment into room without covering it would contaminate it and a plastic bag cover may interfere with scanning.	Koppel et al., 2008	415	4
63	Nurses rush to complete tasks or omit steps because of insufficient staffing for patient care needs. (Stated justification for not having time to scan patients or medications.)	Koppel et al., 2008	415	
64	Noise in hallway or patient room (e.g., intensive care unit monitors, loud talking, patient distress noise) prevents nurse hearing scanner alarms.	Koppel et al., 2008	416	
65	Patient in operating room or radiology: Patient in area that does not allow BCMA use.	Koppel et al., 2008	416	
66	Patient does not accept scanning (e.g., combative, too agitated), or the patient is engaged in an activity that makes it difficult (e.g., central line being inserted, showering, breastfeeding). Scanning or administration would disturb patient (e.g., one who is asleep). Also, patient may vomit or refuse medication after administration documented.	Koppel et al., 2008	415	
67	Because it's an emergency case, we had to give [the medicine] first before [the physician] order in the system.	Yang et al., 2012	55	
68	Obvious factors include that wristband barcodes did not scan as reliably as medication bar- codes and that wristbands could not be scanned in some cases (e.g., isolation patients, patients who removed wristbands because of swollen limbs or discomfort, particularly in long-term care).	Patterson et al., 2002	548	4
69	Wristband barcodes did not scan as reliably as medication bar- codes and that wristbands could not be scanned in some cases (e.g., isolation patients, patients who removed wristbands because of swollen limbs or discomfort, particularly in long-term care).	Patterson et al., 2002	548	

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No.	Quote	Reference	Page	Code
70	Most nurses tried to avoid disturbing sleeping patients, particularly if they anticipated that a patient had no oral medications during the medication pass.	Patterson et al., 2002	549	
71	They tried to minimize interrupting discussions between patients, family, and health care practitioners.	Patterson et al., 2002	549	
72	Baby ID bands often difficult to scan due to size/curvature.	Bargren and Lu, 2009	364	
73	ID band difficult to access or do not wish to awaken patient to scan ID band.	Bargren and Lu, 2009	364	
74	Nurses drop activities to reduce workload during busy periods.	Bargren and Lu, 2009	364	
75	Such work-arounds are created because bar codes on patient wristbands are often inaccessible or unreadable because of position, dressings, or damage	Peace, 2011	318	
76	Insufficient numbers of workstations	Peace, 2011	319	
77	For example, staff may not scan because patients were not wearing a wristband due to patient self-removal or a wristband not fitting the patient's limb because of casts or bandaging.	Rack et al., 2012	237	
78	An example is when an acutely ill patient is involved and the bar code on his wristband does not scan. In such a situation, she said, a nurse would not want to jeopardize patient care while waiting 15 minutes for a new wristband to be delivered.	Vecchione, 2005	2	
79	In addition, for new admissions who arrive in a very unstable condition, nurses don't have to wait around for the wristband to provide care. In that case, a nurse is able to identify the patient by typing in the account number and other identifier checks such as name and birth date until the wristband arrives.	Vecchione, 2005	2	
80	The pediatric bar coded wristbands were too big for the infants in the neonatal ICU and would fall off. To accommodate, we secured the bar coded wristband to the baby's incubator, which would be scanned at the time of drug administration.	Agrawal & Glasser, 2009	28	
81	Environment unsupportive of BCMA, e.g., a patient in isolation; lack of access to patient wrist and not wanting to disrupt patient	Lawler et al., 2011	341	
82	The interruptions noted are exclusive of the aforementioned automation surprises and alarms.	Carayon et al., 2007	38	
83	Interruption while charting	Halbesleben et al., 2010	129	4
84	Pharmacy paperwork requirements during codes	Halbesleben et al., 2010	129	

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TABLE B1
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No.	Quote	Reference	Page	Code
85	Users fail to perform required safety checks because they rely on technology, e.g., they do not perform a visual check of the patient's ID band or of medication name and dose.	Koppel et al., 2008	413	5
86	User's BCMA training inadequate, e.g., users do not know: (1) which of several barcodes on medications to scan, (2) which screens have needed information, (3) computer confirmation procedures, or (4) how to respond to allergy notification.	Koppel et al., 2008	415	
87	Unaware that scanning of patients and medication barcodes affords added safety benefits beyond human checks.	Koppel et al., 2008	415	
88	Users not aware of hospital medication use policies, e.g., double-check of high-risk medications, barcoding of patient medications brought from home. Problem associated with high turnover of providers, use of traveler and agency nurses, and RN transfers among units.	Koppel et al., 2008	415	
89	When a new healthcare information system is implemented, users may encounter hindrances in workflow caused by various reasons such as inefficient process design, poor system usability, inadequate user training.	Yang et al., 2012	43	
90	There are a lot of times we get held back because the nurses will say that somebody accidentally signed on their dose or rather they missed their dosage then they sign on the next dose. So in the end we have to write a stat dose for them to sign.	Yang et al., 2012	55	
91	A lack of awareness among nurses regarding medication safety could contribute to a low percentage of bar-code verification.	van Onzenoort et al., 2008	646	
92	Clinicians do not know how to retrieve information (allergies, administration parameters, etc.) or are unaware that it is there, so a combination of screen redesign and additional training was required.	McNulty et al., 2009	31	
93	The nurses tended to be more familiar with the patients in long-term care, so the risk of patient misidentification was judged to be less.	Patterson et al., 2006	18	
94	May be due to barcode, scanning technique, or technology capabilities. User uncertain whether there is barcode confirmation.	Koppel et al., 2008	413	6
95	BCMA system times out a user after a preset number of minutes because user has not confirmed medication administration.	Koppel et al., 2008	413	

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No.	Quote	Reference	Page	Code
96	Users report the barcode will not scan without specifying whether difficulty is with the barcode, scanner, or other BCMA function.	Koppel et al., 2008	413	
97	Sometimes nurses choose the easy way out instead of scanning the patient they scan the clinical board. However the nurse then went to the wrong bed and caused a medication error.	Yang et al., 2012	55	6
98	Sometimes we have this medicine that should be served before meals but doctor order [to be served at] 8 pm. So what we do is that we will serve before meal but justify it accordingly as an early serving. The physician should change the timing though.	Yang et al., 2012	55	
99	The five most cited reasons for not verifying bar codes were (1) difficulties in scanning bar codes on the medication labels, (2) lack of awareness of bar codes on medication labels, (3) delays in responses from the computerized system, (4) shortage of time, and (5) administration of medication before prescription.	van Onzenoort et al., 2008	646	
100	BCMA system downtime	Bargren and Lu, 2009	364	
101	Almost one half of the nurses were aware that workarounds occurred with the BCMA system, and narrative responses suggested that these were initially prompted by "faulty equipment."	Morriss et al., 2009	139	
102	When asked to describe factors that limited the impact of the BCMA system effectiveness, responses included "technical problems," including bar codes that did not scan and reliability of the computer equipment, as well as medication administration scheduling control by the clinical pharmacists who entered those data into the system.	Morriss et al., 2009	138	
103	The wristband and bar codes are subject to water damage, soiling, stretching and must be deleted carefully to minimize the need for replacement. To evaluate durability, several members of the steering committee wore different wristbands for one week, before finalizing the selection.	Agrawal & Glasser, 2009	27	
104	Time constraints and meeting preset administration time	Lawler et al., 2011	341	
105	Lack of barcode to scan	Lawler et al., 2011	341	
106	Nurse was unable to scan the barcode on the package (insulin and eye drops in particular)	Carayon et al., 2007	37	
107	The RN disabled the audio alarms on the handheld device. The causes of the alarm were noted in 11 instances and included the following: wrong dose scanned, double check required, disabled order, bar code not readable because of nonformulary medication, checking icon for information before administration, missing medication, and request to create new order because of lack of a current order for a scanned medication.	Carayon et al., 2007	38	
108	Unable to understand order.	Halbesleben et al., 2010	129	

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TABLE B1
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No.	Quote	Reference	Page	Code
109	Conflict between workflow efficiency and proper/safe BCMA use, e.g., extra time to scan medications or to return to supply room for each patient's medications or to retrieve scanning equipment that works. Also, emergency medication administration may be viewed as superseding scanning protocol.	Koppel et al., 2008	414	7
110	User dissatisfied with BCMA: Users know how to use BCMA systems but find them slow or cumbersome. Often this response reflects negative views of the software design.	Koppel et al., 2008	413	
111	There were cases where nurses pick a medication and they key in their colleague's password to co-sign the medicine. By doing so, integrity is compromised.	Yang et al., 2012	55	
112	BCMA work-arounds may also be related to problems with task (e.g., the BCMA scanning procedure is slower or more cumbersome than other methods).	Peace, 2011	318	
113	BCMA work-arounds may also be related to problems with organizational factors (e.g., BCMA procedures are not compatible with workflow).	Peace, 2011	318	
114	Six of the scenarios described by staff nurses in which there was a need to administer medications without scanning the bar code related to the process being "too time consuming."	Rack et al., 2012	237	
115	We observed 7 nurses in acute care and 7 nurses in long-term care bypass the approved procedure by typing in the Social Security number. We observed 5 nurses in long-term care scan surrogate wristbands not located on the patient's wrist. Interview data indicate that all the observed nurses believed both workaround strategies to be more efficient than scanning the patient's wristband.	Patterson et al., 2006	17	
116	Most BCMA systems are linked to the eMAR on hospital's server. Lost connection—wireless or corded—prevents scanning.	Koppel et al., 2008	413	8
117	Batteries fail on handheld devices or computer carts. Experience with some batteries failing leads to charging batteries continually, leading to batteries failing more quickly. This led to replacement of batteries in all machines in all hospitals of one system.	Koppel et al., 2008	413	
118	Wireless connectivity loss: Location does not allow appropriate BCMA use.	Koppel et al., 2008	416	

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TABLE B1
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No.	Quote	Reference	Page	Code
119	For the COW sometimes you can push it to the patient but sometimes it's so slow so usually we have leave the COW outside because of poor wireless connectivity.	Yang et al., 2012	54	
120	For the COW sometimes you can push it to the patient but sometimes it's so slow so usually we have leave the COW outside because half of the time we need to charge batteries	Yang et al., 2012	54	
121	Connectivity with the hospital server is lost during scanning	McNulty et al., 2009	32	
122	BCMA work-arounds may also be related to problems with hardware (e.g., multiple scanning attempts are needed to read the bar code).	Peace, 2011	318	
123	Battery failures on mobile units	Peace, 2011	319	8
124	Malfunctioning medication carts, computers and/or scanners can create unsafe workarounds, e.g., not scanning medications at the POC, and delays in timely medication administration, and documentation.	Agrawal & Glasser, 2009	27	
125	Technical issues such as battery life and failure, handheld scanner freezing and connectivity issues with eMAR.	Lawler et al., 2011	341	
126	The "hallway scanning" occurred after a failed attempt at scanning the ID band on the patient because of a technology failure.	Carayon et al., 2007	37	
127	During five of the observations, the handheld device either froze or would not associate with the wireless network; it timed out before the task was complete.	Carayon et al., 2007	37	
128	One nurse commented that the reliability of the handheld devices was poor and that sometimes there only two working scanners for four nurses. Another commented that the device timed out too quickly during administration	Carayon et al., 2007	39	

Note. eMAR = Electronic Medical Administration Record; COW = Cart On Wheels; BCMA = Bar Code Medication Administration; EMAS = Electronic Medication Administration System; IMR = Inpatient Medication Records; STAT = *statum* (Latin, meaning 'immediately'); UD = unit dose; FDA = Food and Drug Administration; KCHC = King County Hospital Center; POC = Point Of Care.