Evaluation of Nurse Interaction With Bar Code Medication Administration Technology in the Work Environment

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Objectives: This study explores nurses' use of bar code medication administration (BCMA) technology from a human factors viewpoint. The BCMA technology consists of a medication network server and handheld devices that connect to medication administration record data through wireless radiofrequency link.

Methods: A total of 62 observations of medication administration were conducted in 1 academic hospital. Observations were performed by a team of 2 people (a human factors engineer and a pharmacist) in a variety of critical care and medical/surgical units. Data were recorded on the medication administration task, the BCMA technology, organizational factors (in particular interruptions), the physical environment, and various individual factors related to the nurses and patients.

Results: Eighteen different sequences were identified and represented very large variability in the order in which steps of the medication administration process are performed; some of the sequences can be considered as potentially unsafe acts. We identified various working conditions that can hinder the medication administration process. For example, 20 instances of interruptions were observed. Some patient factors (e.g., isolation patients) were also identified that made the BCMA-based medication administration process challenging.

Conclusions: When introducing a new technology into the health care environment, it is important to assess changes in workflow and tasks that may result from the use of the technology. Our study shows the use of direct observation in helping to identify the work system factors that facilitate or hinder the medication administration tasks. This information can help health care organizations identify opportunities to redesign the process and/or the technology to maximize worker efficiency, interaction with the technology, and patient safety.

Key Words: bar code medication administration, human factors engineering, observation, nurse, patient safety

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Bar code medication administration (BCMA) technology is being implemented slowly across hospitals in the United States. A national survey of pharmacy practice in hospital settings by the American Society of Health-System Pharmacists found that bar code technology use only increased from 1.1% to 1.5% of hospitals from 1999 to 2002, although 43% of hospitals were considering its implementation.[1] A similar survey performed by the Wisconsin Patient Safety Institute found that 2.6% of Wisconsin hospitals in 2002 had fully implemented bar code technology (compared with 1.4% in 2000), 53% were planning to implement, and 40% had decided not to implement the technology.[2] One of the Joint Commission on Accreditation of Healthcare Organizations' National Patient Safety Goals for 2005 clearly highlighted the need for technology such as BCMA to help with "patient identification (ID) and reporting the medications used accurately."[3] Specifically, bar code technology can ensure that the right medication and dose are administered to the right patient at the right time while easily documenting the administration details.[4] Starting in 2006, the Food and Drug Administration requires bar codes on most packages of pharmaceuticals and blood products.[5] The Joint Commission on Accreditation of Healthcare Organizations has also considered requiring accredited hospitals to implement BCMA.[6] Therefore, there is a strong push from legal and accreditation bodies to encourage hospitals to implement BCMA technology.

To foster the adoption of BCMA technology, several organizations including the Institute for Safe Medication Practices, The American Society of Health-System Pharmacists, and the University HealthSystem Consortium have published white papers for health care organizations on how to assess readiness and plan for BCMA implementation.[4,7] These organizations recommend analysis of medication administration workflow and analysis of the physical environment in which the technology will be used. However, methods and approaches may not be available for hospitals to effectively perform this assessment. Hospitals also need to continue assessment of technology usage and workflow after implementation; many of the issues and workarounds associated with the use of the technology may only be apparent once the technology has been implemented. This paper presents the application of an observation method to evaluate nurses' interaction with BCMA in the work environment.

The BCMA technology is often seen as a means of reducing medication administration errors.[8] The implementation of BCMA in a 240-bed regional hospital allowed

the prevention of 1300 medications errors for a period of 8 months.[9] In 6 hospitals of a community hospital network, the implementation of BCMA led to the prevention of 187 medication errors (1.1% of medication administrations).[10] The implementation of BCMA technology in a 326-bed primary and tertiary care center was found to lower the medication error rate; improve the legibility of medication records, scheduling of medications, and communication between nursing and pharmacy staff; and increase the accuracy and timeliness of medication-related billing.[11] Misidentification of patients during the transfusion process can lead to major negative outcomes. A study of the use of bar code technology in a hematology outpatient unit led to positive results, such as simplification of the patient ID process and improvement in practice.[12] The implementation of BCMA technology in a 28-bed hematology-oncology hospital unit was followed by a decrease in medication administration errors from 9% to 1.2% as recorded by direct observation and audit.[13]

Human factors experts have warned against the belief that human errors in complex sociotechnical systems, such as health care, can be completely eliminated by automation.[14] Technologies induce changes in work and work processes that need to be understood to anticipate and avoid negative consequences, such as new errors created by the use of the new technology.[15,16] Human factors concepts and methods can help analyze technologies and anticipate changes in work and workflow.

Patterson and colleagues[15] have performed ethnographic observations to study the human factors aspects of BCMA implementation. They identified negative consequences of BCMA implementation, including nurse surprise by certain BCMA software automation features, worsening of nurse-physician communication, and decreased awareness of administered medications. Nurses also avoided activities (e.g., scanning wristbands to identify patients) to deal with heavy workload during busy periods. The researchers concluded that although BCMA technology can help prevent some errors, the consequences of BCMA may lead to new medication administration errors. On the basis of this research, they proposed 15 recommendations to support the effective use of BCMA.[17] The recommendations address the issues of implementation and continuous improvement, training, troubleshooting, contingency planning, equipment maintenance, medication administration, and wristband maintenance.

The objective of this study was to further understand nurses' use of BCMA technology, particularly from a human factors viewpoint. We developed an observation method that focused on the interaction between nurses and BCMA in situ.

METHODS

Study Design

Structured observation of the medication administration process was performed to evaluate the use of BCMA technology by nurses. Observation of the end user (nurse) interacting with a technology in the natural health care environment is an important method to understand the human-technology interaction.[18] It allows direct visualization of tasks in the context of patient care and the complex health care work environment.[19]

Study Setting

The study, approved by the institutional review board, took place at a 472-bed Midwestern academic medical center with a level-1 trauma center, busy transplant and interventional vascular services, and a 60-bed children's hospital. The hospital pharmacy department is an early adopter of technology and safe practices with robotics, unit-dose bar code dispensing, Smart intravenous pumps, and decentralized clinical pharmacists performing medication reconciliation and rounding with medical teams.

Point-of-care BCMA technology was implemented unit by unit for a 3-year period from 2001 to 2004 to improve the safety of the medication administration process. The implementation of BCMA was carefully planned with a pilot study conducted in 1 unit and pharmacy and nursing staff specifically dedicated to the implementation and during full use of BCMA.

This BCMA technology uses bar code scanning of the medication, patient, and nurse as a double check system to ensure the 5 *R*'s of medication administration: the right patient, right medication, right dose, right form, and right time. The BCMA technology consists of a medication network server and handheld devices that obtain medication administration record data through wireless radiofrequency connection. The BCMA also allows documentation of medication administration.

Data Collection Instrument

The observation data collection instrument allowed the recording of various elements of the medication administration task and the physical and social environment in which the task was performed. The work system model of Carayon and Smith[20] and Smith and Carayon-Sainfort[21] was used as the framework for developing the content of the observation form:

- Tasks: number and type of medications, sequence and duration of the medication administration process, registered nurse's (RN's) observation of patient taking medication, sanitization of hands, and occurrence of handoffs.
- Technology: automation surprises and BCMA alarms.
- Organizational factors: shift when observation took place and interruptions.
- Physical environment: unit where observation took place: lighting, noise, neatness, organization, and crowdedness of the patient room and medication room.
- Individuals: patient factors (e.g., isolation), comments of nurse and patient during medication administration relating to the medication administration process.

The duration of the observation was also recorded. Further details on the development and implementation of the observation instrument are described elsewhere.[22,23] A copy of the observation instrument can be found at: http://cqpi2.engr.wisc.edu/smarthf/tools/BCMA_observation_form.pdf.

Study Procedures

Observations were performed by a team of 2 people: a human factors engineer and a pharmacist. This combination of expertise was important to ensure adequate understanding of the following: (1) task analysis and observation (human factors engineering background) and (2) the technical content of the task being observed (pharmacy). This combination facilitated recording of observation data from the engineering point of view (human factors, interruptions, and automation surprises) and the pharmacy point of view (medications and errors).

The observers contacted the nurse at the beginning of the medication administration rounds on the respective unit, explained the purpose of the study, and obtained verbal consent to observe and record the details of the administration process. Observer interaction with the patient was limited. Upon entering the room, either the nurse or the observers gave the patient a brief explanation of the study and indicated that observers were watching the nurse administer medications for research purposes and then obtained verbal consent.

Observations were conducted at 8 AM and 10 PM when medication administrations were commonly scheduled. The observers arrived on the nursing unit 30 minutes before the medication pass was scheduled to begin because nurses could pass medications 1 hour before and after the scheduled administration time to help with workload associated with administering medications. The observation period began either when the nurse entered the medication room and logged into the bar code technology handheld device by scanning her/his badge or when she/he obtained medications. The nurse was then observed accessing the patient medication profile on the device, taking the medication from the patient-specific medication drawer(s), scanning the medication, entering the patient room, and administering the medication. The observers also noted the handheld device audible alarms. If any action by the nurse or software seemed different than expected, the nurse was asked what had happened and for her/his explanation of why it occurred. If the observers witnessed an action that would result in a medication administration error (e.g., wrong dose or wrong patient), the observer was required by the institutional review board to inform the nurse of the potential for error. The mean duration of the observation was 7.7 minutes (SD, 5.9 minutes; range, 2 to 29 minutes; median, 5 minutes).

Sample of Observations

We chose a well-accepted method, known as theoretical saturation, to determine our observation sample size.[24] Saturation in data is reached when collecting additional data would not lead to new information. The observers periodically met with study investigators to review observation data for this determination. A total of 62 observations were conducted, 28 (45%) during the first shift and 34 (55%) on the second shift. Observations were conducted on 3 adult critical care units (18 observations [29%]) and 5 adult medical/surgical units (44 observations [71%]).

Two hundred twenty-five medications were administered in the 57 observations that medication information was recorded or a medication administered (mean per observation, 3.9; SD, 3.8; range, 1 to 19). In 42 of 57 observations, at least 1 oral medication was given to the patient (range, 0 to 14 oral medications). Medications were given with a syringe in 15 observations and as an intravenous medication in 11 observations. Medications were administered through multiple routes in 19 observations, 1 route in 38 observations, and not administered or not recorded in 5 observations.

Nurse Interviews

After each observation, if not obviously hurried, nurses were asked to participate in a short interview. The intent of the interview was to gain insights from users on their perspective of both the positive and negative aspects of the BCMA technology and the impact of the technology on their work. Nineteen nurses agreed to be interviewed. Comments similar to those made during the observation were shared with the study investigators; however, further detail was generally provided.

RESULTS

Data were reviewed and analyzed by a pharmacist, a nurse, a physician, and 3 human factors engineers. The data were reported for each of the 5 elements of the work system model[20,21]: tasks (task sequences and potentially unsafe medication administrations), technology (automation surprises and alarms), organizational factors (interruptions), physical environment (patient and medication rooms), and individuals (patient factors, nurse comments, and nurse interview data).

Tasks

Task Sequences

Eighteen different sequences for medication administration were recorded for 59 observations with sequences ending with administration (see Fig. 1 for a full description of all 18 sequences). Three observations were not included because of lack of data on sequences (1 observation) or only partial sequences being documented (2 observations). In general, the first 4 (5, including double check) process steps most commonly occurred in the medication room, and the last 4 steps occurred in the patient room. The most common sequences followed the recommended procedure for administering medications and occurred in 23 observations (sequences D and J): scan self-ID→ obtain medications→ check medication versus handheld device→ scan medication bar code→ (double check by second RN, when indicated)→ enter patient room→ scan patient ID band→ give medication to patient→ document administration.

The next most common sequences (21 observations, sequences A, F, K, L, O, and R) reflect the most frequent workaround where the last 2 steps of the recommended sequence were reversed: documenting medication administration on the handheld device occurred before the medication was given to and ingested by the patient. Thirteen other sequences were observed; 11 were observed once, and 2 were observed twice (sequences C and H). Other reasons for variation in the sequence included checking the medication against the medication administration record after scanning

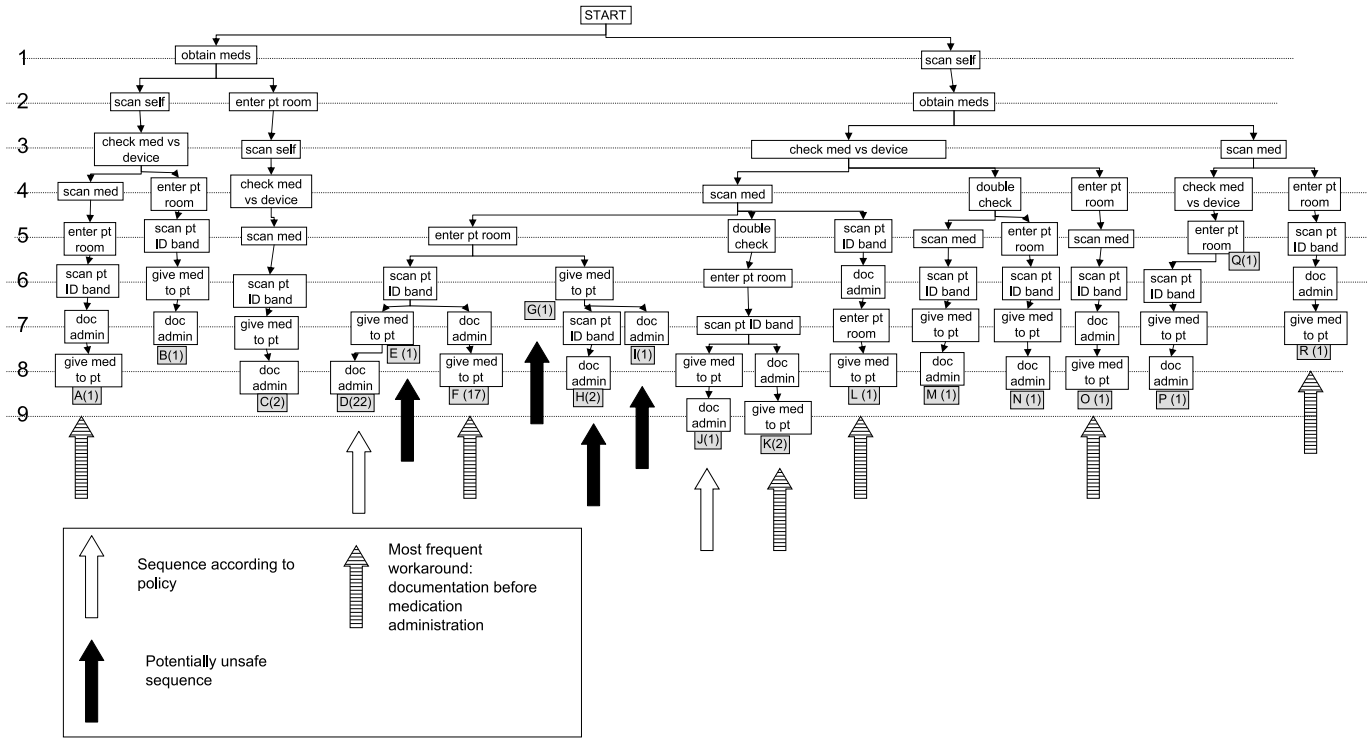

FIGURE 1. Process of medication administration—task sequences. Admin indicates administration; doc, document; med, medication; pt, patient; vs, versus.
Note: Each sequence is labeled with a letter and a number. The number indicates the number of occurences of the sequence.

the medication and obtaining the medication and entering the patient's room before scanning one's own ID.

During 21 of the observations (34%), 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. The most common reasons for not scanning a bar code included the following: (1) the medication was nonformulary; therefore, the bar code had not been entered into the database (4 observations); (2) there was no bar code on the medication (5 observations); and (3) the nurse was unable to scan the bar code on the package (insulin and eye drops in particular; 4 observations). In 2 observations, the nurse encountered a discrepancy or problem when scanning the medication. In 1 case, the medication was not in the system as ordered, and the nurse was given the option by the device to create an order and canceled the screen and gave it nonbarcoded. In the second observation, the device indicated that the tablet size scanned for the as needed medication was larger than what was ordered in the system, and the nurse proceeded to give the tablet nonbarcoded. In 6 observations, the reason was not recorded.

Potentially Unsafe Medication Administrations

Ten observations (16%) had 7 distinct actions recorded that could be considered potentially unsafe. Four of these were sequence related. In 2 observations (sequence G and I), the medication was administered to the patient without scanning the patient ID band. In 2 other observations (sequence H), the medication was administered, and the patient ID was scanned afterward. Other potentially unsafe practices included undocumented administration of the medication (sequence E and, again, G) and recording (incorrectly) that a medication was administered when it was not observed as being given during the observation. In 2 other observations, a nurse scanned a patient bar code on the patient chart outside the patient room rather than scanning the ID band on the patient. In one of these observations, the "hallway scanning" occurred after a failed attempt at scanning the ID band on the patient because of a technology failure. During another observation, the available dose of the as needed medication was higher than what was ordered, and the nurse proceeded to give the dose. Finally, 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. These unsafe acts could lead to wrong patient, wrong dose, omitted dose, and duplicate medication administration errors.

Technology

Automation Surprises

Automation surprises were operationalized as unexpected or unpredictable responses by the technology.[25] In 10 observations (16%), automation surprises were noted (Table 1). During 5 of the observations, the handheld device either froze or would not associate with the wireless network; in 2 observations, it timed out before the task was complete.

TABLE 1. Automation Surprises and Consequences

Automation Surprises	Nurse Responses	Consequences
Handheld device disconnected from network (3 observations)	Frustration	Discontinued task
	In medication room, got new device	Continued task
	In patient room, unsuccessfully tried to reset device and stopped using device	Gave medications nonbarcoded
Handheld device froze (2 observations)	Called nursing assistant from patient room to get new device	Handoff—nursing assistant scanned patient ID band for nurse
	In medication room, got new device	Continued task
Handheld device screen misalignment (2 observations)	In medication room, obtained new device which also was not aligned; frustrated, obtained second device which worked	Continued task
	In medication room, obtained new device	Continued task
Handheld device timed out while crushing medication (2 observations)	RN logged back in	Continued task
	RN logged back in	Continued task
Handheld device did not recognize RN ID (1 observation)	Scanned self twice	Continued task

The handheld device screen alignment was a problem in 2 observations. Another issue included the following: not recognizing the nurse ID badge during the first scanning attempt (1 observation).

Consequences of automation surprises were also recorded. The nurse continued the process after responding to the automation surprise in 7 observations and discontinued the process in 1 observation after becoming frustrated by the machine. In another observation, the nurse administered medications nonbarcoded when the handheld device lost the wireless connection while scanning medications in the patient room. Finally, a nurse requested assistance from a nursing assistant after a device froze while scanning a patient ID band in an isolation room. The nursing assistant then obtained a new ID band and handheld device and scanned the patient ID band for the nurse in the hallway.

Alarms

Handheld device audible alarms occurred during 26 of the observations (42%) including multiple alarms in 2 observations for a total of 29 alarms. Alarms were not recorded for 5 observations and were noted not to occur during 32 observations. Also, during 1 observation, the RN disabled the audio alarms on the handheld device. The causes of the alarms were noted in 11 instances and included the following: wrong dose scanned (3 observations), double check required (2 observations), disabled order (1 observation), bar code not readable because of nonformulary medication (1 observation), checking icon for information before administration (1 observation), missing medication (1 observation), and request to create a new order because of lack of a current order for a scanned medication (2 observation).

Nurses' responses to alarms were recorded. Three wrong dose alarms occurred after scanning the medications. One alarm prompted the nurse to retrieve the correct medication dose for administration. The second was correctly overridden, and the third was incorrectly overridden; the pharmacist observer intervened to prevent the medication from being administered. Alarms for medication double checks were followed by observed double checks. After a disabled order alarm, the nurse experienced another automation surprise previously discussed; the device disconnected from the network, and the nurse discontinued the task. After a nonreadable bar code alarm, the nurse proceeded to administer the medication nonbarcoded. A missing medication alarm prompted a nurse to retrieve a forgotten medication from the patient medication drawer. In another observation, an alarm sounded to create a new order for a tablet medication (It should be noted that since the time of this observational study, the BCMA software has been upgraded to prevent nurses from creating new orders when they scan a medication that is not ordered for the patient.). Both the tablet form and the suspension form of the same medication were in the patient drawer. However, only the suspension form had a current active order; the tablet form had been discontinued. The nurse recognized that the suspension form had an active order and recorded that the tablet was not given. For the second "create new order" alarm, the nurse tapped cancel and proceeded to give the medication nonbarcoded. The action after the "check icon" alarm was not recorded.

Organizational Factors

Interruptions

An interruption was defined as the occurrence of an event recognized by the nurse that disturbed the normal processing of the current task performed by the nurse.[26–28] The interruptions noted are exclusive of the aforementioned automation surprises and alarms. Interruptions were recorded in 20 observations (32%) for a total of 33 interruptions. Eleven observations had 1 interruption, 5 had 2 interruptions, and 4 had 3 interruptions. Interruptions can be grouped into 4 categories:

1. patient and family issues (11): family member asking questions, getting water for patient, patient asleep or in bathroom, intravenous catheter infiltrated, and dressing change.
2. provider interruptions (7): physician at patient bedside examining and talking to patient and nurse talking to another nurse.
3. medication task–related interruptions (8): looking up medication-related information, obtaining missing medications, obtaining new patient ID band, getting needle for

administration, getting extension tubing for intravenous medication, and waiting for previous intravenous bag to complete before administering the next bag.
4. equipment and technology interruptions (7): intravenous pump sounding alarm, nurse requiring assistance with pump programming, and wrapping handheld device in plastic to enter a patient's room in contact isolation.

All provider-related interruptions occurred during the morning medication administration period.

Physical Environment

The evaluation of the physical environment by the observers is summarized in Table 2. The lighting was always full in the medication room; however, in only 23 (37%) of 62 observations was the lighting full in the patient room. Loud noise levels in the medication room were observed in 5 observations (9%). The observers perceived the general physical environment as messy/disorganized for the patient room in 16 observations (26%) and for the medication room in 11 observations (18%). In addition, an alarm sound from the BCMA technology was recorded for 26 observations (42%).

Individuals

Patient Factors

Patient factors related to interruptions are previously noted. In 10 observations, the patient was noted to be in contact isolation. Contact isolation requires covering the handheld device in plastic before entering the room. Problems with device scanning through the plastic were noted. Likewise 4 handoffs occurred, all of which were related to patients being in contact isolation. One handoff occurred between an RN and a nursing student when the nursing student administered an intravenous medication to a patient after the staff RN performed all the scanning. Twice, a nursing assistant scanned the patient ID for the RN. The last handoff occurred when a nurse scanned herself and the medications and gave them to a nurse entering an isolation room who proceeded with scanning the patient, administering the medication, and documenting the administration.

TABLE 2. Evaluation of the Physical Environment by Observers

	Patient Room, *n* (%)	Medication Room, *n* (%)
Lighting		
Full	23 (38)	60 (100)
Dimmed	33 (55)	0
None–minimal	4 (7)	0
Noise		
Quiet	34 (57)	14 (24)
Normal	26 (43)	39 (67)
Loud	0	5 (9)
General physical environment		
Neat/organized	13 (21)	9 (15)
Normal	32 (52)	40 (67)
Messy/disorganized	16 (26)	11 (18)

The numbers in the table represent the number of observations for each of the characteristics of the physical environment.

Nurse Comments

Five nurses made comments to the observers about the BCMA technology and workarounds and error recovery. One nurse commented that the reliability of the handheld devices was poor and that sometimes there were only 2 working scanners for 4 nurses. Another commented that the device timed out too quickly during administration (3½ minutes after the last tap of the screen). Regarding workarounds, 1 nurse commented that it was much easier to document the medication administration before it was given and to edit this if needed after administration. A second nurse stated that she relied upon the technology to alarm if a medication dose was scanned over the limit rather than checking the dose against the MAR first. Concerning error recovery, 1 nurse described trying to give medications to the wrong patient and getting a "weird noise" when scanning the patient.

Nurse Interviews

A total of 19 nurses (31%) agreed to be interviewed and provided a total of 48 comments that were categorized into 29 negative and 19 positive comments on the BCMA technology (Table 3). Most of the negative comments were associated with the performance and availability of the device. Most positive comments described design issues of the device that resulted in increased patient safety; this result is consistent with an early survey of nurses performed at the institution showing a 42% improvement in the mean score of overall nursing satisfaction with the medication administration and documentation system after BCMA implementation.[13]

DISCUSSION

We have described the use of direct structured observation of end users interacting with BCMA technology in the health care environment. This is an important method to study the actual use of the technology in its intended work setting and with the physical, social, and organizational environment of intended use in place. These observations provide some insight into the variation of the medication administration process 1 to 3 years after implementing BCMA technology and the occurrence of potentially unsafe acts in the process. The data on task sequences clearly show significant variability in the order in which steps of the medication administration process are performed: a total of 18 different sequences were identified. Some of these sequences were contrary to hospital policy and the original design of the medication administration process and can be considered workarounds or potentially unsafe acts.[29] Suboptimal performance and potentially unsafe medication administrations were observed in a number of observations.

Impact of Work System on BCMA Use

The type of research reported in this paper allows for recognition of the precursors of errors and workarounds, such

TABLE 3. Comments by Nurses on the BCMA Technology (19 Interviews)

Comments	No. of Comments
Negative comments related to negative consequences associated with the performance and availability of the device	
Slowing down of the medication administration process including the addition of steps or changes to the previous process	8
System downtime/timing out/dead batteries/access to devices	8
Delays related to scanning bar codes and interfaces with the pharmacy system	2
High alarm volume	1
Negative comments related to screen and/or software design	
Screen too small	1
Screen misalignment	1
Limited free text space	1
Inadequate screen contrast	1
Negative comments on patient safety	
False sense of security when using the device	2
Overly "restrictive" nature of the technology ("less room for error")	1
Other negative comments	
Hardware size and bulkiness	2
Necessary precautions for patients in contact isolation	1
Positive comments on the design of the device that resulted in increased patient safety	
Increased overall accuracy and avoidance of error, including the need to double-check particular medications	10
Greater ease in obtaining accurate medication information	4
Positive aspects of alarms	2
Prevention of workarounds	2
Ease associated with scanning a bar code rather than visually confirming a medication	1

as interruptions or patient factors that may not be easily obtained from other sources of data collection. The focus is on working conditions in the microsystem of the nurse administering medications.[30] Our method allows the identification of specific performance obstacles (i.e., factors in the nurses' immediate work system that might hinder or facilitate their performance of medication administration).[30,31] This type of approach produces useful information for redesigning the workflow and technology use to prevent errors or adverse events. Interruptions often occur during tasks, like medication administration, that require a user's attention for task completion and critical decision making.[32] In 20 observations (32%), interruptions were observed. Interruptions were related to the needs of the patients and their family, initiated by another provider or by the nurse himself/herself, and caused by equipment, technology, and medications. Patient factors, like unique patient populations (children, the disabled, or the critically ill)[33] or contact isolation requirements, may not have been taken into consideration during the development of the technology, and direct observations with patients present in the natural environment can give insight into the need for process and technology redesign to accommodate safe care.

Our study identifies a range of work system factors that affect nurses' use and interaction with BCMA technology during medication administration. These factors are related to the 3 phases of the following: (1) technology design (e.g., size of screen), (2) technology implementation (e.g., nonbarcoded medications), and (3) technology use (e.g., interruptions by providers).[34] Technology design issues should be addressed as soon as possible, preferably by the designer and manufacturer of the technology. Issues related to the implementation of the technology can be addressed by the project team in charge of the implementation; such a team needs to have knowledge in human factors engineering to anticipate some of the potential human and organizational issues of technological change. Issues related to technology use can be addressed if the health care organization has systems and processes for capturing problems after the technology implementation. This type of continuous technology implementation approach[35,36] requires analysis of the technology in its actual environment of use. In a study of the implementation of BCMA in 6 community hospitals, Sakowski and colleagues[10] have advocated a similar need for "periodic assessments" of the actual use of BCMA technology. This is particularly important when health care providers are dependent on the technology for specific tasks; such a dependence on technology may affect their safe and effective completion of those tasks when the technology malfunctions or breaks down. At the stage of technology use, issues related to the design of the technology may emerge but are more difficult to address, except when the manufacturer is planning upgrades. Therefore, continuous communication between the health care organization and the manufacturer is valuable even after the technology implementation.

Methods for Planning Technology Implementation

When introducing a new technology into the health care environment, it is important to study how the use of the technology will change the workflow and the tasks.[37,38] Direct observation of end users before and after technology implementation allows the collection of data to document current practice and ensure that the new process has taken into consideration current practice needs and the design of the

environment in which the new technology will be used. In this particular health care organization, much attention was focused on the planning and implementation of the BCMA. It is important to recognize that prospective analysis and careful planning cannot completely predict and avoid unintended consequences related to the actual use of the technology. Therefore, health care organizations should be encouraged to continue analyzing the use of technology after implementation.

Process mapping of the task can show variations in practice and perhaps may show an "ideal" or more efficient mode of practice (i.e., a series of process steps that still result in proper administration of medications without errors and work-arounds). For instance, our data identified a few instances in which medication administration was not performed according to hospital policy. Process mapping is a commonly used quality improvement technique in health care organizations, and the addition of information provided by structured observation of the actual process (e.g., alarms encountered by end users, potential or real medication errors, interruptions of work flow, and patient problems) can help the organization identify opportunities to redesign the process and/or the technology to maximize worker efficiency, interaction with the technology, and patient safety. This also allows health care organizations to align policies and procedures with current practice.

Prior research in the implementation of BCMA in health care guided the development of solutions to problems that arise with the use of this technology.[17] However, these solutions should be understood within the organizational context in which the BCMA technology is implemented. The solutions need to be adapted to policies and procedures of the organization, the physical environment, and the patient populations. The observation methodology used in our study can produce useful information for health care organizations that are implementing BCMA technology and need to adopt the best practices as outlined by Patterson and colleagues.[17]

The method of structured observation as a means to collect data about people performing tasks in the natural work environment has a variety of applications in health care. Structured observation has been used to improve the implementation of many technologies, such as computerized provider order entry,[39] intravenous infusion pumps,[22,23] and wireless alert pager systems.[40] It has also been used to evaluate and redesign processes when concerns have arisen about safety or quality of care,[41] to further define adverse events and human errors occurring in care settings,[42,43] to evaluate organizational and team culture and its effects on safety and work,[44] and to evaluate the number of tasks that nurses think about and perform simultaneously.[32]

Study Limitations

There are limitations of the structured observation data collection method. The observer training, the type of observer, and the presence of the observer may affect the data that are collected and the quality of the data. In this study, we used 2 observers, a pharmacist and a human factors engineer, who were trained in observation technique, to collect data about medications and human factors issues. The use of a pharmacist to observe nurses administering medications using BCMA provided clinical knowledge about the process (e.g., medications and BCMA technology) but not necessarily about nursing work. The review of the observation data by a nurse provided this missing viewpoint about nursing work. Both observers collected general observation data and discussed the observation when it was complete and combined data into 1 observation. Therefore, it was not feasible to measure interrater reliability, yet the 2-observer method maximized data capture. In the health care setting, the presence of observers may not always be practical or feasible, for example, in the setting of acute patient decompensation when access to the patient without others in the way is critical or in situations that involve discussion of sensitive information in which prior patient consent would likely be required. Also, the emerging infections in hospital settings have increased the use of contact and airborne precautions for which the risk to the observer may outweigh the benefit of the research. Usually, observers can be instructed on the different types of isolation found in the hospital setting, how to take precautions to safely enter the patient room, and which rooms or patients to avoid observing all together. With BCMA technology, it is difficult to view the handheld devices carried by end users or to read the labels of the medication used in the administration process; therefore, limited interaction with the end user is needed if this information is to be collected. Using videotaping may allow easy and reliable capture of task performance, especially in the instances of patient isolation needs or difficult-to-view equipment.[45,46] Another issue is that the timing of the observations may have influenced the numbers and type of interruptions observed. For example, performing observations during the morning medication administration time coincides with the typical time that the physician teams perform patient rounds and when more nurses are present on the nursing unit. However, this information may be useful in those instances when considering workflow redesign to avoid interruptions. Finally, the results of the nurse interviews should be interpreted with caution, given that only 31% of the nurses agreed and were able to be interviewed.

CONCLUSIONS

Our observations show a large degree of variation in the medication administration process several years after implementing BCMA technology. We also observed a few instances of potentially unsafe acts in the medication administration process. A number of characteristics of the work system were identified as potential precursors of errors and workarounds, such as interruptions, technology issues, and patient characteristics. Hospitals and other health care institutions that are implementing BCMA should study the work system in which the technology will be used and how the characteristics of the work system can either facilitate or hinder the safe administration of medications.[30,31] The method described in this paper could be used to perform such an analysis.

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