# CHALLENGES AND PROBLEM SOLVING STRATEGIES DURING MEDICATION MANAGEMENT: A STUDY OF A PEDIATRIC HOSPITAL BEFORE AND AFTER BAR-CODING.


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## 1. INTRODUCTION

The safety related outcomes of health care work—errors, injuries, fatalities, financial costs—are well documented, well researched, and hardly in need of repeating here. From a designer's or scientist's point of view, knowing the outcomes is of some interest, but of no less interest than knowing what causes them. In their proposal for a new paradigm for patient safety, Karsh, Holden, Alper, and Or (2006) presented a human factors model of patient safety stating that outcomes, good and bad, are the result of health care provider (HCP) performance processes, or the "mental, physical, social, and behavioral activities carried out by HCPs toward some (usually patient related) goal" (p.i60). System design and redesign, they argued, should therefore focus on supporting these performance processes. Similarly, Carayon et al.'s (2006) systems model of patient safety proposed that work system interactions produce processes, which lead to patient and provider outcomes of interest. Both of those models intentionally followed the familiar form of Donabedian's (1988) structure-process-outcome organization for health care performance measurement. Both models also stressed that the study of outcomes must be supplemented by the study of work processes and the work system conditions that shape them.

Patient safety research exploring work systems (structure) and HCP performance (process) is increasingly perceived to be important, although there is still much work to be done (Buckle et al., 2006; Gurses & Carayon, 2007; Hope, 2004). Research is needed to answer structure and process questions of the following variety:

> How do practitioners encounter and deal with ordinary and extraordinary situations? How *do* they discover relevant domain semantics and learn the underlying domain invariants? How does their cognition work at work, in situ, in vivo? How do they balance demands, shift work, and sacrifice goals? How do they make the brittle work world plastic and resilient? How does technology change all this?
>
> (Cook, 2005, p.8)

The present study pursues answers to these kinds of questions in one particular context: nurse medication management in pediatric hospitals. In the next section, we will present the conceptual framework with which we approached this task.

### 1.1 Complexity, Challenges, and Problem Solving

Health care work, particularly the nursing work that is the subject of the present study, can be characterized by complexity (Cook et al., 2004; Institute of Medicine, 2004). Tucker and Spear (2006) describe two indicators of complexity:

- those related to constant changes in patient conditions and to the coordinating role that nurses play within the care team, or "factors inherent to caring for patients" (p.645), and
- breakdowns in the reliable provision of resources needed for patient care, or "avoidable factors unrelated to patients' conditions" (p.645).

The authors call these so-called avoidable events *operational failures*. They relate several types of operational failures, including interruptions in the process of care and missing supplies such as medications or equipment. Gurses and Carayon (2007), who use the term *performance obstacles* to describe the same concept, identify these and other breakdowns in the process of intensive care nursing: unavailable equipment or supplies; time spent dealing with family needs or teaching family; delays in medication delivery; delays in receiving medical orders; searching for patients' charts; distractions from family members; and insufficient space, among others.

Other researchers have described similar or identical concepts, and these go by various names. A sampling of the terms includes "ambiguities" (Gurses et al., 2007; Spear & Schmidhofer, 2005), "blocks" or "disruptions in workflow" (Halbesleben et al., 2008); "difficulties" (Cook et al., 2004), "gaps" (Cook et al., 2000; Patterson et al., in press); "glitches" (Uhlig et al., 2002), "hassles" (Beaudoin & Edgar, 2003), "problems" (Cook et al., 2004; Tucker et al., 2002); and "surprises" (Woods & Shattuck, 2000). From a safety science perspective, these concepts come close to that of a "hazard," defined as a "condition, event, or circumstance that could lead to or contribute to an unplanned or undesired event" (FAA, 2000; see also Karsh, et al., 2006).

Finally, a more generic and outcome-neutral concept that belongs in the list of indicators of work process complexity is the sociotechnical systems theory concept of variances (Hallock et al., 2006), broadly defined as "any unprogrammed event" (Cherns, 1976, p.787). Although a variance need not lead to any undesirable outcome, some researchers argue that variances in healthcare should be eliminated by standardizing work processes (e.g., Spear, 2005).

Thus far, we can summarize that the complexity of health care/nursing work is associated with states or occurrences that make it potentially difficult to carry out work. These states or occurrences go by various names that refer to similar but slightly different concepts. For present purposes, we will use a different term—challenging preconditions, or *challenges*—which we define thusly:

**A challenge is any occurrence, state, or requirement that, unless dealt with, prevents some pre-established goal from being accomplished *relative to standards established or implied for the accomplishment of the goal*.**

This definition is perhaps closest to the one for "problems" given by Tucker et al. (2002, p.124): "an undesirable gap between an expected and observed state … that hinders a worker's ability to complete his or her tasks." Much like pre-existing concepts of a similar variety, challenges:

1) can be traced back to something about work system elements or interactions thereof (Gurses & Carayon, 2007; Karsh et al., 2006)
2) are related to goals and plans, namely, because they conflict with the accomplishment of goals according to plan (Gurses et al., 2007; Tucker et al., 2002; Woods & Shattuck, 2000)

Challenges, thus, are one aspect of complex technical work in healthcare that we can now attempt to identify and describe in the course of medication management performed by nurses.

Another aspect of technical work that has received recent attention is the responsive actions that nurses/HCPs take in order to deal with challenges. As is the case with challenges, there are variations in how these actions are defined and the words that are used to refer to them. To list a few: problem solving behavior, strategies, coping, adaptation, resilience, improvisation, gap-bridging, and work-arounds.

We use the term *problem solving strategies*, which carries the following definition:

**Problem solving strategies are any response to (perceived) challenging preconditions (or, challenges) in which a process or system is manipulated, in order to accomplish some pre-established goal *relative to standards established or implied for the accomplishment of the goal*.**

This definition is similar to the one used by Tucker et al. (2002, p.124): "identifying and resolving problems that occur in the execution of day-to-day work routines." Here we do not describe the concept of problem solving in any further depth. However, in the Results section we do identify and describe a number of examples of problem solving strategies performed by nurses and other HCPs during medication management.

Thus, very generally, our conceptual framework for understanding technical work, in nursing, states that (1) nursing work is characterized by complexity, (2) this complexity produces challenges that threaten goal accomplishment, and (3) sometimes these challenges are dealt with by implementing problem solving strategies (see Halbesleben et al., 2008, for a similar view).

## 1.2 The Current Study

In the present study we sought to identify a few illustrative examples of challenges and problem solving in the process of medication management at a pediatric hospital. We chose to focus on medication management for two main reasons. First, errors in medication related processes, particularly medication administration, may be the main source of adverse events or injuries in acute care (e.g., Barker et al., 2002). Second, prior studies of challenges in nursing (e.g., Gurses & Carayon, 2007; Tucker & Spear, 2006) reported that medication-related challenges were the ones that were most frequently encountered. For the analysis, we drew primarily from observations of nurses performing medication administration and related activities, although below we will also describe instances implicating pharmacy processes and workers.

This study was conducted in a pediatric setting because a number of special medication-related considerations differ in this setting, compared to adult care: e.g., medication doses based on patient weight; potentially greater susceptibility of patients to medication errors; lower likelihood that patients can communicate meaningfully with providers (Karsh & Scanlon, 2005; Scanlon, 2007; Scanlon, Karsh, & Densmore, 2006).

One last key characteristic of the study is its ability to record challenges and problem solving behavior before and after the implementation of a bar-coding medication administration (BCMA) system, a medication management health information technology. As such health information technologies are increasingly recommended for implementation in hospitals (Anderson & Wittwear, 2004; Bates & Gawande, 2003), it is important to ascertain how they interact with challenges and problem solving strategies. To compare pre- and post-BCMA technical work, particularly in terms of challenges and problem solving, we will report a number of cases in which the impact of BCMA is evident.

# 2. METHODOLOGY

The target facility was an academic tertiary care pediatric hospital in the Midwest, with 222 beds. The hospital was using computerized provider order entry, among other systems, and in December 2006 began a six-month roll-out of a commercial

BCMA system. Data collection took place about one year prior to BCMA (December – February, 2005) and about one year post (February – March, 2008).

We followed an established work system analysis method (Karsh & Alper, 2005) to understand the technical work process and related system factors. Six researchers (Industrial Engineers) observed nurses' working in a general medical-surgical (MED) unit, a hematology-oncology (HEMONC) unit, and a pediatric intensive care unit (PICU), as well as in the central inpatient pharmacy and PICU and HEMONC satellite pharmacies. Observers took real-time field notes on every activity, though they focused on medication-related activities. Researchers asked observed participants clarifying questions if the opportunity arose, and participants sometimes volunteered explanations spontaneously. Not all data were analyzed for this paper.

Field notes were analyzed in narrative format to yield exemplar cases, and coded for instances of challenges and problem solving, as defined in Section 1.1. In addition, flowcharts were generated to map within-unit processes. These flowcharts were validated or modified in November, 2007, during 68 follow-up interviews with 45 unique nurses and 15 unique pharmacy workers.

Total elapsed observation time in nursing units was 89.5 hours pre-BCMA (79 unique nurses observed) and 71.5 hours post-BCMA (29 unique nurses observed). 96.3 hours pre-BCMA and 25.5 hours post-BCMA were spent observing in pharmacy.

# 3. RESULTS

In the follow sections, we briefly describe seven illustrative cases before and after BCMA implementation at the study hospital.

## 3.1 "Playing Games"

***(CASE 1:** Post-BCMA, PICU, based on an interview)* During morning rounds (0900) in the PICU, a physician ordered a 20mg dose of a blood pressure medication that would be scheduled starting with the first dose at 0900. A resident entered an order for 20mg for this medication into the computerized provider order entry (CPOE) system. Soon afterwards, Pharmacist 1, who was on rounds with the physician, entered the 20 mg dose into the information system used by the BCMA software, timing it to start at 0900. Even though the medication was scheduled to be given right away, it would take some time for pharmacy to prepare it. Prior to this 20mg dose order, the patient had a standing PRN order (per RN, or at the discretion of the nurse), for a 10mg dose of this medication. Thus, there were 2 available 10mg doses of the medication available at bedside, in the nurse's medication lockbox. However, when the resident placed a new order into CPOE for the 20mg dose, s/he also discontinued the 10mg PRN order. At this point, the BCMA system was "expecting" a single 20mg dose, and would not allow two 10mg doses to be scanned in as acceptable. Under these conditions, the available medication could not be administered according to the goals of the ordering physicians (and, likely, the goals of the nurse).

A second pharmacist (Pharmacist 2, from the PICU satellite pharmacy), recognizing this problem, instructed the nurse to administer two 10mg doses of the available medication, at once, to avoid delays. To allow this to happen within the restrictions of the BCMA software, Pharmacist 2 first reinstated the 10mg PRN order, so that the nurse could scan one of the 10mg doses and administer it as if it were a PRN. However, the BCMA system does not allow a second dose of PRN medication to be given so close to the first. In response, Pharmacist 2 created a new one-time order for a 10mg dose of the medication, in the BCMA system. The nurse was then able to administer the second available 10mg dose. Afterwards, Pharmacist 2 had to very quickly discontinue the new 10mg PRN medication, so that it would no longer be available in the system. Pharmacist 2 also had to request that Pharmacist 1 change the scheduled 20mg order so that the first dose was now scheduled for 1500 as opposed to 0900, so that no extra dose would be given. During an interview, Pharmacist 2 remarked on this situation, *"Sometimes you have to play games with the system to make it work."*

**Comment:** "Playing games," here, is synonymous with problem solving, but the specific terminology is potentially insightful. It conveys an interaction with the BCMA system that may be at times adversarial (a competitive game, in which the BCMA system poses a barcode scanning challenge) or collaborative (a cooperative game, in which the BCMA system has functions that allow the pharmacist to work around the 20mg dose order). As in other games, dealing with challenges may be fun, frustrating, or merely an ingrained part of the job. Going beyond this in-vivo term, we can view this case as exemplifying workarounds (Halbesleben et al., 2008) or necessary violations (Reason et al., 1998). These are often clever ways "to get the job done despite the local difficulties" (Reason, 1998, p.304). Because this pharmacist's workaround accomplishes the important goal of medicating the patient on time, management would presumably evaluate the behavior positively, although had an adverse event occurred, management may have viewed the behavior with disapprobation (Dekker, 2003). Unfortunately, the clever problem solving strategy that the pharmacist employed, although it did not lead to an adverse event, posed a new challenge: Pharmacist 2 needed to request that Pharmacist 1 change the timing of the 20mg order. What if Pharmacist 2 had forgotten to warn Pharmacist 1? What if Pharmacist 1 had forgotten to retime the order? Thus, the problem solving strategy necessitated a presumably novel set of follow-up behaviors, vulnerable to memory failures, increasing the risk of error. Finally, the case demonstrates that the BCMA system may be a very stubborn and unforgiving teammate, because it will not accept two 10mg doses of medication that are qualitatively and quantitatively identical to the physician's order. From one view, the system poses a new, unneeded challenge, requiring the pharmacist to "trick" BCMA into accepting a clinically appropriate action.

## 3.2 Back and Forth

***(CASE 2:** Post-BCMA, MED)* A scheduled 30mg dose of medication is presumed by the BCMA software to have been "missed," but in reality it was administered in the operating room (OR), while the patient was there for a procedure. The nurse attempts to reconcile the discrepancy, first by attempting to determine from the software what really happened, then, with some difficulty, by documenting that the 30mg dose was administered. After another look at the system, the nurse realizes from an OR note that, actually, an 80mg dose of the scheduled medication was administered during surgery in the OR. The nurse must now find a way to reverse the documented 30mg dose, an action that requires verification by a second nurse. The nurse calls over a second nurse and explains the situation; the second nurse verifies the dose reversal. Only the OR note documenting a 80mg dose remains. When prompted by the system to explain why the 30mg dose was missed, the nurse enters the reason as "dose change." Afterwards, this nurse commented *"[the] most time consuming part of this whole thing is you just can't look at a piece of paper and say, 'Okay, somebody signed it off.'"*

**Comment:** This case demonstrates a system that has the functionality for looking up and entering information that is useful to a distributed patient care team (i.e., what medication did the patient receive, where, when, and how much). In practice, however, the information is not easily accessible and data entry is neither error-free nor error-tolerant. In response to the patient being medicated in the OR, the nurse attempts to document what happened, but confusion and a lack of information leads to incorrect documentation. The BCMA system, seemingly not designed for easy recovery from a mis-documentation, requires a verification process. In the end, there is still a chance that the OR note about an administered 80mg dose will be missed, just as it was initially missed by the observed nurse.

### 3.3 Isolation

***(CASE 3:*** *Pre-BCMA, PICU)* A nurse taking care of a patient in contact isolation has to put on protective equipment (gown, gloves, mask) when entering the room, and takes it off when exiting. She retrieves to-be-administered medications from a cart outside of the room, and compares the medications to the order record, prior to entering the room. Inside the room she "bundles" tasks, doing as many in one session as possible. To minimize infections, she writes patient information (e.g., vitals) on a piece of paper and hangs it on the glass partition between the room and the hallway. In the hallway she looks at this paper to put the information into the patient's chart.

(***CASE 4****: Post-BCMA, PICU*) Nurse1 was asked by Nurse2 in the next room to double check a to-be-administered medication. Each nurse was only responsible for one patient that day, and both patient were in isolation. Nurse2 was using one of the few available handheld BCMA scanning devices. Nurse2 held the scanning device in the doorway of the patient's room, while Nurse1 checked the device-displayed information for accuracy.

**Comment:** Infection hazards are a challenge dealt with by following formal isolation procedures, but these procedures, too, impose a challenge. To save time (other nurses had to do a full five-minute scrub prior to every entry/exit!), nurses bundle tasks. Further, they use a physical artifact and a glass partition to "transfer" information that would otherwise be transferred mnemonically or physically transported from the room. In Case 4, isolated patients pose a challenge to independent medication verification by a second nurse. A handheld device is used to carry out the verification process, but there are only 5 such devices for the entire 32-bed PICU. Nurse2 explained what would happen if a handheld device were unavailable: Nurse2 would have to degown, ask Nurse1 to verify the medication (if Nurse1 was in her patient's room then she, too, would degown), both nurses would have to gown up again to enter Nurse2's patient's room. After completing the verification, Nurse1 would degown and regown before continuing tasks in her patient's room.

### 3.4 Let There Be Light

***(CASE 5****: Pre-BCMA, MED)* To read a patient's identification band, in a dimly lit room, the nurse uses a flashlight for added illumination.

***(CASE 6****: Post-BCMA, HEMONC)* A nurse attempts, repeatedly, and without success, to type in his username and password into the BCMA software, in a dimly lit room. Light from the screen does not fall on the keyboard, which rests in a recessed nook, and the nurse is not a touch typist.

***(CASE 7****: Post-BCMA, HEMONC)* A nurse attempts to use a barcode scanning device on an IV fluid bag. The barcode scans after about 30 attempts.

**Comment:** All of these cases demonstrate an inability to take in information, and this inability extends to barcode scanning devices. Pre-BCMA, a nurse solves the problem by using a flashlight, but no such problem solving is available to help the scanning device. Instead, the nurse just keeps trying. Alternatively, the nurse could have selected the medication in the software, negating the safety function of the BCMA system. Not scanning the medication may have had other consequences: upcoming job evaluations on that unit were to be based partially on nurses' "appropriate" use of the BCMA device. Finally, lighting problems persist post-BCMA, even though the object in need of illumination has changed (an identification band in Case 5, and a keyboard in Case 7).

## 4. CONCLUSIONS

### 4.1 General Conclusions

In the present paper, we addressed the need for "a detailed, calibrated understanding of the actual task requirements of the work domain and the trade-offs and strategies that workers use to meet these demands" (Patterson et al., 2006, p.37; see also Cook, 2005, p.8). Our organizing framework is based on recent work on challenges, which are indicators of health care's complexity, and the problem solving strategies that HCPs implement in response.

It appears from the cases, before and after BCMA, that HCPs—nurses and pharmacists—are adept at managing the many challenges of complex technical work. We did not present cases in which HCPs *failed* to deal (effectively) with challenges, but such cases were relatively infrequent. In each case, aspects of the work system pose challenges. This suggests that system designers, under certain circumstances, can eliminate challenges. An obvious example is to provide better lighting (Cases 5 and 6) or better bar code labels (Case 7), though these suggestions may themselves have many complications. Other challenges (e.g., Isolation, Cases 3 and 4) are not readily eliminable. Redesign might be directed at supporting the problem solving strategies, formal or informal, that are needed to perform well under these circumstances.

Some of the cases reflect impacts that BCMA may have had on HCPs' technical work. Interestingly, BCMA may eliminate some challenges such as the illumination problem in Case 5 and create others, such as the new illumination problem in Case 6. Further, as in Case 1, the BCMA system may have stifled previously successful non-routine problem solving strategies because of digitally formalized requirements for matching the medication precisely to the order. This routinization consequence of automation is similar to the idea of transitioning from a loosely to a tightly coupled system, or "going solid" (Cook & Rasmussen, 2005; note the similarities between those authors' use of the term "flirting with the margins" and ours of "playing games"). A closer analysis will be required to more systematically identify the ways in which BCMA and other technologies: (a) prevent challenges from arising or attenuate their impact on safety outcomes; (b) create new challenges and new types of challenges; (c) offer new problem solving strategies or enhance prior ones; and (d) suppress or make more difficult certain problem solving strategies. We believe that human factors research and theory that examines the impact of automation on work (e.g., Parasuraman & Riley, 1997) and the fit between health information technology and work systems (e.g., Holden & Karsh, 2007) will be tremendously useful for such a future analysis.

### 4.2 The 100 Mile-Per-Hour Design Challenge: Safety During Resilience

Observing the adaptive problem solving behaviors of HCPs, some of which have evolved to become "tools of the trade," may lead one to label the studied technical work system as resilient, because goals are achieved in the face of challenging conditions (Hollnagel et al., 2006). Nevertheless, it is possible that this system, though it can overcome challenges, is not any safer, if not less safe[1] (see Case 1 commentary). That is to say, the problem solving strategies of HCPs are sometimes ad-hoc, and it is very likely that the work system has not been designed to support such problem solving behavior. Thus, not only is this kind of problem solving unlikely to lead to more global hazard reductions (Tucker et al., 2002), but active failures may occur "through the gradual erosion of safeguards by subtle and often well intentioned workarounds or changes in operating practices" (Reason, 2004, p.ii29). We note, as does Reason, that workers engaging in problem solving behavior are not being intentionally unsafe, but rather are forced into action by the conditions of work—thus, the use of the term "necessary" to describe such violations (see section 3.1).

Reason and his colleagues discuss why deviations from expected behavior may be dangerous, using the example of a motorist speeding at 100 miles per hour (mph) (Reason et al., 1998, p.291). The driver is unfamiliar with this high-speed mode of performance, and even if she is, the system is less error tolerant in this mode (see also Cook & Rasmussen, 2005).

But what is the source of low error tolerance? Are all new performance modes doomed to operate at the perilous edge of safety? Perhaps not. Perhaps the reason that systems are not tolerant is that they are built around what is expected of workers, not around the strategies that workers actually employ. This need not be the case. To use the speeding motorist example, we may well imagine professions and processes during which speeding is a necessary strategy: a police officer in a high-speed chase, for example. By designing systems that support high-speed support, law enforcement officers can deal effectively with criminals (challenges) without a substantial risk increase. A siren is installed, training on high speed pursuits is provided, cars on the road move aside, police cars are purchased for high-speed performance, and a well-developed system of pursuit is created wherein officers join and exit the pursuit, at different times. Are health care systems equally well designed to support their breakneck speed? In Case 2, the kind of system support that allows HCPs to safely employ novel problem solving behavior is a piece of paper that allows HCPs to document exactly what happened. BCMA, on the other hand, does not very well support the documentation of novel behaviors.

The design goal is to ensure that resilient problem solving behaviors, which effectively deal with challenges and avert related adverse outcomes, are themselves supported by system design such that *overall* risk is reduced. It is evident from our cases that providers working near the "edge" of safety are to be commended for their resilient work. We ask: *is equally commendable work required of ergonomists and other systems designers to build in support and resources that allows work on the edge to be safer?* If so, we must first gain an adequate understanding of the way that such work is done.

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