Gaps and Resilience

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Introduction

There is great interest in reducing the frequency and consequences of "human error" in healthcare, similar to past efforts in aviation, nuclear power generation, and space operations. Overall, the study of "human error" has been approached two ways. One approach is that *erratic people degrade an otherwise safe system*. With this view, it is critical to prevent fundamentally error-prone individuals from making mistakes. Attempts to reduce human error include reporting errors, developing taxonomies of error types to tabulate counts within the types, estimating likelihoods of error, and implementing procedures and technology to reduce error counts. In contrast to this is an approach where *people are viewed as the primary source of resilience in creating safety* under resource and performance pressure (Cook and Woods, 1994). Progress in this "new look" paradigm comes from aiding people under pressure from conflicting goals to cope with complexity (Rasmussen, 1986; 1990a; 1990b; 1997; 1999). Attempts to improve patient safety are focused on increasing system resilience by investing in a context-sensitive understanding of the gaps that arise in system operation and the expert strategies that are used to bridge these gaps in practice. This chapter provides an overview of this second approach to the study of human error, and illustrates the application of five strategies to increase resilience in medication administration using bar code medication administration software.

The "New Look" Behind Human Error

The second approach, the so-called "new look", is distinguished from the use of the label "human error" to attribute blame following an accident investigation (Woods, Johannesen, Cook and Sarter, 1994). The frequent judgment that human error is a "root cause" of an incident generally serves as the <u>stopping</u> point for an investigation. As a result, recommendations to improve safety typically involve reminding people to be careful, educating them on the proper use of equipment, forcing them to comply more with procedures, and using automation to perform activities that used to be done by a human.

In contrast, when the label human error becomes the <u>starting</u> point for investigations, we find a deeper, multi-faceted story (Cook, Woods and Miller, 1998). This "second" story shows us how multiple interacting factors in complex systems can combine to produce systemic vulnerabilities to failure. The second story is more complicated but more interesting and can point the way to learning and system improvements that can increase system resilience. The 'second story' finds that doing things safely, in the course of meeting other goals, is and has always been part of operational practice. As people in their different roles are aware of potential paths to failure, they develop failure-sensitive strategies to forestall these possibilities.

Looking at technical work throughout an organization, we see people struggling to anticipate paths toward failure, actively adapting to create and sustain failure-sensitive strategies, and working to maintain margins in the face of pressures to do more and do it quickly. Failures occur against this background when multiple contributors -- each necessary but only jointly sufficient -- combine. Work processes do not choose failure but *drift toward it* as production pressures and change erode the defenses that normally keep failure at a distance. This drift is the result of systematic, predictable organizational factors at work, not simply erratic individuals (for a recent example see the Columbia Investigation Board report, 2003; and Woods, 2003 for one commentary).

The following patterns are found in "second stories":

- Workers continually revise their strategies to remain sensitive to the possibility for failure while adapting to increasing resource and production pressures
- Workers are only partially aware of the potential for failure
- Change creates new paths to failure and new demands; even strong and resilient coping strategies can become ineffective over time
- Overconfidence in the coverage of anticipation of the types and mechanisms of failure
- Missed side effects of change.

Very high levels of performance are achievable. For example, researchers have studied organizations that have been remarkably successful in managing potentially hazardous technical operations (Rochlin, 1999). Achieving such high levels of performance does not flow from rooting out error, but rather through anticipating and planning for unexpected events and future surprises. Past success is not a reason for confidence, instead, continued investment in anticipating the changing potential for failure is energized by the deeply held understanding that our knowledge base is fragile in the face of the hazards inherent in work and the changes omnipresent in the environment.

Overall, analysis of "second stories" teaches us that failure represents *breakdowns in adaptations* directed at coping with complexity. Success is usually obtained as people learn and adapt to create safety in a world fraught with hazards, tradeoffs, and multiple goals (Rasmussen, 1997). In other words, success relates to organizations, groups and individuals who produce resilient systems that adapt to change and surprise.

Gaps

Progress in the "new look" paradigm comes from aiding people under pressure from conflicting goals to cope with complexity. One way to characterize complexity is to identify gaps in continuity of care and experts' strategies for bridging gaps (Cook et al., 2000). Continuity refers to the coherent, connected, smoothly evolving care as the individual patient moves from location to location and from provider to provider. During transfers, continuity is accomplished by the person accepting responsibility for care having an accurate, complete model of the patient's history and current status, being aware of significant data or events, being prepared to deal with impacts from previous events and anticipate future events, conducting planned activities, and avoiding an unwarranted shift in goals, decisions, priorities, or plans (Patterson et al., 2004). Large discontinuities in care, such as patient transfers between facilities, are often partly bridged by permanent artifacts such as a transfer form. Smaller gaps, such as a patient transfer to the operating room within a facility (Figure 1), tend to be bridged by less formal, less permanent means, such as handwritten annotations to paperwork or verbal communications. Characterizing gaps, understanding how they develop, how they manifest themselves in the work world in particular contexts, and how they impact care is essential to designing effective means for creating continuity of care.

Gaps arise from a variety of sources and create a variety of problems. For example, lost information about current or past status, the history of care, or plans for future care is a mark of one type of gap. This gap may lead to undesirable therapies, missed opportunities for intervention, incoherent planning, drug misadministration, and so forth. These activities are not only an inefficient use of resources. If the actions taken to overcome gaps are unsuccessful, the result may be patient harm. To examine gaps requires going beyond the *manifestation* of the gap (in this case, lost information) to discover the way that the sources of that loss are embedded in the structure of work. For this reason, any inquiry into gaps is critically an inquiry into technical work.

Gaps are likely at what might be called *fracture points*. Many of these are readily recognized. The physical transfer of patients from unit to unit within a hospital is surely a fracture point, but so are shift changes. In the complex environment with multiple actors engaged in care, roles may shift quickly and obviously or slowly and subtly. Worsening illness may lead to shifts of responsibility for care and decision making. Transfers of authority, responsibility, economic and legal power are also involved. Even age boundaries may be fracture points as legal, economic, and cultural implications either enforce or preclude transfers of responsibility.

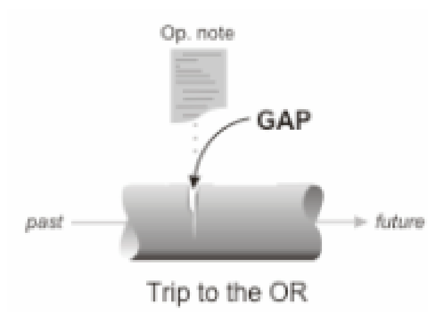

Figure 1. Gap during patient transfer to the operating room

Much of what healthcare people do is already shaped by their awareness of the problems that gaps may produce. Past gaps are easily recognized by their effects, such as the detection of missing or inconsistent data or by expressions of surprise at the behavior of team members. Practitioners restore continuity following the detection of a gap by reassembling coherent world views or making up for the consequences of the gap. Experienced practitioners are able to anticipate possible future gaps (Figure 2), leading them to construct bridges. The bridges offset some but not all of the expected consequences of gaps. Interestingly, the successful bridging of gaps by experienced practitioners limits the impacts of gaps on patient outcomes, but also reduces their apparent significance. As most gaps are anticipated, identified, and bridged and their consequences nullified, gaps rarely lead to overt failure.

The gap driven activities are so intimately woven into the fabric of technical work that neither outsiders nor insiders recognize them as distinct from other technical work. One way to see gaps and bridging is to look at organizational and institutional boundaries that mark changes in responsibility or authority, different roles of professionals, or formal divisions of labor. Gaps can also appear within the processes of care and even in association with single practitioners. For example, when a nurse cares for two patients and must divide attention between them there is a potential for gaps in the continuity of care. Skillfully managing the division of attention is a means for bridging gaps—for example, by increasing the frequency of "checking" on the more ill patient or by putting off routine activities such as charting to provide longer periods for observation.

Observation of work in context quickly demonstrates that workers are continuously encountering new or unfamiliar gaps, and devising new bridges. The introduction of organizational and technological change may undermine the effectiveness of established bridges. Because the pattern and significance of gaps is dynamic, creating safety in the presence of gaps is a continuous process. Understanding how people create effective strategies to reduce the number and significance of gaps is central to understanding the sources of safety in healthcare. Based on this understanding, technology and cognitive tools may be used to aid practitioners in eliminating or bridging known gaps. Given the dynamic nature of gap formation and bridging, efforts to create static defenses are of limited value.

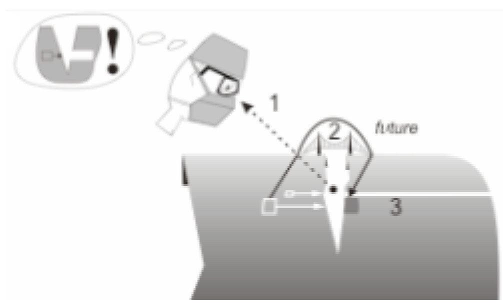

Figure 2. Bridging a future gap

Table 1 summarizes the main lines of inquiry for identifying and bridging gaps:

(1) where and how gaps arise (*sources*),
(2) how people *cope* with gaps (effective and ineffective measures),
(3) how proposed and predicted *change* in the system can be assessed in terms of its likely effect on gaps,
(4) how to assess approaches intended to *reduce* gaps, and
(5) how to help people *overcome* gaps.

Table 1. Lines of inquiry for identifying and bridging gaps

Analyzing Gaps	Examples
sources of gaps	• Increasing specialization of workforce • New, complex technology • Transitions between units, caregivers, facilities • Cognitive decline of elderly patients • Language differences, e.g., caregivers vs. patients • Personnel turnover, organizational memory loss
coping with gaps (effective and ineffective measures)	• Ad hoc cognitive tools (e.g., "cheat sheets", work lists, lab notebooks) • Adaptations and work culture • Problem simplification • Retreats to robust operational boundaries • Preplanning responses to (anticipated) failure
effects of change on gaps	• Reduction in robustness of rehearsed strategies • Creation of new, unanticipated gaps • Elimination of old gaps (perhaps leaving behind old, now unneeded countermeasures) • Change in consequences of gaps • Changes in the effectiveness of established countermeasures
strategies for reducing gaps	• Reliance on independent information generation and verification – the "we do it ourselves" approach • Simplification of work environments to reduce consequences of unbridged gaps • Creation of redundancy in process and information
aiding practitioners to overcome gaps	• Improving gap detection and characterization • Information tools (computer and paper based) • Creating institutional memory libraries • Improving coping strategies • Reducing authority/responsibility mismatches

Resilience

With the "new look" paradigm, attempts to improve patient safety are focused on increasing system resilience to gaps in the continuity of care. Resilience is the broad application of failure sensitive strategies that reduce the potential for and consequences from erroneous actions, surprising events, unanticipated variability, and complicating factors (Woods and Shattuck, 2000). Several researchers have begun to explore how to increase system resilience to improve safety. A non-inclusive list is Hollnagel (1999) and Svenson (2001) exploring barrier analysis; Carthy et al. (2000) and Reason (2001) looking at the resilience in surgical services; Woods and Shattuck (2000) in analyzing an accident; Weick et al (1999) in characterizing how high reliability organizations show high resilience. Overall, the theme that leaps out from this work is that high reliability organizations treat safety as a value, not a commodity. Rather than view past success as a reason to ramp down investments, these organizations continue to invest in anticipating the changing potential for failure because they appreciate that their knowledge of the gaps is imperfect and that their environment constantly changes. One measure of resilience is the ability to "create foresight—anticipate the changing shape of iatrogenic risk, *before* patients are injured" (Woods, 2000).

To illustrate how system resilience can be increased, we now describe five strategies applied to medication administration supported by Bar Code Medication Administration (BCMA) software used in all Veteran's Health Administration (VHA) hospitals:

1. model adaptive systems and variability
2. identify unintended cascading effects from systemic change
3. make activities and communications of team members observable
4. support "sacrifice decisions"
5. monitor the gap between standard operating procedures and actual practice.

Strategy #1. Model adaptive systems and variability.

A cornerstone of the new look approach is that interventions to improve resilience are grounded in a detailed, context-sensitive understanding of how sharp end practitioners "on the front lines" adapt to cope with potential hazards in the face of variability and complexity. In order to model how nurses in the Veteran's Health Administration (VHA) identified and bridged gaps in medication administration with the use of Bar Code Medication Administration (BCMA), we employed two methods: 1) a detailed analysis of a "near miss wrong patient" incident and 2) observing how nurses simulated bridged gaps while using prototypes of future versions of BCMA prior to implementation.

Near miss wrong patient incident

We learned that a "wrong patient" incident nearly occurred three weeks after implementation of BCMA on an acute care ward. As BCMA is explicitly designed to reduce "wrong patient" errors via nurses scanning barcoded wristbands to identify patients, we felt that a detailed analysis would reveal opportunities to improve resilience.

At the time of the incident, the previous paper-based medication administration record (MAR) was used in parallel with the new Bar Code Medication Administration (BCMA) software. The incident occurred on the evening shift when three nurses were caring for 26 acutely ill patients. The day prior to the incident, three nurses had cared for one patient in a particular hospital bed. The primary nurse was a Licensed Practical Nurse (LPN) who provided nearly all of the direct care but did not administer medications because she had not yet completed orientation. A "covering" Registered Nurse (RN) administered medications for the patient. A third "agency", or substitute nurse not affiliated with the VHA, Registered Nurse (RN) discharged the patient.

The day of the incident, a new patient was in the particular hospital bed. Although there were three beds in the room, only one bed was occupied. An experienced Registered Nurse (RN) was administering medications to her patients. The nurse looked at the paper MAR for the patient. She then unsuccessfully attempted to scan the patient's barcoded wristband. She then typed in the social security number from the paper record to identify the patient, a common "workaround" (Patterson et al., 2002). A dialog box appeared with the message "Patient [000-00-0001] Not Found" (note that the number has been changed). She told the patient that the computer could not find his record. The patient said that he was going to be discharged today, so perhaps he had already been taken out of the computer. The nurse prepared the medications from the MAR. The nurse manager walked by and the nurse showed her the dialog box and asked her to help figure out how to find the patient record in BCMA. The nurse manager went to the clerk and asked about the patient, using the last name from the MAR to identify him. The clerk told her that the patient had been discharged the day before, so the nurse manager alerted the nurse not to administer the prepared medications. The nurse manager and the nurse checked the name on the patient's armband and discovered that it was similar, but different. In addition, the diagnoses for the two patients were similar, and so the medications had all been available in the new patient's medication drawer. It was discovered that the paper MAR from the previous patient had not been discarded upon discharge by the agency nurse (who likely was not very experienced with the discharge procedure) and that the paper record for the new patient was beneath the previous patient in the three-ring binder. The nurse then typed in the social security number on the patient's wristband to access the correct patient record in BCMA, and subsequently prepared and administered the ordered medications.

We have organized the insights gained from this analysis by vulnerabilities to hazards and sources of resilience at the organizational, equipment design, team, and individual levels (Table 2). Organizational contributors to this near miss incident included ambiguous roles for the three nurses caring for the single patient, use of an agency nurse to discharge a patient, use of the MAR and BCMA systems in parallel without designating a primary system, having 3 nurses care for 26 acutely ill patients on the evening shift, a poor process for evening shift nurses to recruit additional nurses, assigning a nurse to different patients on consecutive days, and nurses who were not trained on BCMA. Equipment contributors included unreliable scanning, design choices that rendered some aspects of the system "opaque" to the users, such as confusing error message text when a discharged patient's social security number was entered, and a lack of support for error detection. Team factors included no verification that the paper MAR was removed upon discharge for the previous patient when the MAR was added for the new patient, and individual factors included incomplete and partially inaccurate, or "buggy", knowledge about how the system functioned, partly due to the short time that it had been in use.

Table 2. Vulnerabilities and Sources of Resilience

Categories	Vulnerabilities	Resilience
Organizational	Ambiguous roles for 3 nurses caring for 1 patient Agency nurse not familiar with discharge process Paper and BCMA records used in parallel 3 nurses for 26 acutely ill patients on evening shift Poor process for evening shift to recruit additional nurses Nurse had different patients on consecutive days Nurses not trained on BCMA	Nurse manager addressed BCMA issues daily during implementation Nurses encouraged to scan patient wristbands by nurse manager
Equipment Design	Scanning not consistently reliable "Patient Not Found" message unclear No visualization of patient history No alerts for patients with similar names on the same ward or in the same bed on sequential days	Names printed on wristbands
Team	No verification that paper medication administration record was removed at discharge	Nurse manager available to provide help with BCMA Clerk detected that it was the wrong patient Nurse heard the clerk say that it was the wrong patient
Individual	A nurse not finished with orientation could not administer medications Nurses were inexperienced with BCMA Agency nurse was not trained on BCMA Patient was inexperienced with BCMA	Nurse manager knowledgeable about BCMA

Consistent with expectations, people served as the primary source of system resilience. The nurse manager proactively identified ways to make the system work as intended on a daily basis through discussion at the end of each shift and by being available to answer questions during implementation, as well as encouraged scanning wristbands despite the efficiency cost of having to maneuver large patient carts into the rooms to use the tethered scanners. It is interesting to note that although BCMA is intended to increase patient safety by automated barcode reading, detection of the mistaken patient identity was partly accomplished by people reading the social security number on the patient's wristband, which would not be possible if only the barcode were available. It is also interesting that the error was detected by an unlikely person, the clerk, who had worked the previous day and remembered the discharged patient's name, suggesting that people who are not officially responsible or specifically trained to do a task may serve as an important source of resilience. Finally, the nurse manager recognized that the situation was not a "false alarm" due to her detailed knowledge of the software and recent issues.

These insights suggest a number of possible interventions to increase resilience. For example, the parallel use of both the paper MARand BCMA to document medication administrations added complexity, increasing the opportunity for gaps. Although it is likely necessary to employ parallel systems during implementation to aid with troubleshooting and provide a "backup" when problems arise, this period of time could be minimized and clear expectations could be communicated regarding which system is primary and which serves as a backup. A contributor to this incident was that the paper record for the discharged patient was not removed. When new records are added or new patient names are put on medication drawers, it could be verified that outdated records and medications have been removed. We feel that these suggestions differ from suggestions derived from the first approach to human error, which would likely center blame squarely on the nurse who typed in the social security number to identify the patient. Examples of interventions using the first approach to human error might include retraining the nurse on the proper use of BCMA, reminding nurses of the importance of using the system as intended, or forcing nurses to type an explanatory comment each time that they do not scan a wristband to open a record.

Observing how nurses bridge gaps during simulated complex scenarios

Although analyses of "near miss" incidents provide valuable information, they necessarily are done after a patient is nearly injured. By simulating work, gaps and ineffective bridging strategies from an anticipated change can be identified without putting patients at risk. With this advance knowledge, some gaps or ineffective bridging strategies may be eliminated or reduced without incurring side effects from change and effective bridging strategies can be supported.

Prior to the implementation of the second version of BCMA, we simulated its use in a laboratory setting (see Patterson et al., 2004, for a detailed description of the methods and findings). Video data were collected of a total of fourteen nurses using a series of three functional prototypes to simulate medication administration on an acute care ward to six patients during a frequently interrupted medication pass.

The simulations provided a better understanding where new gaps might emerge and where bridging strategies might be ineffective. For example, all of the nurses administered a medication to which a (simulated) patient was allergic. When asked, the nurses were aware that allergy information was displayed, but had not noticed that patient's allergy information. This was a surprising finding because the software in the third study had been modified to prominently display allergies in red font on the top center of the primary display. Despite this prominent display, nurses were highly vulnerable to missing the allergy information. A number of approaches could be used to increase the system resilience to the hazard of patient allergies, such as by having pharmacists update allergy information in the patient record and verify that patients are not allergic to ordered medications. Allergy information could be incorporated onto the barcoded wristband. Nurses could ask patients to recite allergies prior to medication administration. Patient's caregivers could be taught medications to avoid. Note that we feel that the coordination of multiple approaches is more effective than reliance on an elusive "silver bullet."

In addition to vulnerabilities to known hazards such as allergies, we also discovered vulnerabilities to new, unexpected hazards. For example, with the first version of BCMA, all medications were listed on a single display. With the second version, medications were separated onto three tabs labeled unit dose, IVP/IVPB, and IV. In the study of an early prototype of version 2, four of five nurses did not administer any of the ordered intravenous (IV) medications for at least one (simulated) patient because they did not access the IVP/IVPB tab during the simulated medication pass. For the single participant who did administer all IV medications, he forgot to administer unit dose medications to one patient because he did not access the unit dose tab (at the time, BCMA defaulted to the tab that was last selected for the last patient). Based on these findings, BCMA always defaulted to the unit dose tab and a pop-up warning dialog box was added when a user tried to close a record where active medications had not been administered. During the simulated use of the revised prototype, only one of four nurses failed to administer any IV medications, and only to a single patient. To gain a better understanding of how well these bridging strategies worked "in situ", it would be necessary to monitor how often nurses missed administering medications on "background" tabs.

Strategy #2. Identify unintended cascading effects from the introduction of change

The introduction of any change, regardless how good, has unintended cascading effects that potentially create new paths to failure (Rasmussen et al., 1994). Proactively identifying these paths allows system redesign prior to undesired outcomes. Based on direct observations of medication administration on acute care wards prior to and following BCMA implementation, we identified five negative, unintended effects that could lead to new paths to failure (see Patterson et al., 2002, for more details regarding the study methodology and findings) . Note that none of these were inherent to the technology, and so they all could theoretically be mitigated or eliminated.

First, nurses were sometimes surprised by automated actions taken by the BCMA software. For example, BCMA removed IV medications from a patient's prescription list four hours after the scheduled administration time, even when the medication was never administered. This situation could occur when a patient returned to his room from a dialysis procedure more than four hours after a scheduled administration time. In this case, the nurse had no indication that the medication had been removed and therefore the ordered medication would not be administered.

Second, the use of BCMA was correlated with a degraded coordination between doctors and nurses. Before BCMA was implemented, the physicians could look quickly at the patient's bedside at the handwritten Medication Administration Record (MAR), which no longer existed after BCMA (in most hospitals). Although BCMA data were available electronically through the Computerized Patient Record System (CPRS), for several months physicians could only access a seven-day hard-coded window of data unless they asked the nurses directly for the information.

Third, nurses used strategies to increase efficiency that circumvented the intended use of BCMA. For example, some nurses routinely input a patient's social security number by typing rather than scanning the patient's bar-coded wristband, because typing was more efficient.

Fourth, nurses felt that timeliness of medication administration was greatly increased in priority, because BCMA required nurses to type in an explanation when medications were given late. Particularly in long-term care settings, some nurses were observed to scan and pour medications for unavailable patients so that they would appear "on time" in the record, thereby relying on memory to administer the unlabeled medication cup with opened, unlabeled medications to the intended patient.

Fifth, nurses found it harder to deviate from the routine sequence of activities with BCMA. For example, when a patient refused a medication that had already been automatically documented as given when scanned, the nurses had to manually document the change in a time-consuming process in another software package. Based on our recommendation, the software was then revised so that the nurse could easily document the change in BCMA by selecting the medication and selecting a menu option.

There have been many recommendations for the use of technology to reduce human error. For example, computerized physician order entry is advocated to reduce misinterpretations of handwritten prescriptions. We feel that it is critical to appreciate that little of the former roles, strategies, and paths to failure are preserved across the technology change boundary. As a consequence of added or expanded machine roles, practitioners take on new roles and transform their previous roles, the nature of standard practice changes, the expectations for what is normal and what is unexpected changes, and new paths to failure arise (Woods and Tinapple, 1999; Woods and Sarter, in press; Barley and Orr, 1997; Sarter, Woods and Billings, 1997; Woods, Sarter, Graham, and Dekker, 1999; Dekker and Woods, 1999). An appreciation of the complexity and magnitude of effects stemming from such a change does not imply that a technology is "bad" or should not be introduced – rather, the implication is that much of the hard work to increase resilience occurs *after* the system is implemented, including the explicit search for unintended cascading effects that create new paths to failure.

Strategy #3. Make activities and communications of team members observable. We have learned from experiences in other domains that a powerful strategy for increasing system resilience is to support "listening in." For example, Luff, Heath, and Greatbach (1992) observed that controllers thought out loud about schedule changes that they made during crisis situations in Line Control Rooms in the London Underground. When the controllers expressed changes out loud, others in the vicinity noted changes that affected their own schedules. They also had the opportunity to detect erroneous assessments or decisions before they were acted upon. Similarly, Rochlin, La Porte and

Roberts (1987) noted for voice loop communications in aircraft carrier operations that: "everyone involved...is part of a constant loop of conversation and verification taking place over several different channels at once. At first little of this chatter seems coherent, let alone substantive, to the outside observer...one discovers that seasoned personnel do not 'listen' so much as monitor for deviations, reacting to almost anything that does not fit their expectations." Finally, paper flight strips that are used by air traffic controllers to track airplane movement have been attempted to be replaced by electronic versions. One reason for rejection of the electronic versions is that "cocking" of the paper flight strips could be seen by other controllers from a distance with little effort, and this was not possible with the electronic versions (Mackay, 2000).

In addition to innovative uses of so-called "Groupware" technologies such as voice loops (Patterson, Watts-Perotti and Woods, 1999), this strategy can be used with existing systems. For example, BCMA was modified in several ways to make activities and communications of team members more observable. First, BCMA originally displayed "Record in use by another user" when another person had the patient's record open. In some cases, the user accidentally left the record open for hours, effectively blocking documentation of medication administration during that time. Modifications included time-out features and specification of who was using the record ("Record in use by ___"). Second, BCMA originally only allowed physicians access to the medication administration data via their order entry software for a seven-day hard-coded window. In other words, physicians could not access the data from Saturday on Monday. Modifications enabled physicians and others unrestricted access to requested data windows (except when those requests crashed the server). With this change, the physicians could more easily detect their erroneous orders and mismatches in expectations between what was ordered and what and when medications were actually administered. Finally, BCMA originally required an inefficient, complex process to change automatically documented medication administration information, and in some cases, blocked users from changing the information. Modifications made it easier to adjust the status of some automatically documented information, such as changing a medication's administration status from given to refused.

Strategy #4. Support "sacrifice decisions"

One of the hallmarks of a highly resilient organization is that individuals feel supported in deviating from a planned path associated with high productivity for a path that "sacrifices" productivity in order to avoid a potential threat to safety, even when in hindsight there was no need to deviate. For example, in the recent Columbia space shuttle accident, engineers missed that foam hitting the wing could damage the integrity of the aircraft. The concern is not about whether foam hitting the wing had been investigated for its effects during landing. The concern is to model the ability to back off when a practitioner feels like they are near a safety boundary and to monitor how well the organization has mapped and updated the safety boundaries. For example, in this case, NASA did not monitor the range of what had been tested to see if it needed to be broadened.

It does not matter if organizational decision makers are accurate in their sensitivity to risks in this framing – what matters is the degrees of freedom available to them to deviate from an expected path. Managers are often seen as meta-monitors who might override the astronauts, thereby reducing the ability. Or they might ask the astronaut if he's a "go". Or there might be a policy that any team member can hold veto power on a "go" kind of decision. Accuracy and criteria are two different parameters. The pilot might be wrong or right, but if you NEVER see anyone back off on a decision within an organization, that is evidence of a criterion setting.

In a sense, the use of Bar Code Medication Administration (BCMA) could be viewed as a sacrifice decision because productivity was chosen to be reduced in order to improve safety. Pragmatically, however, decisions made at top levels of an organizational hierarchy do not always "trickle down". Several hospitals clearly supported the use of BCMA by purchasing additional equipment, allocating staff to maintenance and continued improvement, and identifying barriers to intended use such as scanners tethered to large, unwieldy medication carts. Similarly, some gaps in the system design, such as the inability for nursing aides to document the administration of creams and ointments in BCMA, were addressed in ways that reduced productivity or increased costs, such as by creating dedicated laptops for nursing aides or by creating a paper form for ointment administration data. Less resilient approaches taken due to productivity considerations included asking nurses to document the administration of all ointments without verifying if and when they were actually given.

Strategy #5. Monitor the gap between standard operating procedures and actual practice

One frequently cited contributor to accidents is the failure to follow standard operating procedures. Nevertheless, this contributor often ignores the empirical fact that the documented standard operating procedure and the actual practice often diverge. The standard operating procedure is a static image of work that is distanced from the event-driven, time-pressured local nature of continuously trading off priorities to meet sometimes conflicting goals. Although there will always be a gap between documented standard operating procedures and actual practice, highly resilient systems continuously monitor and work to reduce the gap. As the gap grows, predictions of how changes, such as new technologies, will impact work will be less grounded in an understanding of how work is accomplished. In addition, under production pressures, actual practices will drift towards increasing productivity at the cost of increasing risks of potentially catastrophic failures unless managers reinforce to practitioners the value of resisting this "drift towards failure" despite the lack of feedback that safety boundaries have eroded prior to failure.

We made 15 "best practice" recommendations with BCMA in order to narrow the gap between documented procedures and actual practice (Patterson et al., 2004). In some cases, we wanted to disseminate a procedure to all VHA hospitals. For example, we learned that patient wristbands in long-term care settings scan less reliably after several days of being worn and washed. Therefore, we explicitly recommended that all wristbands be replaced on a periodic, such as weekly, basis by clerks in long-term care settings, which was already being done in 4 of 16 VHA hospitals. In other cases, we wanted to have the documented procedure better reflect actual practice. For example, we learned that nurses routinely used printouts as overviews of the due medications during a medication pass in 15/16 VHA hospitals. Only 8 of these 15 hospitals had a policy documenting this practice.

Conclusion

In the final analysis, safety is not a commodity to be tabulated, it is a chronic value 'under our feet' that infuses all aspects of practice. *People create safety under resource and performance pressure* at all levels of the socio-technical system. They continually learn and adapt their activities in response to information about failure (Cook, 2001). Progress on safety ultimately comes from helping workers and managers create safety by helping them get information about the changing vulnerabilities and to innovate new means for adaptation.

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