Technology, work, and information flows: Lessons from the implementation of a wireless alert pager system

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Abstract

The combination of collaborative work practices and information technology affect the flow of information in clinical settings. The introduction of a new technology into these settings can change not only established work practices but also the information flows. In this paper, we examine the introduction of a wireless alerts pager in a surgical intensive care unit (SICU). Through a qualitative study, we analyze the effects that this new information tool had on both the work practices in the SICU and the information flow in the unit. We describe four challenges that SICU staff members faced with respect to the alerts pagers. We found that the pager provided new routes of information to SICU staff but in doing so disrupted existing work practices and information flows.
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1. Introduction

Information and information practices are at the heart of organizational work. For instance, computer users increasingly report that their primary daily activity is handling electronic mail—a means of moving information from one place to another [1]. Organizations are realizing the importance of providing the appropriate content, order, and structure of information to its workers [2]. Although the role of information in decision-making is well-known, it also plays a vital role in coordinating work activities and providing awareness of others' activities. Therefore, understanding "information work" [3] in organizations is the key to developing successful information management technologies and strategies.

We have been investigating the problems of information and work in the context of hospital care. For successful patient care, workers must have appropriate information when it is needed. Therefore, understanding how technologies and work practices affect *information flow* in healthcare settings is of growing importance. Although there is some disagreement about the precise meaning of the term information flow [4,5], we use it here to describe patterns of information movement in an organization. Flows of information connect the units of the hospital (OR, labs, and external physicians) and the members of each unit (nurses, physicians, pharmacists, and therapists). To understand how information flows are affected by the introduction of a new technology, we studied the adoption of a wireless alerts pager system.

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Medical informatics researchers are designing and implementing wireless technologies in various clinical settings [6]. Wireless technology is becoming a popular method for delivering patient-related information quickly to medical decision makers. Mobile devices linked to clinical information systems can provide real-time event notification to health-care workers [7–9]. These technologies hold the promise of improving information flow by providing users real-time notification of critical patient-care events. However, when introducing wireless tools, organizations often underestimate the impact these tools will have on users' work practices and consequently information flow. If a new technology provides little benefit and requires major disruptions in current practice, then health-care workers will resist the change. For example, the hierarchical structures of teaching hospitals support useful work practices such as residents and fellows attempting to deal with most patient-care problems before contacting an attending physician. This practice allows the attending physician to focus on the most critical patient-care issues, and allows the residents and fellows to take care of the rest. The introduction of wireless technology could affect these work practices. For instance, wireless technology can allow the attending physician to learn about a problem at the same time or before a resident or fellow. Although potentially beneficial for patients, such early notification changes the visibility of the residents and fellows' work. The same kind of hierarchical change could be ascribed to the simultaneous availability of data to all caregivers provided by an electronic clinical information system. However, a wireless alerting system can invoke more dramatic hierarchy changes because data is "pushed" to caregivers rather than being passively available on a video screen.

In this paper, we focus on the use of a wireless tool, an alphanumeric alerts pager, by staff working in a Surgical Intensive Care Unit (SICU) of a major teaching hospital. The alerts pager supports real-time notification of events including critical lab results, potential medication problems and critical patient trend information. Through a qualitative field study, we analyze the effects that this new information tool had on not only the work practices in the SICU but also on the information flows in the unit. The paper is organized as follows: in the next section, we discuss information flows and the role of pagers in hospitals. We then present an ethnographic field study of the adoption of a wireless alerts pager in a surgical intensive care unit. We describe four challenges that SICU staff members faced with respect to the alerts pagers. Next, we discuss how some challenges could be addressed by improving the wireless technology, but how other challenges are inherent to the nature of medical work. We conclude with some final thoughts concerning the importance of appropriately designing and implementing wireless technology in order to support information flows in people's daily work.

2. Information flow and pager use in hospitals

Hospitals and especially intensive care units are information-rich and information-driven environments. On a hour-by-hour, and even minute-by-minute basis, health-care workers must have the most up-to-date information in order to provide appropriate patient care [10]. The introduction of new technologies has, in many ways, improved the flow of information to the decision-makers; this improved flow in turn has facilitated critical health-care processes such as coordination of patient care activities in hospitals [11]. However, new technologies can also have negative consequences on information flows. For instance, in an implementation study of a hospital-wide information system, Bardram [12] found that the system did not support the information flow as well as an older planning board that was used in a radiology department of a Danish hospital. Therefore, the nurses would enter the information on the planning board and also in the system. This created double work for the nurses and was one of the reasons that the system was underutilized.

One tool that has been integrated into everyday use in hospitals and has affected the information flows in these settings is the pager. Pagers generally have two major roles in a hospital. First, they facilitate communication among staff members. Second, pagers serve as real-time clinical event notification mechanisms for hospital staff. In this role, an individual page notifies a user of a significant event and conveys relevant clinical information.

Pagers are key tools for keeping hospital staff members in touch with each other. In a study of clinical communication, Coiera [13] noted that the pager is a favorite tool of physicians when contacting each other because they can get an immediate response to a page. In related work, Coiera and Tombs [14] described the role of pagers and phones in the communication behavior of physicians and nurses in a general medicine department of a British hospital. They found that the mobility of the staff created communication patterns that resulted in an "interruptive" workplace, which lead to inefficiencies in work practice. They advocated better design of mobile technologies such as pagers to reduce these interruptions.

In addition to providing a communication mechanism for hospital staff, pagers tied to clinical information systems can automatically provide vital patient-related information to the staff. Although they used an early style PDA, Shabot and LoBue [9] were the first to send an alphanumeric text "alert" message directly to physicians from a clinical system, bypassing nurses, pharmacists, and laboratory technicians entirely. Their work showed

the viability of using wireless technology to transmit alphanumeric alerts directly to the responsible clinicians. Tate et al. [15] studied the use of pagers to send nurses patient-specific critical lab results from a hospital's clinical information system. Using system logs of alerts and questionnaires, the researchers concluded that without the pager, the nurses were unaware of the critical values the majority (67%) of the time. The pagers played a vital part in ensuring that the nurses were notified of essential patient lab information. Eisenstadt et al. [16,17] discussed the use of pagers as mechanisms to deliver clinical information to health-care workers. The researchers point to the mobility of these workers as major barrier that prevents them from receiving information in a timely manner without the use of wireless technology. They described the implementation and use of two-way alphanumeric pagers connected to a clinical event monitor as a way of dealing with the problem of mobile health-care workers. The pagers were assigned to interns and residents who were later surveyed on their use of the pagers. From the survey responses, the researchers determined that the interns and residents preferred receiving clinical alerts via the pager instead of through e-mail.

Although medical informatics researchers have studied the use of pagers, the impact of pagers specifically on users' work practices has generally been understudied. Yet, if we want to develop technology to support the flow of information as intended, we must understand the system's influence on the users' work [18].

In the next section, we present a field study of the use of a wireless alert pagers system in a surgical intensive care unit and its effect on the users' work practices and information flow.

3. Field study: the effects of wireless alert pagers on information flows in a surgical intensive care unit

3.1. Study methodology

We examined the alerts pager use in a surgical intensive care unit (SICU) of an 840-bed urban teaching hospital. The SICU consists of two 10-bed units each of which has the same technologies, staffing, and physical layout. It is an extremely busy unit with 19 of the 20 beds occupied on a daily basis. Patients stay in the unit an average of 5–6 days and are treated by a team of health-care workers. The SICU is also a complex technical environment. It is equipped with sophisticated equipment including digital physiological monitors, web-based applications [19], and a fully computerized patient record system [20]. In most cases, patients are in such critical condition that any minor change in their condition could have rapid and severe implications. The specialized equipment and staff in the SICU allows early detection of even small changes in a patient's condition, thus permitting rapid changes in treatment to prevent problems from developing.

3.1.1. Subjects

At the time of the study, the wireless pager was only used by the SICU faculty, house staff, and pharmacist; we interviewed all the pager users at that time. We focused on the SICU faculty and house staff because they dealt with the majority of the alerts. Each subject had been using the wireless pager for at least three months prior to the study. The unit also had a full-time pharmacist assigned to it. We interviewed her because she carried the alerts pager to follow patient medication problems. As the study progressed, interviews with SICU nurses, and the hospital information systems department were used to elaborate our understanding of the broader impact and system implementation details. Although, the nurses did not use the pager, their work and roles were also affected by its introduction.

The subjects included:

- Surgical residents (4)
- Surgical fellows (2)
- Surgical attending physicians (4)
- SICU nurses (3)
- SICU pharmacist (1)

3.1.2. Methods

We employed qualitative methods such as formal semi-structured interviews and observations utilized in other medical informatics studies of technology use [21]. The first author conducted the interviews and observations over a three-month period. This study and all study related activities were approved by the Institutional Review Board at the field site.

3.1.3. Formal semi-structured interviews

The interviews were used to identify physicians' perceptions of the alerts pager. Each of the interviews lasted 30–60 min. The subjects were asked about their views of the wireless alerts pager and its impact on their work. We also interviewed nurses and the pharmacist in the SICU about their views of the pager's affect on their work. Finally, we interviewed members of the hospital's information systems department to understand the design of the alerts system. The information systems department helped design the alerts system and played an important role in modifying it. The interviews were taped and transcribed.

3.1.4. Observations

The observations were conducted as part of a larger study of information seeking behavior of health-care workers in the SICU. The subjects were shadowed

during morning rounds over a three-month period. Morning rounds lasted approximately 2.5 h. Although the majority of the observations were taken during morning rounds, the researcher also shadowed individual residents and faculty members during other periods of the day. During this time, the researcher recorded, as part of the observations, incidents of pager use. These incidents allowed us to witness the effects of pager use on physicians' and nurses' work practices. The observations also played an important role in controlling for positive impression bias that many subjects often have of relatively new technology.

3.1.5. Analysis

The data were analyzed using grounded theory (GT) [22]. The underlying assumption of GT is that a deep understanding of social phenomena can only occur from real-world observations. GT is a set of methods for analyzing qualitative data like interviews and observations. GT foregrounds this data and helps create an evolving hypothesis through systematic coding of the data[1]. In the course of this coding, patterns become visible giving rise to hypotheses that in turn are strengthened or dismissed through further coding of the data and, in some cases additional data collection. The strength of GT lies in the interaction between the data collection and the coding. The coding is a continual process that occurs not at the end of the data collection but during it; categories (e.g., themes or variables) *emerge* from the data and are strengthened, modified, or discarded as more data is collected. GT techniques were used to identify categories of interactions and work as they emerged from the data.

The observations and interviews were recorded and transcribed as the data was collected. The transcripts were more than 100 pages. As we reviewed the transcripts, certain categories emerged. The lower-level categories included: (a) residents' perspectives of the wireless pager (b) impact of the wireless pager on information flows and (c) physician–nurse interactions. As we examined the data, we attempted to identify incidents related to the pager use. Once we identified an incident, we then classified it in these lower level categories. The lower-level categories were then examined for overlaps and combined together when overlaps were found. In this paper, we present these higher level categories that dealt with challenges.

Although observation of pager use was limited to the SICU, we believe that this study highlights challenges

that many healthcare workers face in using wireless technology.

3.2. Wireless alert pager

The SICU physicians and pharmacist carry alphanumeric pagers (Fig. 1) that automatically notify them of certain critical events as soon as the information is entered into the computerized patient record [23,24]. For example, the alerting system provides critical laboratory alerts. It sends the critical values as an e-mail to the alerts pagers carried by the SICU physicians. The pager also provides other types of alerts:

- Critical trend alerts—checks lab values over time to determine if critical trends exist.
- Dynamically adjusted alerts—checks patient physiologic data to ensure that alerts are only triggered when appropriate.
- "Exception condition" alerts—checks for combination of events at one time or over time, or extraordinary single events.
- Medication alerts—checks medication orders against physiologic and lab data for evidence of adverse drug effects. (The SICU pharmacist follows these alerts closely.)
- Allergy alerts—checks medications orders against the patient's allergy list.

Pagers are assigned to individual physicians and the SICU pharmacist. Each pager has a unique identification number.

3.2.1. SICU wireless expectations

SICU physicians closely monitor patient information ranging from lab results to physiological trends. Traditional information flow requires a significant nursing role; a nurse typically informs the physicians of changes in the patient results. For instance, critical lab values are phoned to the nurse by the lab because of regulatory reasons. At the same time, the lab alert messages are posted to the electronic patient record (EPR) (Fig. 2A). However, if the SICU is busy, nurses might delay notifying the physician about important patient information. The introduction of the alerts pager attempted to change the flow of information by providing physicians with automatic, real-time notifications. The introduction of the pager was designed to alleviate a major concern in the SICU: nurses forgetting to provide physicians with important information because they are too busy. In Fig. 2B, the same lab alert now also goes to the physician. The nurse may still notify the physician but the physician should also have the information at the same time as the nurse gets it. In addition, the algorithms utilized by the alerting system may detect trends or subtle (but serious) interactions between physiologic

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Fig. 1. An example of a wireless alerts pager displaying a combined medication-trend alert.
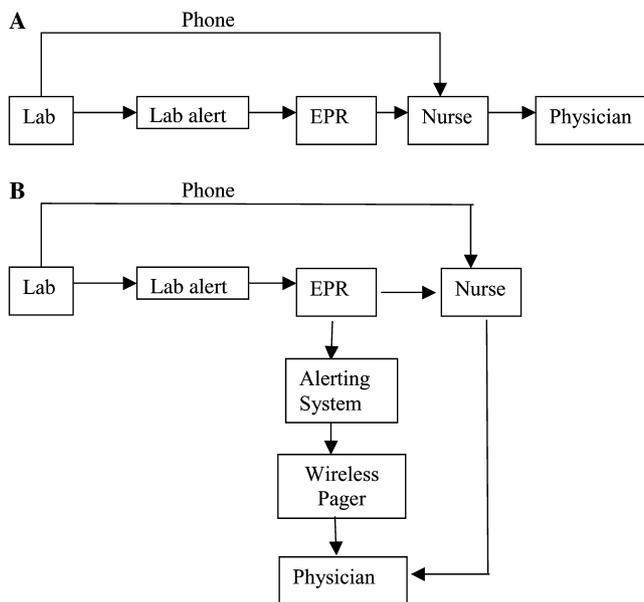

Fig. 2. (A) Depicts the traditional information flow for an abnormal lab result in the unit. (B) Depicts the new information flow for an abnormal lab result.

parameters that nurses may not notice during an 8 or 12 h nursing shift. For instance, the allergy alerting logic detects allergies missed by nurses or pharmacists, who enter all new medication orders into the patient's computerized Medication Administration Record. The pager allows physicians to learn about vital patient information and critical events without having to call the lab or ask a nurse.

Most SICU physicians like using wireless technology in their daily work. One SICU physician stated, "In my version of the future, there is going to be a lot more wireless [use] than we had been able to do in the past." Most of the physicians interviewed believed that wireless technology will promote:

- better collaboration
- quicker event notification
- delivery of more accurate information regarding critical events.

The physicians use the alerts pagers to receive real-time notification of patient-related critical events. This real-time notification provides physicians with novel support for making patient care decisions.

The pager use has changed some physicians' views of how the staff should take care of patients. Because of the change in the information flow, one attending thought that pagers made the staff more "proactive" instead of "reactive" in patient care. He stated,

The pager allows the staff [residents, fellows, and attendings] to react to problems as soon as they are spotted. Instead of waiting for the problem to develop, we can now deal with it sooner.

Instead of waiting for nurses to notify them of abnormal results and subsequent problems, the fellows and residents must decide whether the alert requires immediate attention. Although the ICU nurses did not use the pagers during this study, they thought that the pagers

could potentially help them with their work. As one nurse stated, "It [the pager] could save us some time in notifying physicians about potential problems." Subsequent to this study, the ICU nurses requested and received an alerts pager that is carried by the nurse in charge on each shift.

The SICU pharmacist used the alerts pager to keep track of medication problems that patients may face in the unit. Because patients in the unit were often on multiple medications, the pharmacist had to constantly monitor different medications for different patients. She felt that the pager helped her more effectively do her work.

It [the pager] is actually a good tool for me to prioritize my work. It would electronically send out all the drug levels associated with the [medication] orders. I would use that to screen all these results. Then I determine whether I needed to follow-up something quickly or not. It also indicates real-time critical lab alerts. I no longer have to depend on a manual process to inform me that some critical count has dropped significantly.

Although the pager provided many benefits to the SICU staff, the house staff and attendings did face challenges in using the pager. It also created an unexpected challenge for the nurses in their daily work. In the next section, we discuss four of these challenges.

3.3. Challenges to use and effects on information flows

The SICU staff who participated in the study expressed a generally positive view of the wireless technologies. However, our observations and questions reveal challenges to the use of the pager. These challenges affected the information flow in the unit.

3.3.1. Challenge 1: Loss of hierarchal context

Wireless technologies can lower or remove boundaries among levels of a hierarchy. In some cases, lowering boundaries can facilitate collaboration and improve information flow. For example, the hospital has a web-based paging system. Any employee using this website can send an e-mail to the pagers of other hospital staff members, including those up the hierarchy. By lowering the hierarchical barriers, employees can notify the necessary individuals about important problems. However, removing hierarchical boundaries can have unintended negative consequences.

Traditionally, a nurse notifies a resident when critical results are returned from the lab. The resident either takes corrective action or notifies an ICU Fellow. Similarly, the Fellow either acts or notifies the attending physician. Residents and Fellows often solve simple problems without bothering the attending physician. Thus, following the traditional flow of information,

when an attending physician is notified, he or she knows that the problem is important and needs immediate attention.

In contrast, the alerts paging system was designed to broadcast the critical lab values to all SICU physicians at the same time. This design decision had both positive and negative consequences. On one hand, this simultaneous notification ensures that all the physicians are all aware of the alert. Yet, at the same time, this new information flow causes an associated loss of control that moving issues up the hierarchy provides. With simultaneous notification, it is more difficult for residents to fellows to solve a problem before the attending physician learns about it. Residents and Fellows no longer "control" the bad news (severely abnormal labs, adverse physiologic events, or medication problems) that in former times they relayed to the attending physician. Simultaneous notification also changes the context of the problem for the attending physician. The importance derived from a notification moving up the hierarchy to the attending physician is lost. One attending stated that he "only wants to be notified when there is a problem." However, the alerts pager notified him of incidences that a resident or fellow could easily handle.

Although the main goal of better patient care may be improved by simultaneously delivering information to all levels of the hierarchy, the alerts pager changes the role that the traditional physician hierarchy plays in providing context concerning the importance of specific clinical events.

3.3.2. Challenge 2: Unidirectional nature of information flow

The unidirectional nature of the alerts pager prevents the physician from using it to respond to problems. In the alerts pager system we studied, the flow of information was only in one direction. For example, a physician using a pager may notice that a patient's blood pressure trend has been abnormally high. In this situation, the physician might want to order a medication to lower the blood pressure. Because the physician cannot order the medication through the pager, he must call the ICU and verbally order it. An attending physician noted that just viewing the data is half the job because "you also need to have a mechanism to respond to the problem."

Furthermore, when an attending physician is notified of a problem by a pager, she wants to ensure that the problem is actively investigated and resolved, but at the same time does not want to interfere with the resident's work. For instance, the alerts pager will notify the attending physician when a critical lab result occurs, but the pager does not provide notification that a resident has taken action to deal with the problem. Therefore, the attending does not know if anyone has addressed the problem unless she calls and asks the

resident. Unfortunately, the resident might interpret such a call as a sign of distrust. One attending physician stated, "as an attending, you don't want to miss anything but you also need to trust the residents." An attending physician has to balance patient care requirements with the autonomy that residents require to learn their skills.

The pager's lack of feedback mechanisms can make it more difficult for attending physicians to maintain this balance. One frequently used solution is for the attending physician to check in the computerized patient record system for orders or progress notes that indicate the problem has been dealt with. However, this solution only partially addresses the challenge.

3.3.3. Challenge 3: Information overload and missing context

Another challenge of wireless technology is to provide appropriate information context without inundating users with too much information or overloading the network.

Physicians are concerned about the number of alerts that they receive from the alert pager. On average, the system produces 16 total alerts a day in the SICU [23]. However, the pagers do not provide a prioritization mechanism for determining the importance of these alerts: all the alerts look equally important. The number of notifications combined with the lack of prioritization can create information overload. One physician stated that he received too many notifications throughout the night about results that he considered unimportant.

You got too many pages that really don't correlate with anything that is going on... because it tells you abnormal values but it may not be critical values even though that's what it is meant for.

In this respect, the alerts pager reduces the individual's ability to attend to specific notifications by ineffectually differentiating the importance of one notification from another.

The alerts pager also provides limited context. The small screen size and bandwidth limits the pager's ability to provide context. Traditionally, a nurse would page a physician and when the physician called back the nurse would tell the physician the problem. If the physician needed additional information, nurses could provide that information. The physician could then make the necessary patient-care decisions. The pager provides patient information but without the heavily contextualized information provided by a nurse. Thus, the physician might still have to contact the nurse to get needed contextualized information.

The alerts pager has provided physicians with better notification mechanisms than they have had in the past, but the pager does not always provide the context necessary for the physicians to make their complete decisions.

3.3.4. Challenge 4: Disruption of organizational roles

A fourth challenge for the system is the disruption it causes in the traditional roles that nurses play in the information flow.

Nurses play a vital role in providing information to the SICU physicians about anything patient related [20]. Due to their low patient load in the SICU (1–2 patients per nurse), the nurses are expected to closely monitor all facets of patient care including monitoring for any critical alerts concerning the patient. Prior to the implementation of the wireless alerts pager, the nurses were usually the ones who first noticed a critical alert about the patient's condition. As one nurse stated,

Part of our job is to follow the patient's condition and let the doctor know when something is happening that needs his immediate attention. A lot of times the doctor is too busy to know everything that is going on with the patient.

Thus, in the traditional information flow, the nurse, after receiving the critical alert would page a physician and when the physician called back the nurse would tell the physician the problem. If the physician needed additional information, the nurse could provide that information. However, the introduction of the wireless alerts pager disrupts the nurse's job by providing physicians with the alerts at the same time that the nurses had access to the information. This situation creates a challenge for the nurses. One of the nurse's responsibilities is to keep the physicians informed of important information relating to the patient. If the nurses failed to notify the physicians, they were often reprimanded. Therefore, even after the introduction of the alerts pager, a nurse will often still contact a physician to let her know about a critical alert because the nurse is not aware of whether the physician received or reviewed the pager alert. From a nurse's perspective, she is doing her job of keeping the physician informed. As one nurse clearly articulated

I need to make sure that I'm doing my job and that no-one yells at me for not keeping them informed. I don't know whether they received a page or not. I'd rather annoy them with an extra phone call than get yelled at for not letting them know.

However, one of the goals of the alert pager is to relive the nurses of this notification duty. Yet, from a nurse's perspective, one of her primary roles is to provide physicians with the necessary information. Therefore, the nurses were reluctant to stop letting the physicians know about the critical alerts even with use of the pager. This continuing notification, while in some sense useful as a back-up mechanism, still meant that

the nurses were doing work that was already done. The pager did not relieve the nurses of this duty as intended because of the mismatch between the pager goals and institutionalized work activities of the nurses.

4. Discussion

The alerts pager provides SICU physicians and pharmacist with greater access to important patient information. The pager creates a new flow of information that allows SICU staff to react quicker to changes in a patient's condition. Yet, it also alters the well-established work practices in the SICU. In the previous section, we described four challenges that SICU staff members faced with the pager and the pager's affect on the work practices and information flows in the SICU. In this section, we discuss how some challenges could be addressed by improving the wireless technology, but how other challenges are inherent to the nature of medical work.

4.1. Redesigning the technologies

Technical design changes and further integration with existing systems could help deal with some of the challenges faced by the SICU staff. For instance, technical advances in pager design may reduce information overload. Newer pagers can be programmed to produce different tones and/or vibrations for different alert messages, based on the contents of each message. A simple alert mark-up language would allow these pagers to differentiate the importance of one notification from another. Other technical advances such as two-way pagers and alert records can also improve the challenges faced by the users.

4.1.1. Two-way pagers

One technical advance, the use of two-way pagers, could address some of these challenges. Two way pagers could provide some of the feedback that is missing on both the system and physician levels with one-way pagers. With a one-way pager, the transmitting system sends the message once and has no way to know if it is received. If a pager is turned off or out of range, the message will not be received and is lost "without a trace." In contrast, a two-way paging system can provide three important forms of feedback. First, the receiving pager can automatically send a confirming "message received" signal back to the transmitter when the message is successfully received. Two-way pagers can also send a separate and unique "message read" back to the transmitter when the user brings the message into view on the pager's screen. Finally, two-way pagers can allow physicians to provide direct feedback to other caregivers via the pager to alerts they have received. For example, when an attending physician receives an alert concerning a patient's critical result, he could send a page directly to the resident treating the patient with advice on how to deal with the problem. Two-way pagers also could maintain the benefits of the hierarchical work structure. Because each pager has a unique ID, the system could designate a physician alert hierarchy. Using the unique pager ID and a two-way pager, the system can send alerts to the residents first and then escalate the alert to the fellow or attending if the resident does not respond within a given time. This escalation could be based on multiple criteria, including (1) the severity of the alert; (2) the alert message being received successfully; (3) the alert message being read; and (4) the recipient of the alert responding in a purposeful way.

Sophisticated use of two-way pagers could reduce some disruptions to the staffs work practices and to the traditional flow of information. The information systems team at the hospital is incorporating two-way pagers into the alert system, and has a system in limited use [23].

4.1.2. Alert record

Although the patient conditions that trigger an alert are formally part of the patient record (e.g., lab results, blood pressure reading, etc.), the specific trigger thresholds, when the alert went out, and the response associated with the specific alert are not. The addition of an alert record to the patient record would actually facilitate two things. First, it could facilitate better awareness in the team. Nurses in the SICU could see when an alert was sent, to whom it was sent, and for what conditions. The level of escalation afforded by two-way pagers could also be recorded in the alert record. This level of awareness would allow them to make choices about when to send additional pages to a resident or an attending. As well, it would enable attending physicians and Fellows to see the state of the unit (e.g., how many critical problems are on-going right now?); similar to the awareness that patient status boards and charts have facilitated in the past. Second, the addition of an alert record, combined with two-way pagers, enables a level of traceability. Actions that a resident takes through the two-way pager could be associated with specific alerts. These actions, most of which already appear in the patient record, would be more directly attached to events that the system detects, providing better awareness for the team than the pager system we studied.

4.2. Social and organizational considerations

However, technically redesigning aspects of the system might not resolve all the challenges. One of the implicit goals of the alert pager was to re-organize the work to improve the flow of information to caregivers. However, this goal can conflict with day-to-day collaborative interaction and the roles of the nurses. The information-intensive

nature of medical work requires interaction between caregivers that pagers cannot replace.

4.2.1. Collaborative communication

Effective collaboration is often based on everyday interaction skills. A verbal request for help can be acknowledged in many ways with a gesture, a glance, action or verbal response. Taking this perspective on the alert pager is valuable. The current design of the alert pager pushes what had been a somewhat detailed verbal collaboration over the phone into a new medium. Now, instead of a nurse opening a phone-based collaboration, the alert is broadcast to a wide range of staff. This creates a situation where a communication opening is made, but the acknowledgement or closing is unclear.

The prior section suggests technical solutions to the specific technical problems of one-way paging systems. However, we recognize that even a new, more capable, technical solution is fundamentally altering the social expectations of collaborative communications. Any redesign of the alert pager should identify and help close the loop between the initiation of a communication and the social closing that indicates that the underlying problem was resolved.

4.2.2. Organizational expectations

The pagers have begun to replace some of the notification duties typically expected of nurses. Yet, as discussed in the challenges section, notification is an important aspect of a nurse's job. To fully integrate the pager into the unit, the expectation surrounding the nurses' notification role has to be changed. The nurses must know that they will not be reprimanded if they do not pass on the clinical alerts to the physicians. Otherwise, the nurses are placed in an untenable position of seeming to obstruct the attempt at re-organizing the work and information and yet still held accountable for their traditional information roles. Two-way pagers and incorporation of feedback information with an alert record in the electronic chart will help alleviate some of these concerns. However, we must also recognize that automated alert paging in any form will affect and disrupt the traditional hierarchy of various caregivers sequentially moving critical information ''uphill,'' to the attending physician. Ultimately, critical information needs to be moved swiftly to a physician or other caregiver who can and will take action.

Even if the pager does completely replace the notification aspects of the nurse's job, it cannot replace other aspects of the nurse's information providing role. Nurses use their experience to provide important contextualizing information about patients that a pager cannot provide (e.g., interpreting a patient's verbal response to medication). As one resident stated, the nurses can ''tell you how the patient is looking and the pager can't

do that.'' Improving the pager's ability to provide better contextualizing information will still leave large information gaps that require the nurse's input. Although wireless technologies such as personal data assistants (PDAs) and mobile computers [7,8] provide greater access to information than the smaller-screen pagers, they still cannot provide the rich and varied details given to physicians by nurses.

4.3. Study limitations

In a qualitative study, it is often impossible to observe participants a 100% of the time. Therefore, we conducted extensive observations during morning rounds and then sampled other time periods to make certain that we are not 'seeing' something out of the ordinary. Then as further triangulation we used the observations to frame interview questions and prompted the participants to fill in issues which might not have been covered in an observation period (largely because the participant has more experience and more 'observations' than the researcher). So, although we did conduct much of our observations during morning rounds, the participant interviews combined with observations during other time periods provided us with insights about pager use throughout the day.

A second limitation is the nature of early use studies. Often, in these studies, people will either have an extremely positive or an extremely negative view of the recently implemented technology. In the interviews, the subjects often voice these extreme views. We have addressed this issue by the use of multiple methods (e.g., interviews and observations). We triangulated our interview results with observations and vice versa. This approach allowed us to present a balanced portrayal of pager use in the SICU.

5. Conclusions

Wireless technologies such as the alert pager are still novel technologies for most hospitals. In our research site, pagers provided physicians and other health-care workers real-time notification of critical events in a way that was impossible less than a decade ago. This real-time notification has changed the flow of information in the unit. Often, it has allowed clinicians to improve the quality of care for patients by responding faster to problems. However, it also disrupted the work practices within the institution, which could affect the quality of care. Although, the design and implementation of the alert pager technology is important, we must also pay close attention to the impact of the technology on the work practices of health-care providers. For instance, simultaneous paging of multiple caregivers tends to ''flatten'' the traditional hierarchy of medical infor-

mation flow, in much the same way that email has flattened communications in large organizations.

This early use study has served to reinforce several important aspects that need to be considered when designing any type of wireless technologies. First, developers must understand the *work* of health-care providers because introducing wireless technologies will affect the work and information flow in the organization. Second, because of the collaborative nature of medical work, wireless technologies must support multi-directional interaction between health-care providers because the flow of information needs to be multi-directional. Finally, the limitations of the wireless technologies must be clearly understood.

Wireless technologies provide tools that enhance the healthcare workers decision-making capabilities, create new information flows, and improve patient care. Although technology can change existing work practices, it is difficult to envision wireless technology rapidly changing the institutionalized nature of medical work. Therefore, as these wireless innovations are being introduced, we must ensure that they support existing work activities and information needs.

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