Patient Care and Safety at the Frontlines:

Nurses' Experiences with Wireless Computing

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Abstract

This research provides insights into the efficacy, efficiency and issues surrounding use of wireless patient-care tracking devices in hospital settings. Based on interviews with 43 nurses, organizational managers, and information systems professionals directly involved in wireless computing at three U.S. hospitals, the study documents nurses' expectations, experiences and refinement suggestions. Participating hospitals ranged from 124 to nearly 500 beds.

The authors comment on quality-of-care implementation drivers, such as enhanced patient safety and reduced caregiver error; wireless system acceptance and usage characteristics and obstacles; and actual performance impact. They conclude that wireless computing has tremendous potential for improving care despite existing constraints. Recommendations include detailed suggestions for upgrading current and planned deployments, as well as for extending the technology's promise to other hospital departments starved for real-time patient information.

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Executive Summary

Patient safety is now a primary concern in United States hospitals. The U.S. Institute of Medicine has reported that nearly 98,000 people die each year due to medical error. Yet many grievous mistakes almost certainly could be avoided with faster, more comprehensive, more accessible patient documentation at the point of care.

An increasing number of hospitals are responding by implementing wireless computer systems. Such systems can help reduce caregiver error, streamline convoluted processes and ease hospital staff workloads by providing ready access to current, comprehensive patient information. At the same time, wireless units — which interface with a central medical database — enable hospital staff to record test results, diagnoses, medications and treatments quickly and easily as they are providing care. In contrast, caretakers typically have been required to handwrite notes quickly or enter information into a computer later on, both error-prone and labor-intensive procedures.

Industry analyst Gartner Healthcare reported that in 2002, less than one-third of all U.S. hospitals had operational wireless local area networks (WLANs) in at least one department. That situation may be changing quickly. WLAN vendors have targeted hospitals, which tend to have highly decentralized operations, as a key market, and hospitals clearly are interested. The Frost and Sullivan market research firm predicts strong growth for the hospital market (i.e., reaching nearly $175.1 million in sales by 2005) (Geire, et.al, 2003). A 2003 survey conducted by the Healthcare Information and Management Society (HIMSS) noted that 72% of chief information officers surveyed indicated hospitals that already use wireless systems anticipate expanding them into multiple departments.

Despite this escalating momentum, there has been relatively little academic examination of caretakers' practical, hands-on experiences with wireless computing. This study attempts to address that gap by exploring the efficacy, efficiency and issues of WLAN implementations — including system acceptance, use and performance impacts — at three U.S. hospitals. The goal is to provide insights, based on in-depth interviews, from the perspective of nurses, organizational managers, and information systems professionals directly involved in implementation processes.

Participating hospitals ranged from 124 to nearly 500 beds. All are public entities in the Southeastern U.S., although each has different medical specialties and serves a different type of patient base. Research was conducted between November 2002 and March 2004.

This paper focuses on the practical implications of deploying WLANs to help transform hospitals into safer, more efficient, and more effective institutions. Research include overviews of wireless technology and federal regulatory mandates; actual research findings; and recommendations WLAN implementation and use in patient registration, ongoing charting and medication administration. Our findings demonstrate that wireless computing can strengthen ties between patients and caregivers by allowing more time for conversation, among other significant benefits. At the same time, WLANs are not without meaningful adoption and usage issues.

In summary, the findings are:

- Wireless computing
  - provides nurses with essential information at the point of care.
  - helps nurses create comprehensive, readily accessible records.
  - increases in value when systems support "exception charting" to facilitate detailed record-keeping, reduce charting time and enhance readability.
- System usability and performance
  - are influenced by task environments, such as the frequency and nature of distractions, state of patient consciousness, and rate of patient turnover.
  - benefit from certain hardware characteristics, such as computer cart mobility and multiple-use features. But they suffer from others, such as inadequate battery life for wireless devices or poor software design.
- Wireless-driven processes
  - reduce nurses' charting time and anxiety, enabling them to stay longer with patients and chart on multiple patients simultaneously.
  - may be impeded by nurses' lack of typing skills, genre and recency of professional training, or technology aversion.

- Benefits include
  - reduced time required to validate questionable drug prescriptions and medical interventions, which can delay patient care.
  - greater ability for hospitals to defend against accusations of, and liability for, negligent care.
  - easier and more timely quality assurance for processes and verification associated with patient care.
  - greater ability for registration personnel and nurses to maintain patient confidentiality by silently reviewing existing information.
  - better, more personal relationships between patients and caregivers.
- Limitations include
  - inability to generate desired benefits when technologies such as document and label printing and copying are not "bundled" together with wireless computing units on a mobile workstation.
  - varied acceptance and frequency of use of the wireless information system, which not only differ based on the environment, but also on
    - the actual patient care task performed
    - nurses' need to bond with the patient
    - necessity to learn about the patient, and
    - nature or the task (i.e., diagnosis or treatment.)
    - nurses' desire to defend themselves from liability.

As a result, we recommend that:

- Nursing education programs should integrate electronic patient care documentation into existing curricula immediately.
- Hospital management should use technology as a recruiting and retention tool.
- Hospitals management should create a culture, including a nurse vision statement, emphasizing the benefits of nurses' involvement in technology.
- Hospital IT departments should support development and/or adaptation of wearable devices and multi-function mobile carts by manufacturers to support wireless use.
- Hospital IT departments should physically integrate documentation devices (e.g., scanning, label and document printing) to support ease of use.
- Hospital management should extend wireless use to other tasks that are location-, time-, identity- or inter-dependent, and/or are highly information-intensive.
- Hospital management should institute thorough wireless training for nurses prior to introducing the technology.
- Hospital management should incorporate automated patient and medication identification to ensure nurses are charting on the correct patient.

Research also revealed that, as with virtually all technology deployments, wireless computing does not adopt itself. Hospitals must encourage nurses' involvement in system development — including choice of physical devices, development of interface tools, and refinement of usage processes — for WLAN implementations to succeed. Institutions also must provide training courses, during working hours that do not require nurses to wedge in regular floor duties concurrently. Finally, information systems managers must create a supportive environment for nurses, who often lack experience with computers and have limited or no typing skills.

Under those circumstances, wireless computing can help reduce documentation errors and preparation time while improving information caliber and nurses' working environments. Hospitals that embrace wireless information systems can increase patient safety across a wide range of caregivers, departments and responsibilities. By collecting and delivering vital information when and where it's needed most — at the point of care — hospitals streamline inefficient processes and reduce life-threatening consequences of serious caregiver errors.

Introduction

Improving patient safety and quality of care are among the nation's primary healthcare concerns. A 2000 study by the United States Institute of Medicine (IOM) entitled "To Err Is Human: Building a Safer Health System" reported that as many as 98,000 Americans may die due to medical errors during hospitalization each year[1].

While such tragedies tend to have multiple, inter-related causes, nurses – with their integral role in every stage of hospital healthcare – clearly play a crucial role. Federal funding cuts have impaired many public hospitals' abilities to deliver optimal care. Nurses frequently are confronted by overwhelming workloads and low salaries relative to their skill levels. Yet many receive little additional technological or logistical support that could help them perform crucial activities more readily.

At the same time, the supply of qualified nurses is shrinking rapidly. Estimates are that by 2020, there will be a shortage of at least 400,000 nurses in the US (Buerhaus, et.al, 2003). Overtaxed nurses, already working longer shifts, will be required to assume even more responsibilities to compensate for inadequate staffing. Health policy experts, nursing advocates, and nurses themselves state the situation increases the likelihood of caregiver errors, sharply compromising patient safety (Bass, 2002). The impending crisis may endanger patients nationwide unless definitive steps are quickly taken by hospitals, healthcare regulatory bodies, and nursing education institutions (Joint Commission on Accreditation of Healthcare Organizations, 2004).

Such errors may be exacerbated by inadequate means to access, record and manipulate crucial patient data at the point of care (IOM, 2001). This dire situation springs from outdated data management and transmission systems, often compounded by the existence of separate databases for different patient care functions. Such "data stovepipes" typically are unable to communicate with one another, preventing users from sharing valuable patient information across hospital departments and functions.

In fact, a 2001 IOM follow-up report noted the urgent need for hospitals to automate clinical information and make that information readily accessible to patients and their healthcare teams. Called "Crossing the Quality Chasm: A New Health System for the 21st Century", the report stated that "an improved information infrastructure is needed to establish effective and timely communication among clinicians and between patients and clinicians." (IOM, 2001, pg. 12; most recent IOM study as of this paper's publication.)

Meanwhile, the Department of Health and Human Services (DHHS) in 1996 encouraged hospitals and healthcare providers to automate processes and increase critical data availability at the point of care. (Such systems must be in accordance with the US Health Insurance Portability and Accountability Act of 1996 and the Institute of Electrical and Electronics Engineers (IEEE) electromagnetic compatibility (EMC) standards.)

Wireless Systems: A High-Potential Solution

Wireless technologies, which deliver broad, deep information access and efficiency, clearly can help address both data frustrations and nursing shortages. "As mobile professionals, healthcare providers are required often to make immediate, life-critical decisions away from a stationary information resource (Mobile CommerceNet 2001, pg. 3)."

Wireless computing is defined as the use of computer networks, constructed with wireless technologies, to support personalized, uninterrupted communications and transactions between an organization and its various stakeholders. Remote access, as clearly demonstrated by the ubiquitous access to information from wireless devices among mobile workers, considerably enhances value over that of traditional information systems (Watson, et al., 2002). In a hospital setting, wireless computing can enable physicians and nurses to access essential patient information, and to make critical decisions, at the point of care.

Industry analyst firm Gartner Healthcare estimated that in 2002, nearly one-third of all U.S. hospitals had deployed wireless LANs (WLANs) in at least one department. In a Healthcare Information and Management Systems Society (HIMSS) survey of hospital chief information officers (CIOs), 72% of respondents stated their facilities used some form of wireless information system. In addition, nearly two-thirds of healthcare business-technology executives reported plans to include wireless computing devices among their 2004 IT projects, according to 50 healthcare companies that participated

in the InformationWeek "Research Outlook 2004: Priorities 1Q Study" (McGee, 2004). The responses suggest that CIOs and hospital administrators recognize wireless computing's real advantages in healthcare environments.

Healthcare professionals interviewed for this study observed that, because nurses provide the bulk of patient care, physicians, therapists, technicians and others involved in care benefit from tools that increase nurses' efficiency and effectiveness. Wireless computing provides nurses with capabilities that ideally mesh with nursing tasks, in the way those tasks are performed, at the point information is needed most. In respondents' views, wireless systems should be the tool of choice in the never-ending struggle to upgrade patient safety and quality of care.

Study Approach

Wireless computing can improve task efficiency and effectiveness by decreasing laborious hand-documentation. In addition, the technology can increase ability to assimilate critical information, particularly in stressful work environments like those in which nurses operate. (Watson, et al., 2002). The following research examines wireless technology implementations in various departments at three public hospitals. The goal: to discover nursing safety and quality-of-care performance impacts, including potential for reduced documentation errors, reduced time requirements that enable nurses to attend to patients longer, and effective medical knowledge use at the point of care.

The following concepts guided the formulation of interview questions:

- Values embodied by the intended user population that may promote or interfere with technology use, task efficiency, and task effectiveness. Resistance to change prompted by factors such as increased liability, technology aversion, lack of training and support, task complexity, and space constraints that may interfere with technology adoption and task performance;
- Changes in staff roles and decision-making structure due to the nature of wireless technology and resulting insecurity about usage; and
- Identification of other tasks well suited to wireless computing.

Patient Care Tasks Descriptions

The study tracked standard patient-care-related tasks: registration and triaging, electronic charting, and medication administration**.** Common characteristics include performance in multiple locations, time sensitivity, mandatory identification of nurse and patient for interaction, repeated involvement during a patient's hospital stay, and high dependency on knowledge of previous medical interventions and patient history.

Junglas (2003) provides dimensions that can be used to describe tasks of this nature, per the following figure and Table 1:

Figure 1 Task Cube (Junglas, 2003)

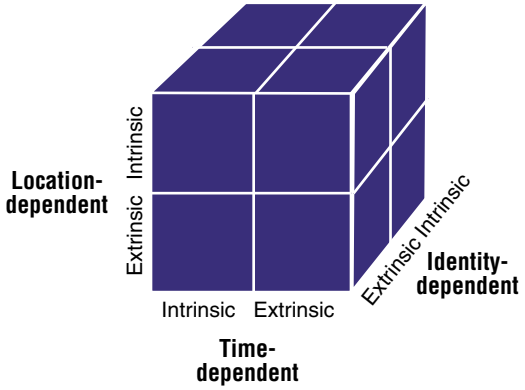
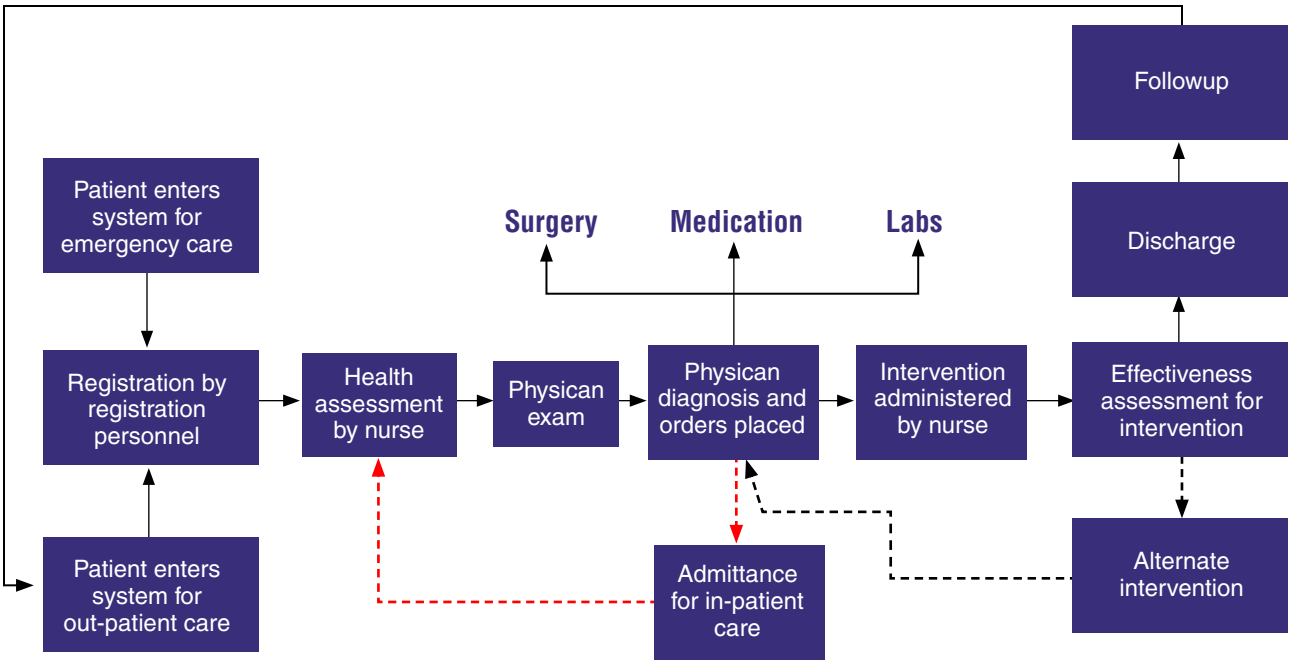


Table 1 Task Characteristics Appeased by Wireless Computing

Characteristics	Definition	Relevance to Patient Care
Location-dependent	Depending on the physical location of that being or thing for which the task is performed (Junglas, 2003)	Patient care is location-dependent (i.e., intrinsic) because technology must accompany a health worker to the point of care, which is dictated by the patient's physical location (i.e., extrinsic). Wired systems are not mobile; thus, the mobility afforded by wireless computing is unique.
Time- dependent	The requirement for the fulfillment of the task at critical times (Junglas, 2003)	Patient care is time-dependent because medication or medical interventions are prescribed at specific times during caregiver shifts (i.e., intrinsic – pertaining to required times that a task must be performed) and critical times for the patient (i.e., extrinsic – pertaining to required times that a task must be received). Patient care is time-sensitive in most cases (i.e., medication administration and charting for vitals at particular intervals). Alerts/reports can be built into a system and accessible, via wireless computing, to prevent caregivers from missing times for vital checks and to ensure when medications are or are not safe to administer.
Identity- dependent	The requirement for validation for whom and by whom the task is performed (Junglas, 2003)	Patient care is identity-dependent because caregivers must validate their own identities, for security and quality assurance purposes, for every patient/caregiver interaction (i.e., intrinsic – pertaining to the identity of the task performer). They also must verify patient identities to ensure that all care is in accordance with prescriptions for each specific patient (i.e., extrinsic – pertaining to the identity of the task receiver). Using some type of patient identification mechanism, such as scanning patient ID bands, and being able to match that ID with valid data ensures patient identity. Conversely, checking a manual chart or simply asking the patient is less effective or reliable, and sometimes not possible. Documentation requirements also dictate that caregiver identity be captured for each patient/ caregiver interaction. Wiring a computer to every possible patient location, and requiring caregivers to sign in and out, is inefficient and infeasible in most cases. Wireless computing affords the ability to capture and access this information whenever needed, without the constraints of a tethered system.
Interdependent	The output from one process serves as input for subsequent processes, which requires extensive coordination and mutual adjustment (Thompson, 1967)	Patient care is interdependent because each caregiver's actions impacts what the next person must do throughout the care delivery system. Wireless computing enables the caregiver to document at the point of care, thus allowing for more timely recording of data needed in subsequent steps of the care system.
Information-intensive	The imperative need for access to information and ability to manipulate data while performing tasks (Thompson, 1967)	Patient care is information-intensive because documentation is required to assess, diagnose, and treat effectively at the point of care. Wireless computing is the most effective, efficient point-of-care information solution.

Tasks such as these place heavy demands on caregivers' communication and decision skills. First, numerous resources (e.g., caregivers and system interfaces) require data manipulation at any given point. Secondly, task processes are highly complex. (Thompson, 1967). The following figure depicts the typical process for patient care system tasks.

Figure 2. Typical Patient Care System



Note: Documentation of all healthcare provider/patient interaction is continouous as the patient processes throught the care system

- Most probable process
- Alternate medical intervention that requires patient to re-cycle through care system
- Alternate process for more acute care

Data Collection Description

Data for this study collected via face-to-face interviews with hospital personnel (i.e., nurses, organizational managers and information systems professionals) to provide insight on pre-implementation expectations, actual use and ongoing performance impacts. Hospital descriptions are as follows:

St. Vincent's Medical Center (SVC)
Jacksonville, Florida
SVC is a 528-bed, not-for-profit health system that has operated for more than 87 years, and now serves an estimated 75,000 residents in surrounding north Florida. Following extensive planning by SVC's information systems staff, the hospital implemented wireless computing in its Emergency Department in February 2004. That system now handles patient triage and registration, and will be followed by electronic charting.

Henry Medical Center (HMC)
Stockbridge, Georgia
HMC is a 124-bed, not-for-profit community hospital, in existence for 25 years that offers medical care to more than 110,000 nearby residents. In late 2001, HMC became the first Georgia hospital to implement wireless computing for creating electronic medical records in the Ambulatory Care and Post Anesthesia Care units. Electronic charting remains the primary patient care task in both of these units. Descriptions are as follows:

- Post Anesthesia Care Unit (PACU): A relatively small, contained, and closed environment (i.e., no family or friends permitted) where the nurses monitor patients immediately following general surgery. Nurses use wireless computing to chart patient medical status while moving freely between patient suites, which are mostly curtained areas. Usage is high: Nurses developed their own application via templates, programs are well-designed, and the unit coordinator and nurse manager instituted solid training.
- Ambulatory Care Unit (ACU): A semi-open environment (i.e., family and friends permitted) where nurses conduct pre- and post-surgery assessments for non-invasive procedures and general surgery. Three bays house individual patient rooms or curtained suites in which nurses perform patient care tasks. Usage was poor due to weak program design, hardware issues and environmental factors, and the system has been abandoned.

Table 2 provides comparative details for each hospital.

Table 2. Comparative Details

Hospital	Inpatient (FY03)	Outpatient	Associated physicians	Clinical and Non-clinical Nurses	Medical Specialties
HMC	10,306	95,653	436	439	Cardiac Catheterization, Diagnostic services, Labor and Delivery, Rehabilitation, Pain Management,
SVC	25,000	50,000	835	800	Cardiology, Geriatrics, Gynecology, Oncology
VAMF	106,000	460,751	294	868	Geriatrics Education and Clinical Research, Oncology, Neurobiology, Molecular Medicine, Pulmonology, Infectious Diseases

A Veterans' Administration Medical Facility (VAMF)
Southeast United States
VAMF is a 478-bed, federally funded medical center providing inpatient care and outpatient programs to veterans, including those with medical, surgical and psychiatric needs. A variety of is also provided. Services also are delivered through outpatient clinics in two other communities. The VAMF complex includes a 120-bed nursing home, a geriatric research site, education center and clinical research center.

Wireless computing has been facilitated for the past three years by a network covering all 13 inpatient floors, and currently is being implemented in the intensive care units (ICUs).

Research Schedule and Information Systems (IS) Implementation Stage Description
A total of 43 individuals were interviewed. Twenty-three nurses provided comments in face-to-face interviews for an average of one hour. At the time of the interviews, each sub-unit was in a different information technology (IT) implementation stage.

Cooper and Zmud (1990) provide a six-stage IT implementation model, based on organizational implementation process and results (e.g., product). Descriptions of each stage follow:

Stage (1) Initiation

Process – active or passive scanning of organizational problems/opportunities and IS solutions are undertaken. Pressure to change evolves from either organizational need (pull), technical innovation (push), or both.

Product – rational and political negotiations ensue to get organizational backing for implementation effort.

Stage (2) Adoption

Process – Rational and political negotiations ensue and to get organizational backing for the IT implementation.

Product – A decision is reached to invest in resources necessary to accommodate the implementation effort**.**

Stage (3) Adaptation

Process – IT application is developed, installed, and maintained. Organizational procedures are revised or developed. Organizational members are trained both in the new procedures and in the IT application.

Product – The IT application is available for use in the organization.

Stage (4) Acceptance

Process- Organizational members are induced to commit to IT application usage.

Product – The IT application is employed in organizational work.

Stage (5) Routinization

Process - Usage of the IT application is encouraged as a normal activity.

Product – The organization's governance systems are adjusted to account for the IT application; the IT application is no longer perceived as something out of the ordinary.

Stage (6) Infusion

Process – Increased organizational effectiveness is obtained by using the IT application.

Product – Realized advantageous attributed to the new IT application outweigh those attributed to prior solutions.

Table 3 details where, when, and with whom the interviews took place, along with each hospital and department's implementation stage at the time.

Table 3. Research Schedule

Site	Subunits and Interviewees	Interview Dates	IS Implementation Stages (adapted from Cooper and Zmud, 1990)
SVC	1 CIO 6 Organizational Manager 3 IS Personnel Emergency Department (ED) Triage in ED – 3 of 6 triage nurses on shift Registration in ED - 2 of 6 registration personnel	1st Entry: 22 May – 22 July 2003 2nd Entry: 26 March 2004	Adoption – IS decision reached to invest Adaptation – IS development in process
HMC	1 Director of MIS 1 Director of PACU – 8 of 13 nurses ACU – 8 of 22 nurses	4-5 Nov 2002 1st Entry: 4-8,11, 13 Nov 2002, 13 Dec 2002 2nd Entry: 6-10 Jun 2003 1st Entry: 18-22 Nov, 6 –13 Dec 2002 2nd Entry: 11-14 Jun 2003	Routinization- IS usage is encouraged or mandated Infusion – effectiveness derived from continued use of the IS Adaptation – IS development in process Abandonment – discontinued use of IS
VAMF	1 Director of Nursing Informatics 5 IS Personnel 4 Floor Nurses	1st Entry: 9-20 Oct 2003 2nd Entry: 10 Dec 2003	Infusion Infusion

Wireless Computing: Technical Specifications

Wireless computing involves the joint use of mobile devices, wireless networks and information systems to access and manipulate data. According to Stephen Gross of Mitre Corporation, an economic and decision analysis center, "Wireless networking enables computer users to access files stored on a network while moving around or working in a temporary office space—or enable one to access a network in other locations (Gross, 2002)."

Wireless also affords direct access to legacy applications and central data repositories via a network. These networks currently are facilitated by the 802.11b standard, also known as Wi-Fi, that has become best known for its appearance at sites such as Starbucks' stores and Internet cafes.

WLANs operate at up to 11 megabits per second (MBPS) in the 2.4GHz frequency band. In most cases, a single wireless local area network (WLAN) access point can simultaneously support up to one end user per megabit (e.g., typically 11 users per access point), in an unobstructed environment within a range 100 to several thousand feet. End users access the WLAN through adapter cards inserted into a laptop, handheld computer or other mobile device. All wireless devices in each of the three hospitals in this study are mounted on mobile workstations that operate on the 802.11b standard.

Table 4 summarizes the typical dimensions of the mobile workstations used at the three hospitals.

The majority of WLAN topologies rely on spread-spectrum technology, a wideband radio frequency technique that provides adequate bandwidth for data services while maintaining data transfer reliability, data integrity, and data security. Wireless data technologies have proven reliable for both commercial and military systems. Radio interference can degrade rates of data transmission, but such interference is rare. "WLANs provide data integrity performance equal to or better than wired networking (Gross, 2002)." Vendor information appears in Appendix A.

Table 4. Workstation Specifications

Workstation Specifications	
Mobile Cart	
Height from floor to top of monitor when upright	Approximately 4ft
Writing surface height	Adjustable from 30" to 40"
Work surface dimensions	23" x 17"
Base dimensions	19" x 19"
Casters	Four swivel
Weight	45lbs
Storage	Retractable keyboard and flip-down monitors
Display	
Diagonal size	15"/17"
Viewable size	15"/17"
Computer	
PC based Windows 2000 or NT operating systems	
Power Supply	
Battery run time	8-12 hours
Charging time	8 to 10 hrs for 100%
Weight	30lbs

Device Electromagnetic Compatibility (EMC) Concerns

The inherent danger in wireless devices is the possibility that electromagnetic output could cause other medical equipment malfunctions, unnecessarily jeopardizing patients' health and lives. To avoid that scenario, manufacturers adhere to electromagnetic compatibility (EMC) standards developed by The Association for the Advancement of Medical Instrumentation (AAMI @ www.aami.org). The US Food and Drug Administration meanwhile offers EMC information and electromagnetic interference (EMI) test statistics on technologies usage in healthcare facilities @ www.fda.gov/cdrh/emc/emc-in-hcf.html.

To date, more than 30% of all US hospitals have implemented wireless computing in accordance with standards developed by the IEEE for all 802 series (i.e., .11b, .11a, .11g. See Appendix B for more detail.) According to the most recent data available, there are not reports of EMI with medical equipment to or by the FDA, according to the most recent data available (Blatt, 2003).

Conversely, cellular radio frequencies at < 900MHz and >600mW Effective Isotropic Radiated Power (EIRP) have been shown to cause EMI in 4% of installations within one meter of medical equipment (Blatt, 2003). Essentially, radio interference is eliminated by the 802-standardized systems, which operate at higher frequency and lower power than cellular systems (Blatt, 2003).

More information on wireless transmission appears in the accompanying sidebar.

Patient Privacy Concerns: Handling HIPAA

Stringent security requirements mandated by the Healthcare Information Portability and Accountability Act of 1996 (HIPAA) make healthcare uniquely challenging for WLAN installations. HIPAA calls for technical safeguards that include access and audit controls, data integrity, authentication and encryption of sensitive patient healthcare information. Beginning in mid-2005, penalties for improper disclosure of medical information range from $100 per person per incident to $250,000 and 10 years in prison for intentional violations (HIPAA, 1996).

WLAN security features must prevent theft, either from stolen devices or hacking, of protected health information. At a minimum, when using portable devices, users must authenticate themselves with passwords, and the actual physical devices must be authenticated by network servers before granting WLAN access. Additionally, cryptographic keys used to access the WLAN must be changed frequently.

The primary encryption protocol, Wired Equivalent Privacy (WEP), unfortunately is plagued by deficiencies that leave WLANs extremely vulnerable to unauthorized access and data capture. HIPAA accordingly suggests that hospitals supplement their network infrastructure with other protective measures that block WLAN communications until client authentication is complete (Gainer, et.al, 2003). Additionally, many organizations use public key certificates managed in-house or Virtual Private Networks (VPNs) to protect data transmission.

Public key certificates feature 128-bit WEP keys that are changed for each wireless session, or after a set time period, to augment network security features. In contrast, VPN use entails encrypting the transmitted data with a more robust encrypting tool before the data are encrypted by WEP, then decrypting after the data are transmitted. The primary cryptographic tools employed in WLAN VPNs include Internet Protocol Security (IPSec).

The primary advantage of VPN use is that it prevents transmitted data from being viewed in clear text despite deciphering of a WEP key. Potential drawbacks include the need to install additional gateway hardware, problems with dropped service if roaming occurs and the costs of deploying VPN-enabled clients (Gainer, et.al, 2003). For other methods of securing the wireless network, see the article "Wireless Wellness: Wireless LAN Security Considerations for the Healthcare Community (Low, 2003 @ http://www.giac.org/practical/GSEC/Caroline_Low_GSEC.pdf)

Study Findings

1. Wireless computing provides nurses with essential information at the point of care.

In hospital settings, nurses are mobile workers who perform the bulk of their tasks at the patient's bedside: assessing medical status, providing medications, or documenting medical intervention. Virtually all health-care professionals involved in hospital patient care rely on nurses' documentation of medical diagnosis, status monitoring, or medical intervention.

To perform their jobs most effectively, nurses need immediate access to a patient's medical information. Yet nurses frequently must walk down the hall to validate information on a stationery computer, handwrite notes at the time, or rely on memory to document information by hand later on. Such processes often are time-consuming, error-prone, and frustrating.

Nurses themselves tend to value oral communication as part of their social structure. In hectic hospital environments, however, they may resent being confronted with numerous questions whose answers can be found in a patient record. Nurses also simply may not have time to give verbal answers, or may have privacy concerns for patients when other patients or practitioners are nearby. The result: Vital information can be difficult to transmit even among willing parties.

Wireless computing enables physicians, technicians, and other nurses to access essential information at the point of care, eliminating the need to leave a patient's bedside or interrupt treatment to answer unrelated questions, locate answers or consolidate patient information.

Consider the following examples:

SVC Triage Nurse A [referring to patient triage]
"The main benefit of having it [wireless computing] in triage is that you can look up information about their previous care (i.e., how many times they have been here for the same complaint) as you triage. …Some don't want to tell you that they are HIV patients, so when you review their history you can see that... It makes the triage process quicker when you learn how the work it. At first it slowed me down but now that I am used to the system I save about 2 to 3 minutes on triaging if there are no major complications.

…We have 6 mobile carts you can take to any part of the ED and we have 60 beds... This also allows us to have 6 more computer terminals to use for triage. We were badly in need of more terminals. There just weren't enough computer sites available for the employees that and need to use a computer terminal. With the system... you can put information right in as you work and it's right there accessible for anybody to use, which is the nice thing."

HMC PACU Nurse [referring to electronic charting]
"If [nurses] are with one patient, they don't have to leave that patient to access records for another patient. They can just look up the information on the carts. Often they need to remind themselves if a patient had a certain medication or the last time [his or her] vitals were recorded. Things like this are easy to forget — and hard to find — when you get busy comforting the patient."

2. Wireless computing helps nurses create comprehensive, readily accessible records.

According to nurses at HMC and VAMF, the primary rationale for implementing wireless computing was to improve patient safety and shift time from administrative tasks to patient care.

Nurses view routine documentation as a necessary evil: something that has to be done to ensure patient/caregiver medical interventions are properly recorded, but a very tedious and laborious task. Those interviewed were more open to charting by exception, which indicates exceptions to a patient's ordinary condition, rather than requiring a long narrative for each entry. The nurses perceived wireless computing to be advantageous in helping them chart by exception at the bedside — and give them access to patient information that decreases the likelihood of errors.

Wireless information systems generally rely on a standardized document format with inherent mandatory fields and automatic error notifications, which simplify data entry, reduce error risk and speed charting time. This was directly observed in HMC's PACU, where wireless is well accepted. In that unit, the system was effectively designed, nurses were integral to program development, and users were properly trained. In subunits where the program design for the information system used for wireless computing is robust, nurses are able to document patient information more easily, comprehensively and quickly, with minimal error because of mandatory data fields.

At VAMF, nurses believed that employing wireless computing on mobile carts to validate medication administration has decreased the likelihood of errors.[2] The system alerts nurses about the appropriate times to administer medication and highlights any prospective conflicts between medications. As a result, nurses feel more secure and less anxious about doing so, even though the validation process has lengthened the time necessary to administer medications.

The following quotes illustrate these points:

SVC Triage Nurse A [referring to patient triaging]
"The main thing is it's [a typed computer entry] legible. Without the system I can register a patient in 2 or 3 minutes, do vitals and what I need to do, but it's not always legible even to me. By the end of the day your hand's cramping. You forget some things or can't read what you wrote, which can cause you to make mistakes."

VAMF Floor Nurse A [referring to validating information for medication administration]
"We have a good record of every med given to the patient since they have been in the [wireless] system... Sometimes here you get so busy and can make mistakes or forget to give meds, but the system makes you slow down and take a breath, which we need to do sometimes. You can check prior orders and you have all the information you need about the patient right there at your fingertips. If you have any questions or concerns, you can call the doctor or the pharmacy. You know who ordered what, when it was validated and who did it. It doesn't save any time. It's just so much safer and that's really what's important. It's better to be a little late than sorry."

Nurses are not permitted to change prescriptions, but they often are first to notice and document adverse reactions, such as allergies or low effectiveness of a medication or medical intervention. Such responses can be annotated more effectively using a wireless system, making information more readily available for physicians to re-assess prescriptions or treatments. For example:

VAMF Floor Nurse C [referring to medication administration]
"As the nurse, you are at the frontline of patient safety. Sometimes it happens that a doctor meant to give another med, [but the mistaken one has been] validated by the pharmacists. You know something isn't quite right, so you can check it easier. It's really important to do that for critical care patients when you can't afford to miss something."

VAMF Floor Nurse B [referring to medication administration]
"[The system] makes you be very careful. There are a lot of alerts that will tell you if something is wrong. Some things you may not have caught [otherwise,] like an expired medication that needs to be renewed."

VAMF Floor Nurse C
"When [our wireless system] goes down, we hate having to go back to writing everything down. We still use the same process of validating, [but] we just have to write it all out. That's hard and time-consuming and people get sloppy. [Wireless] is the safest way to give meds and protects you as the nurse. I know that the physicians and the pharmacists have okayed these medications. I still make sure they pass the common sense test, but the system has so many alerts that you really don't have to worry about messing up."

Nurses in ACU at HMC noted rare occurrences when they accidentally began charting on the wrong patient. These negligent acts could greatly endanger patients and result in litigation against nurses and their employers. However, the ACU nurses noted that once they recognized the errors by manually validating information in the patient's chart with the patient or someone else, errors could be corrected immediately in the system and no harm was done. As this quote illustrates,

HMC ACU Nurse E
"It happens, not a lot, but sometimes we get two patients with the same name. You might start charting on John Smith, but you notice that the record reads that John Smith is a 50-year-old white male but your patient is a 12-year old Hispanic child. You catch it and fix it. It's not a big problem because we [can] go into the system and find the right [one] [by referring to the patient's electronic chart]."

Similarly, IS personnel at each hospital were concerned about nurses charting on the wrong patient via wireless computing. Only VAMF incorporated barcode scanning of the patient's identification wristband to validate that the chart was for the intended patient. Neither HMC nor SVC instituted any automated mechanism to ensure that the recorded information was for the correct patient. However, IS personnel and organizational managers frequently reminded nurses to verbally verify the patient's identity or visually check the patient's identification wristband.

The following quote illustrates this point:

HMC MIS Department Director:
"If you're going to slide [a wireless-equipped cart] over to the other [side of the] curtain [in a patient's room], we told them, 'Make sure you're charting on the right person!"

3. Wireless computing increases in value when systems support "exception charting" to facilitate detailed record-keeping, reduce charting time and enhance readability.

When nurses need to decide on patient interventions, having comprehensive documentation on the efficacy of prior interventions aids in making responsible decisions. The most convenient and efficient manner to document this information is via electronic exception charting, facilitated by wireless computing, at the patient's bedside as a nurse is rendering care.

Electronic exception charting typically incorporates the use of point-and-click navigation, drop-down menus, and auto-text insertion features to speed up the charting process. In addition, software is designed to ensure that (1) mandatory information is added to the records in a logically organized and readable manner, and (2) narratives are needed only for exceptions in the patient's condition (i.e., out of the ordinary occurrences). These features reduce the amount of data entry required, the tendency for errors to creep in when busy nurses must enter data away from a patient's bedside, and legibility problems that can result in erroneous prescriptions or misunderstood instructions.

For example:

SVC Nurse Manager B [referring to future applications of wireless computing for electronic charting]
"We need thorough records. It's too often that [nurses] spend time briefing the next shift, or someone realizes that something wasn't done or at least documented for a patient after the nurse had turned over [responsibility to the next shift]. This greatly impacts the quality of the patient care."

HMC PACU Nurse Coordinator [referring to electronic charting]
"We had four pieces of paper on a clipboard, but only three that dealt with the patient chart. The fourth was a summary of the charges. Doing this process involved ordering the paper every week, collating the paper, and replacing the paper chart when you needed a new one. This took up time that we could use caring for patients... Everyone charts differently and when you are trying to read through the manual charts it would be so time-consuming because of all of the verbiage and handwriting. The [electronic] record is very thorough because it won't let you miss mandatory information. Definitely, legibility isn't an issue anymore with the wireless."

HMC PACU Nurse E [referring to electronic charting]
"Pain medication dosage could mean life or death. You have to be so careful with everything you do for and to the patient. You need to document it all. But the good thing about the system is that you don't have to write it all down. You just point and click and add the stuff you need to."

4. System usability and performance are influenced by task environments (e.g., number of patients to care for, proximity and positioning of beds; frequency of distractions from patients, their family and/or friends, and other caregivers; severity of patient condition.)

Conditions in the task environment, such as proximity and positioning of patient beds, impact actual intended use of mobile carts and wireless information systems (i.e., the mobile workstations). Table 5 shows the characteristics of the task environments for the nurses involved in this study:

Table 5. Task Environment Characteristics

Task Environment Characteristic/ Hospital Unit	Volume of patients entering and leaving the patient care system per day	Physical Confines of Room Space	Access	Patient Status	Degree of acuteness of patients
SVC Emergency Department	High and uncertain, 1:3 registration personnel to patient ratio without wireless computing (WC)	Confined by walled rooms, single patient rooms	Depends on acute or critical status but mostly secured with limited visitation	Either conscious or unconscious	Can be critical or acute
HMC ACU	High and certain because of scheduled procedures, 1:4 patient ratio without WC, 1:3 with WC productivity reduction due to poor IS software design	Confined by walls, large area, 3 main areas with single patient rooms	Open to visitors	Conscious	Moderately acute
HMC PACU	Moderate and certain because of scheduled surgery, 1:2 without WC, 1:3 with WC	Unobstructed by dividing walls, a lot of monitors in headspace, small area with single patient suites	Secured with no visitation	Unconscious	Critical to acute
VAMF Regular Floors	Low and moderately predictable (i.e., they have lead time to prepare for patients being admitted), 1:4 nurse to patient ratio without WC, no change with WC	Very Confined, multiple patients rooms	Open to visitors	Conscious	Moderately acute

Of all environments studied in this research, the environment in the SVC ED has the highest patient turnover, greatest degree of varying patient acuteness, and greatest number of differing types of locations in which nurses and registration personnel must maneuver to in order to care for patients. However, ED triage nurses and registration personnel consider wireless computing advantageous because computers can be moved directly to the point of care when a patient arrives via ambulance or is incapable of walking to triage stations or registration cubicles.

The following quotes illustrate this point:

SVC ED Manager [referring to patient triage]
"[Nurses] can go right to the patient and not have to worry about scribbling notes down and then putting [those notes] into a computer [later on]… [Without wireless,] inevitably [nurses will get interrupted or distracted along the way to the computer. They'll be asked for a drink of water or a blanket and there is just more room for error because you can forget."

SVC Registration Personnel A [referring to patient registration]
"Before the wireless system, we had to do all registrations from the desk. The rescuers and ambulance personnel had to come to us at the desk with the patient information. We have certain information like the insurance information, [like] next of kin, which have to be entered before the nurses and doctors can [begin helping a patient] in most cases. It was inconvenient and hectic.

If they [patients or rescue personnel] can't come to us, we [used to] go to them and write the information down a piece of paper, [then] bring it back to the desk to process it. There is so much going on in those cases that you can forget something or you can't read what you wrote, so you end up making multiple trips back and forth to the patient's room. They [the nurses, doctors, and technicians] end up waiting on us to enter the information to create the financial number.

The financial number is what the nurses and doctors need to find the patient in the system and start orders like labs. With everything that goes on back here, the nurses and doctors get frustrated when they have to wait to start treatment because we haven't finished at least quick registration [an abbreviated process that creates information (i.e., the financial number) needed to proceed.]."

SVC ED Acute Care Nurse A [referring to the patient registration process]
"It's so hectic in here that sometimes I wish we [the nurses] could quick register the patient [with the wireless systems] so that we can start what we need to do. But I do think that overall, having the wireless systems for the registration personnel allows them to do their jobs quicker, which lets us get to treating the patient faster."

The number of distractions and their impact on patient care differed across the environments. Typically PACU is a closed environment in any hospital, meaning no family or visitors are allowed in the general surgery recovery area. Patients also are still anesthetized when they enter the unit. As a result, there are virtually no distracting questions from patients, their family or friends. The low degree of distractions in this environment attributed to nurse acceptance of the technology despite the high learning curve associated with the application and hardware manipulation.

All nurses interviewed in this study value face-to-face communication, but the non-PACU (i.e., ACU and regular floor) nurses want to decrease the number of questions coming from physicians or other servicing nurses. Giving appropriate users access to information, whenever and wherever needed, via wireless increases productivity in the task environment (measured as quality patient care and number of patients for whom care can be provided.)

The following excerpt notes characteristics of the task environment, such as the differences in distractions in PACU and ACU:

HMC ACU Nurse A [referring to electronic charting]
"Their [speaking of PACU nurses] patients aren't anxious because they are asleep. [Nurses] can chart right in front of their patients and it's not a problem. They [also don't have to deal with the family asking questions or people getting in the way."

Physical confines of patient suites or rooms contribute to varying levels of mobile workstation usage across different environments. Because the areas where the patients are placed are not divided with physical boundaries, PACU nurses can move a cart-mounted mobile workstation unobstructed from one suite to another. These suites are in very close proximity to each other as opposed to the actual rooms and separate bays in ACU, so a single nurse can closely monitor multiple patient simultaneously. Since patients come to PACU immediately following general surgery, there are many monitors and medical equipment at the head of each bed.

For the task of monitoring the patients after surgery in PACU, it is more suitable for the nurse to use the mobile cart and information system used for wireless computing at the foot of the bed where she/he has full view of all the monitors and the patient and can input data as needed

The physical environments of the non-PACU units are characterized by physical boundaries between rooms and limited headspace for systems and medical apparatuses. Wireless computing enables a nurse to move a cart near a patient's bedside without permanently cluttering the headspace with another system.

In areas where there is more than one patient in each room, however, maneuverability with the carts becomes problematic. Some VAMF nurses noted that they would prefer smaller handheld devices because it is difficult getting the cart in between the beds within the room. However, very few were observed using the mobile cart and information system used for wireless computing in the hallways or away from the point of care.

The mobile workstations at VAMF are equipped with barcode scanners, attached to the workstation by a cord, which nurses use to scan (1) patient identification bands to automatically access the appropriate patient record and (2) medication labels to ensure that they are administering the prescribed medication and dosage. For VAMF barcode medication administration, the physical setup of rooms (e.g., close proximity of multiple beds in patient rooms) and short length of device cords makes scanning ID bands at the bedside cumbersome. VAMF IS personnel plan to equip carts with wireless scanners, which would solve scanning problems.

At present, some nurses manually input social security numbers, rather than scan identification bands as required, because carts are too difficult to maneuver around beds. This strategy, while not a normal occurrence, clearly introduces the possibility of data-entry error. The majority of VAMF nurses used the mobile cart and information system appropriately (i.e., at the point of care).

As the following quote illustrates:

VAMF Floor Nurse D [referring to medication administration]
"We have to scan the band and then the med to make sure that we are giving the right med to the right patient. …But being able to have the system with you all of the time is really much better for medication administration because I have all the information I need about the medication and the patient at my fingertips."

Changes in the patient's condition from moderately acute to critical are characteristic of healthcare task environments. In all units, having access to information wirelessly affords the caregiver with critical information at the point of care to better deal with uncertain conditions related to the patient.

5: System usability and design benefit from certain hardware characteristics, such as computer cart mobility and multiple-use cart features, but suffer from others, such as inadequate battery life or poor software design.

Mobile workstations serve multiple nursing purposes. In PACU, cart size and design, such as a desktop, enable the nurse to write and place other necessary items (i.e. thermometers, blood pressure cuffs, medications and delivery apparatuses) on the work surface the mobile workstation.

Nurses on in-patient floors, in which patients may require many medications at frequent intervals, were frustrated that carts did not hold adequate medications. Therefore, they were required to shuttle between the central medicine cabinet and the patients' rooms. Many non-PACU nurses also commented that medications tended to slide off carts as they moved from room to room. Non-PACU nurses were observed pushing carts with one hand, holding medications in the other, and carrying medication delivery apparatuses tucked underneath one arm all while trying to wedge a cart between two beds. These conditions add to nurses' frustration and impede effective use.

This excerpt illustrates this concern:

VAMF Floor Nurse B [referring to medication administration]
"I don't really see any other way to deliver medications because of all what we have to do. The carts need to have more space on them, though... or a drawer so that you can sit the meds there and they don't fall off. "

In ACU at HMC, where medications are stable and not great in volume per patient, carts were adequate for serving multiple purposes. Cart design also did not impede mobility in patient rooms, which are individual suites. Instead, the major technical characteristic that thwarted use was program design. ACU nurses felt poor procedures in the implementation process resulted in program design that hindered use.

In fact, nurses were fundamentally responsible for using software design templates to design their own interface screens. Because nurses are clinical by profession, they lacked systems-analysis and design-principle skills. Nurses commented that they are not "IT people" and "it is not our jobs" to develop software. While they liked being involved in the system development process, they felt overwhelmed by the requirement to design applications on their own.

Regarding variations in program design and their impact on usage in different environments:

VAMF Floor Nurse D [referring to medication administration in light of good program design]
"A lot of nurses say that it takes them longer. I don't mind, because I can get to information much faster when I have a question. For example, if I think something is wrong with the order in the computer, I can find out right away who were the ordering physician and the validating pharmacist and get my questioned answered right away."

HMC ACU Nurse A [referring to electronic charting in light of poor program design]
"We were happy about getting something that would help us spend more time with patients, but that wasn't

the case. Having the computers there by the bedside kept us from doing our jobs to some degree. The program was so cumbersome that it made things too difficult, and you felt too rushed to deal with the patient. I don't like that. We all said that the patient is our priority, not that computer."

HMC ACU Nurse B [referring to electronic charting in light of poor program design]
"I didn't make eye contact because I would have to fiddle with the computer. I like computers, but this system was so bad that it really made more work for us than anything. In fact, we went from having three sheets to six for just one patient... It slowed us down so we stopped using them. I need to talk to the patient to make sure they are okay and calm them down... If I'm fumbling with the computer then I can't do that."

HMC ACU Nurse D [referring to electronic charting in light of poor program design]
"If it [the wireless system] worked, we could have been able to check those stats quicker. While you are waiting for a patient to stabilize you could go work with another patient. It just would have been more convenient."

Nurses across all hospitals noted that wireless computers, which are battery operated, can lose electrical charge, thus hindering access to crucial information. Operations at all hospitals are 24 hours, and systems must be functional across all shifts.

Consider this excerpt on how the battery life impeded computing mobility:

HMC B ACU Nurse A [referring to medication administration in light of hardware problems]
"The batteries kept dying on us and [the computers] would lock up. Then it got to the point that the batteries died out and we had to keep them plugged up all over the place. The actual computer wasn't a problem. But we would have to find space in the rooms to plug them in [Instead, nurses] would leave them plugged in outside of the rooms in the hallways or at the nurses' station."

In ACU at HMC, nurses were observed taking notes on pieces of paper or using the old manual assessment checklists, then re-keying data into wireless computers plugged into hallway outlets. According to nurses, this ad hoc system increased charting times by nearly 20 minutes, which in turn delayed scheduled procedures. Despite a "mandatory use" policy, the HMC ACU nurse coordinator eventually abandoned the system.

6. Wireless-driven nursing processes reduce nurses' charting time and anxiety, enabling them stay longer with patients and chart on multiple patients simultaneously.

Wireless computing generally provides sub-second response times for answers to queries that would require several minutes to discern from a manual narrative.

As the following quote illustrates,

SVC Triage Nurse A [referring to patient triage]
"We have the ability to look up previous medical information like allergies and medication effectiveness. The patient may come in by rescue and was found unconscious at home and nobody really knows anything about them… [Before wireless,] it would take use hours to look up the information with the paper charts."

Following the implementation of wireless computing, PACU nurses at HMC have decreased their charting times by 10 to 15 minutes according to the nurses interviewed. This efficiency allows each nurse to care for at least one more patient, increasing the potential nurse to patient ratio from 1:2 to 1:3 due to decreased paper-reporting requirements.

While wireless computing may allow for a nurse to chart on more patients simultaneously, those gains may not translate into operational efficiencies. PACU nurses at HMC had no control over the number of surgeries scheduled each day without changes to administrative procedures. PACU nurses benefited, however, as their charting-related anxiety decreased.

For example:

HMC PACU Nurse Coordinator [referring to electronic charting]

"If you got behind the old way because you had a lot to do for the patient or some complications occurred then it was pretty hard to get caught up on all of that charting... It's just easy to catch up now with the wireless. You can care for the patient without stressing out

about getting the chart completed."

HMC Nurse Manager [referring to electronic charting]
"I know that it's faster. Even people who can't type are getting their charting done faster. I say on average it cuts down about 15 minutes, which gives [us] more time to see after other patients if they have complications, like pain following the surgery."

ACU nurses at HMC noted that their anxiety about charting increased because of difficulties entering the information, either due to program design or poor typing skills. This slowed patient throughput: that is, processing a patient into the system for care, rending care or procedures, and out-processing a patient for discharge or in-hospital stays.

Some ACU nurses at HMC reported that when their anxiety increased due to frustrations associated with wireless computing, they felt their patients' anxiety also increased. These nurses believed that patients translated their view that nurses were incompetent with wireless computing to the assumption that nursing care was incompetent. Increased patient anxiety has physical ramifications (e.g., increased blood pressure, nervousness, convulsions, vomiting, or frequent urination) for patients, and complicated nurses' ability to render care.

Consider that:

HMC ACU Nurse B
"…when I tried using the 'thing'[referring to the wireless system] in the rooms I always felt like the patient was watching my every move. I think to myself that the patient must think I'm stupid… I know I would get upset if I was a patient and my nurse was fumbling... [As a patient,] I could see [the nurse's] frustration, but at the same time, this computer is taking her attention away from me... If the patient's blood pressure [then rises] too high we can't administer the anesthesia, [and the process is delayed.]".

7. Wireless-driven nursing processes may be impeded by nurses' lack of typing skills, genre and recency of professional training, or technology aversion.

The demographics of the majority of nurses interviewed at all hospitals are (1) an average age of 40 and (2) work experience of more than 15 years. These averages are expected to rise in coming years as fewer individuals enter the nursing profession (Bass, 2002). Fifteen years ago, nursing curricula did not emphasize the vital importance of documentation, nor did technology exist to aid in documentation.

These next quotes highlight such issues:

SVC Triage Nurse A
"I was so afraid of the computer... I didn't even know what a mouse, until someone told me."

SVC Acute Care Nurse A
"People here don't like change. Most nurses are in their forties or fifties and they just don't want to deal with the computer. So when we go to charting [in addition to triaging and registering patients] with the computer it's going to be difficult for them."

VAMF Organizational Manager
"You've got nurses who finished school long before any of this technology became available and we're putting it right in the middle of the core to what they do – giving medications to patients. It slowed them down [because (1) there are more steps involved using the wireless system than in manual medication administration and (2) lack of typing ability. When you put that on top of them being intimidated by the technology, you have a hard time getting them to buy into it."

In this study, nurses are designated in two categories – demographic A (i.e., trained under "old" regimen, which took place 15+ years ago and did not expose nurses to information systems patient care) and demographic B (i.e., trained under "new" regimen, which took place less than ten years ago and minimally exposed nurses to information systems patient care).

The nurses in demographic A still view documentation as a laborious task and themselves as not technically savvy. They do use PC based systems for other tasks such as monitoring vital statistics or maintaining an apparatus for intravenous drug administration. However, these users view wireless computing differently from other systems. In the view of nurses in demographic A in ACU at HMC, monitoring and delivery systems directly aid them in doing their jobs by outputting vital patient status data.

Conversely, information systems used for wireless computing requires nurses to input data, which they believe impedes their ability to render quality care. Demographic A nurses used the wireless system the system only when mandated because (1) they were technically intimidated, (2) did not have typing skills and (3) felt the system was non "nurse friendly".

Nurses in ACU at HMC in demographic B view themselves as somewhat technically savvy, and attributed their non-use of the system to program design flaw. According to demographic B nurses, some demographic A nurses were so intimidated by the wireless system that they would offer to do demographic B nurses' patient assessments in exchange for help with computing tasks. This inefficient use of the work force, coupled with technical problems, slowed patient throughput in ACU at HMC.

Prior to that point, if demographic A nurses use the wireless system on their own, they did so in hallways so patients would not see them struggle. If the system is easy to use and has few technical problems, nurses can overcome technology aversion and lack of typing skills.

HMC PACU Nurse D
"At first it was frustrating for me because I can't type. But we had so much practice during our training. Now I love it and would never want to go back to doing it [documenting] by paper. Even though I still have problems typing, it's easy because we do exception charting. So the only time I have to really type something out …is when something out of the ordinary happens and we document it."

VAMF Floor Nurse D
"A lot of us don't even use computers and we were never really trained in nursing school to operate this way. The younger nurses seem to be much more comfortable with the technology."

8. Benefits include reduced time required to validate questionable drug prescriptions and medical interventions, which can delay patient care.

When nurses question the validity of the prescription, the process of locating a physician, correcting the prescription, having the prescription revalidated by a pharmacist and receiving a new prescription can be extremely time-consuming.

Contrast that with wireless procedures:

VAMF Floor Nurse C [referring to medication administration]
"There are times when you need to know stuff right away to make a decision about what to do for the patient or to troubleshoot what's going on with the patient. You may not have time to hunt down the physician, a pharmacist, or another nurse to ask questions...

Sometimes it does happen that the doctor meant to give another med and it does get validated by the pharmacists but you know something isn't quite right so you can check it easier. With the system that can be done right at the bedside and it's really important that you don't miss something regardless of who the patient is and you don't want to have to leave the patient to go hunt down answers. "

9. Benefits include greater ability for hospitals to defend against accusations of, and liability for, negligent care.

Administering the wrong medication to a patient can be detrimental, if not fatal. Prior to wireless computing, physicians might write orders that were incorrectly transcribed by a technician or another nurse, then incorrectly validated by pharmacists – potentially greatly increasing patient risk. At VAMF, nurses were required to ensure that prescriptions were valid before administering medication, a situation that provoked considerable stress.

VAMF physicians and pharmacists now must validate medication orders within the information system before nurses administer drugs. As a result, nurses have the assurance they will not be solely liable in the event of treatment error. Having access to information the physician actually entered into the database deepens nurses' understanding and greatly increases their sense of security.

For example:

VAMF Floor Nurse C
"I know that the physicians and the pharmacists have OK'd these medications for me to give. I still make sure that they pass the common sense test, but the system has so many alerts that you really don't have to worry about messing up."

VAMF Practicing Nurse in Nursing Informatics [referring to medication administration]
"In the old days it was just you in that boat, and now there are at least two other people in there with you. It's less prone for error and protects you as the nurse as well as the patient. With this technology I can build progress notes, and I can build it with all of the bells and whistles that you need to get everything in your charting that protects you legally. You can protect yourself some 5 years from now when some lawyer's got you on the stand."

The primary threats in this instance are acts of the caregiver that could result in harm to the patient, which can jeopardize nurses' professional licensing and make the hospital a target for legal action. Equally important, point-of-care documentation can serve to disprove negligence.

However, some organizational and nurse managers believe some nurses apparently do not understand all of the ramifications from poor documentation, according to nursing managers:

SVC Manager A [referring to electronic charting and medication administration]
"Nurses really don't get to see how what they do with that chart impacts the radiologist or the pharmacist or and the doctor. They need to understand that what they do or don't do has consequences. If they don't charge properly, the hospital loses revenue and our costs go up, so we [have to] charge even more for care. Or a pharmacist has to take a loss in inventory because the nurse failed to document a charge. Another example is when the nurse misses doing something for an assessment or discharge, and the patient has to stay longer, [which can drive up costs.]"

SVC Manager B [referring to needing a Nurse Vision Statement that specifically addresses how important the nurse is to the patient throughput process]

"We need to show them where they fit into the grand scheme of things and then they can better see why documentation is so important.."

10. Benefits include easier and more timelier quality assurance for processes and verification associated with patient care.

Nurses cite the ease of accessing information via wireless computing, versus belaboring over narratives in a manual chart, as one of the technology's primary benefits. Wireless also enables accreditation teams to review records and standards compliance easily, without referring manually to paper records and charts. This also has the potential to make it easier for accreditation bodies to standardize information within categories, and thus promote apples-to-apples comparisons between hospitals. Nursing managers more easily can consolidate information to develop reports for medication effectiveness, late medication administration, patient assessment scheduling, and inventory tracking.

For example:

HMC PACU Nurse Manager
"I can... review the work for quality assurance much easier. I don't have to go through all of these narratives, and I can actually review these if I need to from wherever I am. So if I have some downtime from charting, I can check to make sure that the meds are getting charged or see if [nurses] are using the narrative section of the program the right way."

HMC PACU Nurse Coordinator
"With the electronic chart, we chart by exception so it doesn't take me long at all when I need to look at a chart that one of the nurses complete. "

11: Benefits include greater ability for registration personnel and nurses to maintain patient confidentiality by silently reviewing existing information.

Because wireless systems are mobile and can be taken to the point of care (i.e., private rooms or semi private locations), nurses or registration personnel are less likely to inadvertently divulge patient information in the presence of strangers or unauthorized persons. Such privacy can have substantial benefits for patient assurance concerning safeguarding of their information and regulatory compliance.

SVC Triage Nurse A [referring to patient triaging]
"At the desk, patients sometimes do not want to tell you if they are an HIV patient or if they have TB or Hepatitis. You can see it in the system [with wireless, which saves having to ask.]"

SVC Registration Personnel [referring to patient registration]
"When people come to the registration desk we have to ask questions like 'What is your Social Security Number, your address, phone number, next of kin and insurance carrier?' There are always other people around who could overhear. I feel so much better knowing that I can take the wireless system with me to the patient and ask those questions."

12. Benefits include better, more personal relationships between patients and caregivers.

The following excerpt illustrates how wireless computing can help patients learn about their own conditions, enhancing patients' comfort levels and patient/caregiver relationships:

VAMF Organizational Manager with Nursing Experience
"You can use the computer system to be a part of the patient/physician relationship. You develop interfaces with graphics that the doctor can use to better explain conditions to the patient. For example, you can create a graph of depicting how a patient's blood sugar is not under control based on historical data. You can show them and ask, 'what are they doing? Are they not taking the medication?'

Or you can say, 'You are doing very well on this weight reduction for the past three years,' and you can show that to them in terms and schematics that they can understand. The patient becomes engaged that way in [his or her] own healthcare information."

In addition, technology can reassure patients that the care they are receiving conforms to their physicians' diagnoses, even when a nurse is the primary caregiver. Such as:

VAMF Floor Nurse B
"To me, the patients seem more comfortable with us using the computer to give them the medications. They ask questions about what they are getting and you can show them what the doctors ordered. It calms their nerves by showing them this in the system and then showing them how the pharmacist validated it. And then I say, 'I look at it a third time before I give it to you.'

They seem to like this idea. Actually with the computer you spend even more time with the patient sometimes. Since the process takes a little longer you end up spending more time in the patient's room. They like that."

13. Limitations include the inability to generate desired benefits when technologies such as printing and copying (of documents and labels) are not bundled correctly on the mobile workstation.

The following excerpt addresses the registration process in the Emergency Department of SVC:

SVC Nurse Manager ED [comments made prior to implementation of wireless patient registration]
"Registration personnel have to take the information, make copies of the insurance and ID, and then print out labels for the arm band and for the chart. So regardless of being wireless, they still have to go back to the [cubicles] to get the printout and come back. I'm not sure if it will really save time."

SVC Registration Personnel B [referring to registration process]
"Registration is much easier and more convenient with the wireless system compared to what we used to do, but we still have to come back the desk to print [forms after inputting patient information. Management] should at least put printers in different areas in the ED."

Nurses in ACU at HMC pointed out that printers were available only at the nurses' station, and there were frequent backups for retrieving printouts at these sites. These assessments needed to accompany patients to their next units because the facility's WLAN was not operational hospital-wide. Additionally, the ACU and PACU applications were not database–driven, and

could not interface with any other application. Equipping workstations with mobile printers would have alleviated printing problems and overcome the frustration and inefficiency of retrieving papers elsewhere.

In fact, printing issues at HMC were so severe that they overshadowed the benefits of mobility:

HMC ACU Nurse D
"…you still had to go back to the printer because a paper copy of the chart had to go with the patients into surgery. We don't have a lot, or at least enough, printers and we had to run back and forth. A lot of times you would go to get your printout and couldn't find it because someone placed it to the side. It was a nightmare."

14. Limitations include varied acceptance and frequency of use, which not only differ based on the environment but also based on (1) the actual patient care task performed, (2) nurses' need to bond with the patient, (3) necessity to learn about the patient, (3) and desire to defend themselves from liability.

Lawrence and Nohria (2002) assert that four fundamental human drives (i.e., drive to acquire belongings for well-being, the drive to bond with other human beings, the drive to learn about our environment, and the drive to defend from threats) impact all human behavior. Three of these drives (i.e., the drive to bond with other people, the drive to learn about the environment and task, and the drive to defend against threats or liabilities) appear to impact wireless acceptance and actual use, which varies across nursing tasks and hospital environments.

The key points that expose the connection between human drives and IS acceptance are:

1. In closed environments there are few distractions, the dominant drive is the drive to learn. This drive tends to promote system acceptance and use.
2. In open environments in which there are many distractions, the dominant drive is to bond with patients. This drive tends to restrict system acceptance and use.
3. In both open and closed environments, the drive to defend from litigation is not dominant, probably because most nurses have not been called to testify in court or give legal depositions. However, the drive to defend against erroneous medication administration is extremely strong, largely because nurses are keenly aware of potentially severe consequences in case of mistakes. This drive – which is far less evident for electronic charting and patient triaging – also promotes system acceptance and use.
4. In medication administration, the drives to bond and learn are very important. Nurses' ability to reassure patients that the correct medication is being administered, which enables nurses to render care with less patient interference, and to learn about the effectiveness of prior medications or other history, which increases nurses' own confidence levels, promotes system acceptance and use.
5. For electronic charting and patient triaging, the strength of the drive to bond on IS acceptance and use depends on patient status. If the patient is conscious, the intense drive impedes system acceptance and use because nurses may feel that their attention is consumed with entering data, especially when the software is problematic as in ACU at HMC. At VAMF, in contrast, some nurses felt that being able to show conscious patients their data in the system promoted the patient's trust in the nurse's caregiving abilities. However, if the patient is not conscious as in PACU at HMC, nurses' drive to learn may be a the most dominant and positive influence on system acceptance and use. (See Appendices C and D for supporting data associated with this finding.)

Recommendations

The study demonstrates that wireless computing can both improve working conditions for nurses and promote patient safety. This finding has practical implications for both any hospital that seeks to improve its caliber of care, information, and defense against malpractice. Additionally, this research may provide regulatory agencies and professional associations with insight into wireless computing's ability to improve highly interdependent patient care tasks.

Recommendations for implementing wireless computing in hospital environments are as follows:

1. Nursing education programs should integrate electronic patient care documentation into nursing curricula immediately.

While some nursing programs include basic information systems/personal computing classes, many still do not. The result is that, while nurses may be exposed to PCs in other parts of their education, they may not be deeply familiar or comfortable with either wireless technology or information systems concepts. Nursing informatics is available as a separate discipline, but nurses trained in these programs typically do not perform daily clinical tasks. At the very least, an organizational manager at VAMF suggested that nursing schools partner with hospitals employing wireless computing to expose nurses-in-training to the technology.

2. Hospital management should use technology as a recruiting and retention tool.

A 2002 statement by the President of the American Federation of Teachers/AFT Healthcare on the Joint Commission on Accreditation of Healthcare Organizations Report in Nursing Shortage reports the following statistics:

1. One in five registered nurses plan to leave the profession.
2. 53% of nurses say the job is too stressful.
3. 20% of nurses say irregular hours are problematic.
4. 35% comment on poor working conditions.
5. 81% of the potential leavers report poor morale.
6. 64% say they do not have enough time to spend with the patient.
7. 60% note the paperwork burden.

These alarming statistics are likely to worsen further as the pool of qualified nurses dwindles and those remaining are pressured still further. However, this study suggests wireless computing can directly and/or indirectly address the majority of those factors, including job stress, working conditions, morale, patient time constraints and paperwork burdens. It is possible that no other technology currently may be as useful, at relatively low cost, for addressing such a wide range of nursing frustrations.

Hospitals that implement wireless computing – and provide ample, supportive training in its use – may find themselves more able to recruit and retain talented nurses, a significant advantage in a fiercely competitive labor market.

3. Hospital management should create a culture, including a nurse vision statement, emphasizing the benefits and value of nurses' involvement in technology.

One nursing informatics manager (from a hospital not directly involved in this study) stated that nurses and hospitals benefit from understanding the value they will receive from large-scale IT/IS implementations. Otherwise, nurses tend to focus on their strength, patient care.

According to the manager, who works with a Large Healthcare System in the Northeast, hospital management and IT departments must make initiatives

"You have to make this [technology implementation] salient to [nurses], and explain how what they do or don't do impacts the whole care delivery process. But you [also] have to show how you are going to support them in supporting the organization… You just can't dump the technology there and expect them to use it, especially if you are replacing this chart they use to carry around now with a computer on a stick… They think you are giving them more to do in attempts to make the physicians' jobs easier."

The added benefit of such acceptance, of course, is that wireless buy-in from nurses actually does impact quality of care, and protect the hospital, throughout a patient's stay.

4. Hospital IT departments should support development and/or adaptation of wearable devices and multi-function mobile carts by manufacturers to support wireless use.

"Wearables," such as handheld scanners and small tablets that can be clipped onto waist belts, free nurses' hands to hold a scanner, deliver medications, or aid a patient in numerous ways. More streamlined design similarly might make carts more maneuverable, more able to fit easily between beds, and – with additional shelves and/or desktop space more conducive to multiple uses.

These innovations already are in place in other industries. For example, aircraft mechanics have similar need for mobility and access to critical information at the point of service. US Air Force mechanics now use wireless tablet to access technical data while performing maintenance on parked aircraft. These mechanics wear tool belts and have mobile tool cabinets located near their work areas.

5. Hospital IT departments should physically integrate documentation devices (e.g., scanning, label and document printing, copying, and electronic signatures that maintain patient confidentiality) to support ease of use.

As long as nurses and registration personnel must make trips back and forth to a desk or station to generate and retrieve paperwork or ID tags, they will have a significant disincentive to use wireless computing. Patient registration typically requires validating identification and insurance information, copying documents or cards, printing wristband labels , and securing signatures on documents.

This time-consuming process can be expedited, while significantly reducing nurses' frustrations, when supporting devices are combined on a single mobile cart.

6. Hospital management should extend wireless use to other tasks that are location-, time-, identity- or inter-dependent, and/or are highly information- intensive.

Table 6 describes other tasks that may be well suited to wireless computing:

7. Hospital management should institute thorough wireless training for nurses prior to introducing the technology.

Informatics and nursing education personnel at VAMF reported the greatest success with the following program: first, orienting nurses to wireless computing in a classroom setting, which requires excusing nurses from floor duties; second, hands-on training on the floor; and finally, advanced software training after they have become more comfortable with maneuvering carts and operating the systems. IS personnel also note the effectiveness of periodically visiting nurses on the floor to reinforce good mobile software and hardware usability techniques.

In their experience, relying solely on hands-on training in the work environment, without initial classroom instruction, was not effective. In fact, lack of classroom and on-floor instruction may endanger patients because of greater likelihood of technology confusion or misuse.

VAMF documentation also is very detailed and user-friendly for both hardware and software. In addition, these materials describe the system's purpose and the IS department's commitment to providing nurses with continuous support. As a result, the nurses at VAMF applaud their Informatics and Education personnel.

Interestingly, HMC's ACU nurses strongly felt their training was inadequate, while the same hospital's PACU nurses raved about the training program. PACU training, which was developed by the unit's nurse coordinator and manager, involved charting via wireless three times per week, for several weeks, prior to the live implementation.

No such introduction was provided in ACU. At HMC, there was minimal interaction with the IS staff for training and no user manual explaining operation of the system for either unit. However, PACU nurses developed their own training, which fostered support among colleagues and ensured nurses understood how the technology would ease their jobs.

Table 6. Tasks Amenable to Wireless Computing

Task	Current Process	Prospective Wireless Process
Inpatient meal ordering	- Food administration personnel (FAP) make rounds to gather patient meal requests. Or patients write meal request and forward to FAP. - FAP reconciles physician-ordered meal restrictions with patient meal request. - FAP sorts orders and prepares requests based on food availability. - Patient may or may not receive request; no real-time access to ingredient availability.	- FAP carries wireless information system (WIS) on rounds. FAP is able to let patients know immediately, via real-time data access, whether their requests are available and meet physicians' orders. - Kitchen staff access requests and begin preparing meals as FAPs gather meal orders. - Patients receive meals they ordered, or explanation about why they can't, and faster meal service – both increasing their quality of experience. Hospital has opportunity to save food spoilage and better match supply to demand, potentially reducing costs.
Medical supplies inventory	- Inventory personnel or healthcare provider manually inventory supplies and enters data into IS. - With no real-time information access, supplies may be double-ordered [NOTE: true?]. - Manual process is time-consuming and error-prone.	- Inventory personnel utilize integrated barcode and handheld scanner system to automatically update inventory as supplies are used and re-stocked. - Supplies are in stock when needed; hospital potentially gains significant inventory management savings.
Patient transport within hospital	- Transport personnel use walkie-talkies to communicate with nursing stations and a transport base about patient movement. - Records of transport instructions, requests and patient whereabouts are maintained manually. - Long transport wait times due to inefficient routing of transport personnel and equipment.	- Transport personnel access patient data, transport requests and related information via wireless devices. - Patients are moved more quickly, improving quality of care, and more efficiently, potentially reducing hospital needs for transport staff and equipment.

8. Hospital management should incorporate software and hardware necessary to support automated patient and medication identification on the mobile workstations such as barcode-scanning technology or Radio Frequency Identification (RFID[1]) to ensure nurses are charting on the correct patient.

Manual charts typically are kept at patients' bedsides or in boxes outside of their rooms, rather than carried by nurses as they make rounds. Conversely, wireless devices by definition are mobile, and a nurse effectively takes all patients' records with him or her. Safeguards accordingly must be in place to ensure that nurses are charting on the right person.

VAMF's medication administration system requires barcode scanning of the ID wristband issued during registration and the medication label to ensure the correct medication is given to the correct patient. The system alerts the nurse if any scanned information is inconsistent with the prescription, such as incorrect patient, inaccurate medication or dosage, and invalid time for medication delivery.

Some form of identification (i.e., barcoded wristband or an RFID tag) that (1) patients wear throughout their hospitals stays and (2) can be decoded and validated by embedded wireless security features is imperative for patient safety and hospital liability protection.

RFID (radio frequency identification) is a technology that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency (RF) portion of the electromagnetic spectrum to uniquely identify an object, animal, or person. RFID is coming into increasing use in industry as an alternative to the bar code. The advantage of RFID is that it does not require direct contact or line-of-sight scanning. An RFID system consists of three components: an antenna and transceiver (often combined into one reader) and a transponder (the tag). The antenna uses radio frequency waves to transmit a signal that activates the transponder. When activated, the tag transmits data back to the antenna. The data are used to notify a programmable logic controller that an action should occur. The action could be as simple as raising an access gate or as complicated as interfacing with a database to carry out a monetary transaction. Low-frequency RFID systems (30 KHz to 500 KHz) have short transmission ranges (generally less than six feet). High-frequency RFID systems (850 MHz to 950 MHz and 2.4 GHz to 2.5 GHz) offer longer transmission ranges (more than 90 feet). In general, the higher the frequency, the more expensive the system. RFID is sometimes called dedicated short-range communication (DSRC) (http://ttarget.adbureau.net/hserver/acc_random=9682116/site=searchsap/area=glossary.gDefinition/aamsz=interstitial/position=interstitial_13/keyword=c805987/vibe=searchsap.glossary/pageID=57645085).

Reading of RFID tags do not require line of sight as does barcode scanning of patient ID bands that can provide patient identification irregardless of their location within the hospital (i.e., in the waiting room, in transport, in the operating room, etc.), which can prevent erroneous medication administration and intervention; thus reducing liabilities (cited from discussion with Dr. Rolf Wigand, Chair and Distinguished Professor of Information Science and Management at the University of Arkansas). Cost effectiveness of RFID vs Barcode scanning is debatable. For one, the cost of antennas and transceivers are considered as a one time infrastructure expense and transponder (i.e., tags) may be comparable in price to barcode labels. The primary cost would differ based on the use of low or high frequency RFID systems. Either technology can be used to safeguard devices from misuse or theft.

Conclusion

This research has revealed that wireless computing (with effective program design that integrates electronic physician orders, pharmaceutical verification, and medication administration at the point of care coupled with fitting mobile devices) allays potentially fatal errors, improves patient safety, and boosts overall quality of care. Additionally, wireless computing provides a comprehensive view of the patient's medical information, which is imperative for caregivers to effectively and efficiently service the patient at every point in the patient care system.

The research also shows the factors that hinder acceptance of wireless computing – but that once wireless computing is accepted (that is, the technology is amenable to the task and that human drives are appeased), performance benefits greatly overshadow those of prior technologies.

Thus far, there are no hospital-wide implementations known that enable wireless computing. Access to information is vital to the way hospitals do business, but tethered technologies cannot deliver the state of performance needed to adequately decrease administrative workloads and promote patient safety, especially for extremely mobile workforces.

It is possible hospital administrators are comfortable with the performance of tethered systems, in which they have made substantial investments, while understanding that these technologies are no longer the best option for all tasks. As the status quo, tethered computing appears to have become a *sustaining technology* (i.e., one that maintains the rate of historical performance improvements that stakeholders have come to expect (Christensen and Bower, 1996).

Therefore, for many hospital administrators wireless computing may be viewed as a *disruptive technology*. Such technology "disrupts an established projectory of performance improvements or redefines what performance means (Christensen and Bower, 1996)." Benefits aside, disruptive technologies may not be considered the most effective means to bring about desired performance benefits, particularly in more conservative healthcare organizations. Christensen and Bower (1996) state, "sustaining technologies appealed to established customers in existing mainstream markets and disruptive technologies rarely could be employed in these markets."

Disruptive technologies such as wireless computing may require business process re-engineering, technical restructuring of the infrastructures, or interoperability with existing systems in order to derive great benefit. As a result, hospitals may need a paradigm shift to view these technologies, not as *disruptive* but as *dovetailing* a convergence between the technology characteristics, organizational assets, and task performer capabilities that disrupts the old economics of the task without disrupting the task environment. In this process it is imperative to integrate the task performers into the implementation process by ensuring that the new technologies truly support the way they actually do work. For optimal success, the task performers need foundational skill sets such as typing and an understanding of how using the technology *directly* benefits them (e.g., decrease in administrative workloads) and *indirectly* benefits the organization.

We suggest that hospital administrators evaluate their entire organizations for departments in which mobile workers would greatly benefit from accessibility at the point of care/work, and identify ways in which wireless might dovetail with existing care processes and computing systems while considering the system use and acceptance issues presented in this research.

This research has practical implications for both public and private sector hospitals that seek to assess the gains from wireless computing, or those that are considering implementing innovative technologies to support this method of data access. The findings and recommendations provide regulatory bodies in the healthcare industry and government insight into applicability of wireless computing in patient care and in the quest to improve working conditions for caregivers, specifically nurses. The insights can transcend industry boundaries and help to transform subunits and their respective organizations into more efficient, effective, and most importantly safer institutions.

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Footnotes

[1] The IOM 2000 report derived this estimation based on secondary data collected from a large sample of New York hospitals in 1984 by the Harvard Medical Practice and 1992 data collected in a large sample of Colorado and Utah hospitals.

[2] The research protocol at VAMF restricted nurses from divulging statistical data or opinions about the actual numbers associated with error reduction in medication administration or documentation. However, they could provide generic comments that serve as qualitative data for this research.

Appendix A: State of the Wireless Local Area Network (WLAN) Industry

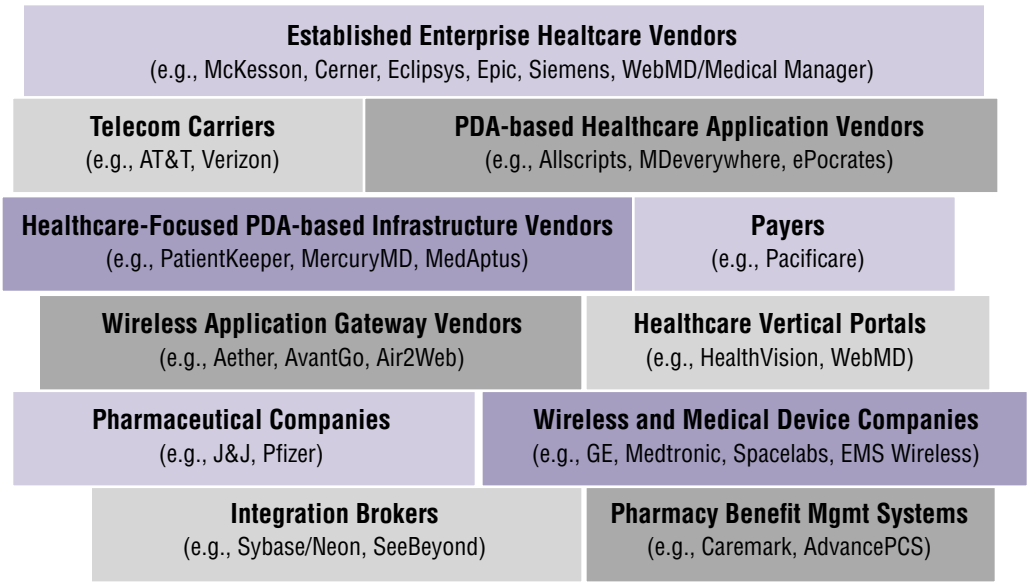
Recent adoption of improved wireless data transmission standards and supporting devices contribute to the current growth in the WLAN market for organizational implementations (i.e., 73 percent growth and $2.8 billion in revenue in 2003 (Dataquest, Inc., 2003). International WLAN shipments total nearly 26.5 million units in 2003, an increase from 15.5 million 2002. This healthy growth is predicted to continue through 2007.

Gartner indicates that North America is the largest region for WLAN shipments and accounted for nearly 63 percent of shipments in 2002. Gartner's telecommunications and networking group note that regulatory restrictions continue to delay adoption in the Europe but Asia Pacific shipments will equate to more that 22 million units by 2007 (Dataquest, Inc., 2003). The recent adoption of the 802.11g standard fueled an actual 2 percent growth in the WLAN market during the second quarter of 2003 (Dell'Oro Group, 2003). 802.11g revenue grew 48 percent to comprise 24% of the total market revenue.

Organizational acceptance of this technology, equipped with additional security features, is increasing and positive returns on investments (ROIs) are being reported within US business and academic organizations (WLANA Association, 2004). Public hospitals can potentially reap the same organizational benefits from use of this technology if they learn how to deploy it successfully.

Currently the market is saturated with vendors marketing in the healthcare industry but Gartner Healthcare predicts that established enterprise vendors for healthcare information systems will provide the needed integration in for wireless computing in hospitals in the near future (Gartner Healthcare, 2002). The following figure depicts the mix of players vying for wireless market share in the healthcare industry.

Figure 1 Healthcare Wireless Market share Vendors (adapted from Kleinberg, 2002) (Disclaimer: This vendor review is not professed as being all encompassing but the best reflection of the market status in 2002.)



These vendors differ in terms of completeness of their implementation vision and their ability to executes. Vision entails the following (Kleinberg, 2002):

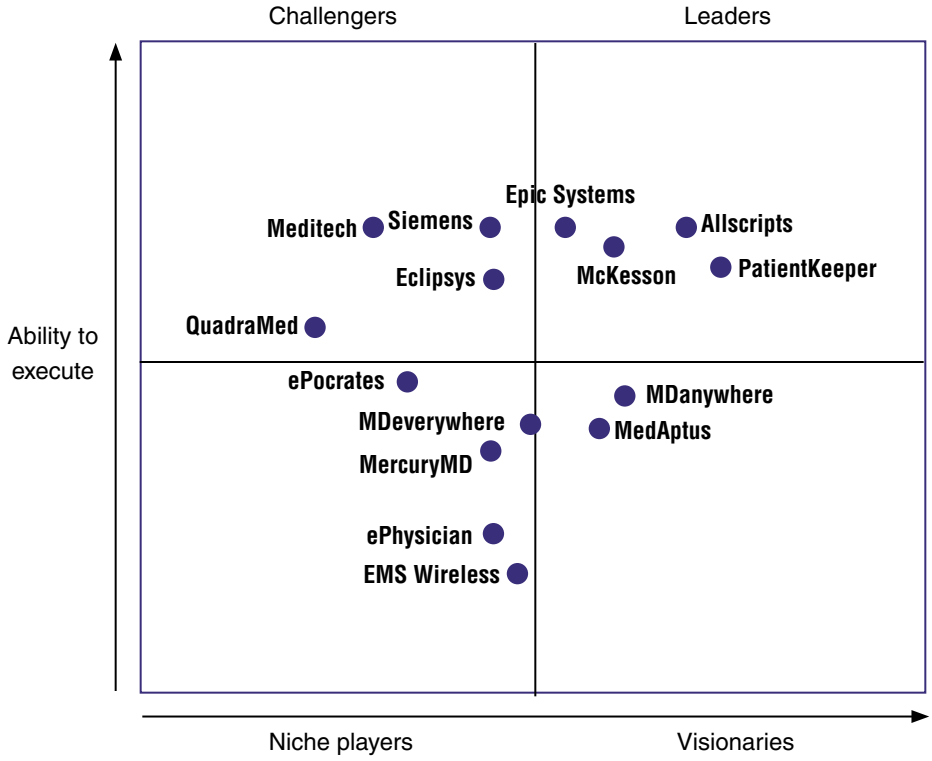
- Functionality in ambulatory and acute care settings such as medical content (i.e., electronic charting), electronic prescribing, charge capture, lab report viewing, and medication administration).
- Architecture and delivery, such as thin and thick client models, read-only and data capture/interactive applications, synchronization and security approaches.
- Integration with back-end and legacy systems.
- Support for multiple operating systems (e.g., PocketPC, Palm), networks (WLAN, WWAN, WPAN) and mobile device form factors (e.g., smartphone, PDA, tablet PC).

The following comprises the ability to execute:

- Number and types of users (e.g., adoption by physicians, nurses and other mobile clinical professionals).
- Strength and breadth of marketing/sales channels and partnerships to reach prospects.
- Number and experience of dedicated professionals to mobile/wireless healthcare development, implementation, customer service and support.

The following figure shows where the vendors who are vying for market share in this fall are situated in terms of their implementation vision and their ability to execute:

Figure 2. Wireless Healthcare Vendor Market Matrix (adapted from Kleinberg, 2002)
(Disclaimer: This vendor review is not professed as being all encompassing but the best reflection of the market status in 2002.)



Appendix B: Wireless Standards

802.11 refers to a family of specifications that are widely followed and developed by the Institute of Electrical and Electronics Engineers (IEEE) for wireless LAN technology. IEEE is renown for standards development for the computer and electronics industry since 1963. 802.11 standards specify over-the-air interfaces between wireless clients and base stations or between two wireless clients. The IEEE accepted the specification in 1997. The following table denotes the different wireless standards and the characteristics of each (Missouri Research and Education Network, 2003).

Standard	Definition	Advantages	Disadvantages
IEEE 802.11a	High-performance IEEE wireless LAN (WLAN) standard. Operates in the unlicensed 5 GHz frequency band. Delivers up to 54 Mbps data transfer rates. Radio, or Physical Layer (PHY), based on an Orthogonal Frequency Division Multiplexing (OFDM) modulation scheme. Media Access Controller (MAC) based on the standard IEEE 802.11 MAC architecture (consistent across 802.11a, 802.11b and 802.11g).	Availability: Solutions are not widely available from a broad range of companies in many form factors. Best in class speed: High throughput (up to 54 Mbps) to support heavily-loaded networks and rich multimedia content like HDTV and multiple MPEG-2 (DVD quality) video streams. Interference: The 5 GHz band is still relatively uncluttered, so there is less interference than in the 2.4 GHz band.	More expensive than 802.11b. Range: Will deliver significantly less range than 802.11b. QoS/multimedia support: Standard 802.11 MAC is Ethernet-based and does not support multimedia streams (particularly concurrent streams) well. Interoperability: 802.11a products are not interoperable with the large and growing base of 802.11b networks.
IEEE 802.11b	IEEE WLAN standard. Operates in the unlicensed 2.4 GHz frequency band. Delivers data throughput of 11 Mbps. PHY is based on a Direct Sequence Spread Spectrum (DSSS) modulation scheme. MAC is based on the standard 802.11 MAC architecture. Features an interoperability mark called Wi-Fi, which is earned via third party interoperability testing. Wi-Fi certified products will communicate with each other.	Availability: Solutions are widely available, from a broad group of companies and in a variety of forms. Interoperability: Large and growing installed based of 802.11b networks in businesses and public areas; beginning to emerge in the home as well (802.11b has won the battle with HomeRF). Cost: Price points for technology and products are rapidly declining. Adequate Speed: Maximum data rates of 11 Mbps, equivalent to 10BaseT Ethernet. With a multimedia enabled MAC, this speed enables high-speed Internet sharing, CD-quality audio and single MPEG-2 streams. Range: Offers superior range versus 802.11a; up to 150 feet depending on product and operating environment.	Lack of QoS and multimedia support: Designed for the enterprise, 802.11b is limited in its ability to support rich multimedia. Cannot support concurrent media streams well. Interference: Susceptible to interferers in the 2.4 GHz band, such as microwave ovens and cordless phones. Complexity: Most 802.11b products are hard to install and reconfigure. Range Degradation: Generally, offers ranges up to 150 feet, much more than 802.11a. In most cases, however, data rates begin to drop back (to 5.5 Mbps, then 2 Mbps, then 1 Mbps) far in advance of the maximum range, and many products can't reach 150 feet at any speed.
IEEE 802.11g	2.4 GHz physical layer specification that offers faster data rates than 802.11b (up to 54 Mbps). Uses an OFDM PHY operating in the 2.4 GHz band. MAC based on standard 802.11 MAC architecture. Can interoperate with 802.11b nodes.	Speed: 802.11g's higher data rates versus 802.11b enable both richer content to be sent across the network, as well as enabling more concurrent streams. Interoperability: 802.11g is interoperable with the large growing installed base of 802.11b networks.	Lack of QoS, Interference, Complexity, Range Degradation: 802.11g presents the same disadvantages as outlined in the 802.11b section above.

Appendix C: Influence of Drives Across Different Environments

Environment Vs Drive	Drive to Bond (with the patient to establish trust and lower patient anxiety to enable task performance with less impediment)	Drive to Learn (information about the patient)	Drive to Defend (from liabilities because of ability to thoroughly document patient/caregiver interaction)
Closed - Secured to visitors - Anesthesized patients - Little distractions from other caregivers or other patients - Low nurse to patient ratio (i.e., low work volume)	**Drive Characteristic** Low or unnecessary because of the unconscious status of the patient. None of the 8 PACU nurses interviewed noted the need to bond with the patient to ease anxiety or establish patient/caregiver trust. **Impact on System Acceptance and Use** Bonding is not a driver because of the patient's status. However, use is high because of adequate design, lack of distractions, no aversion to using the system despite technology aversion because of no fear of appearing incompetent to patients due to the patient's status. **Supporting Data** HMC PACU Nurse Manager: "I think it's great. The best thing is that you can do bedside charting. The nurse to patient ratio for us is very low compared to PACU. …we have a small contained unit. We don't have a lot of distractions like over there [referring to ACU]." HMC PACU Nurse C: "Most of what we do is monitor [because the patients are anesthesized] so having the wireless system helps us stay right there at all times at the patient's bedside and be able to chart. …I am not used to computers at all but this system is really easy."	**Drive Characteristic** High because of the need to rely on documentation because the patient cannot provide or validate information due to their unconscious state. 8 of the 8 nurses interviewed in PACU noted the importance of learning about the patient or accessing patient information via the system. **Impact on System Acceptance and Use** Learning is the superior driver because of poor fit relative to alternative methods of gaining patient information. Use is high because of adequate design that incorporates charting by exception, which allows easy access to data and ability to quickly document as they work. **Supporting Data** HMC PACU Nurse C: "I think it's wonderful. Sometimes I won't know what a particular code is and as opposed to asking someone I just look it up on the computer. I can wheel it with me to each area that I go into. I think it's great and it is so much better than writing or looking through a chart. I feel like I don't miss anything."	**Drive Characteristic** Moderate because the majority of nurses did not view the benefits of using the system to guard from liabilities unless they had been called to deposition in a legal suit and required to provide documentation of their patient interaction. Only 3 of the 8 PACU nurses interviewed noted any relationship between wireless computing and appeasing a drive to defend against liabilities and these 3 nurses had all been involved in a deposition process. **Impact on System Acceptance and Use** Defending is second to Learning as a driver. The ability to learn about and assess task efficiency and effectiveness of caregivers performing patient care overrides the desire to defend from liabilities and the primary driver influencing perception of fit and system use. **Supporting Data** HMC PACU Nurse D: "Nowadays all the legal stuff that goes with healthcare it's critical that you be able to justify everything that you do. Because you know with all the law suits nowadays everything you do ill be looked at and you have to say why you did this and that. It's better if you have it all documented. I like this system because I know it's hard to miss something so it really covers us. Before either you might overlook something because a lot was done by narrative or you just forgot because you didn't have time to write it down. Everything is really there for you and if you forget to put something in put something in that doesn't

Appendix D: Influence of Drives Across Different Tasks

Task Vs Drive	Drive to Bond (with the patient to establish trust and lower patient anxiety to enable task performance with less impediment)	Drive to Learn (information about the patient)	Drive to Defend (from liabilities because of ability to thoroughly document patient/caregiver interaction)
Electronic Charting (observed in ACU and PACU of HMC)	**Drive Characteristic** The Drive to Bond is very important when charting on conscious patients and not a major concern when charting on unconscious patients based on data from ACU and PACU. All 8 of the ACU noted influence of the drive to bond with the patient but none of the 8 interviewed in PACU noted it as a concern in charting. **Impact on System Acceptance and Use** Nurses performing e-charting in all of the units involved in this study initially perceived wireless computing as advantageous for charting because of the convenience documentation provided by the system. Having wireless computing and incorporating charting my exception aids nurses in PACU to chart effectively and efficiently while they perform patient assessments with less impediments, which has resulted in a decrease in time to complete charts, more time attending to the physical needs of the patient as vital statistic monitors indicate, and an easier means of assessing quality of care in patient/caregiver interaction but there is no real influence from a Drive to Bond between the patient and nurses because of the unconscious state of the patient. In ACU, wireless computing was a poor fit for e-charting because of the non "nurse-friendly" design of the application in light of prevalent environmental distractions but the bond is essential to ensuring that the nurse can chart effectively or with less impediment. **Supporting Data** HMC PACU: No data HMC ACU Nurse D: "I thought it would help me care for the patient better but it didn't work like that. The program was so hard to use and really didn't help us at all... I suppose if the system was working right then it would have given usmore time with the patient because we could document quicker. We could just take care of the patient or just talk to them or the family for a while to get them to feel comfortable with you. Some come in really grumpy or in pain and it's helpful if they are comfortable with you because then they kind of let their guards down and they aren't so hard to deal with... when they are like that it can take a while to get your assessments done. Anytime the patient's are upset about something it kinda affects you too. We are trained to deal with this but sometimes it does get to you. You really are concerned about getting the patient comfortable and getting your assessment done because that's the first step in them being able to get the procedure done. If you take a long time doing the assessment then it takes longer to get them in for the procedure. Everybody gets upset about that and so we try to not let that happen."	**Drive Characteristic** The Drive to Learn is very important regardless of the status of the patient to maintain data on the patient's condition that is used to determine the type of intervention and to assess medical interventions. All 16 PACU and ACU nurses interviewed noted the importance of learning about the patient to be able to chart properly. **Impact on System Acceptance and Use** Nurses performing e-charting in all of the units involved in this study initially perceived wireless computing as advantageous for charting because of the accessibility to consolidated real-time patient information on patients as they work irregardless of location. PACU must rely on documentation and other devices to learn about the patient's status until the patient regains consciousness. Wireless computing allowed PACU nurses to learn about the patient and record patient data as they work allaying the problems associated with reliance on memory, having to read though long narratives, or asking other caregivers. ACU nurses learn from both the patient and initially thought they would be able to use the system to learn about the patient's status because the ability to ubiquitously access and record patient information. This was not the case. **Supporting Data** HMC PACU Nurse: HMC ACU Nurse D: "…we have to know if they are in pain or if they have followed the instructions given to them to prepare for the surgery like if they ate anything when they were told not to. Sometimes we have to monitor them for a while before we can administer certain medications to prep them…If it worked we could have been able to check those stats quicker. While you are waiting for a patient to stabilize you could go work with another patient and take the computer with you and be able to look at the other patient's record to see if it's about time to check the vitals again. It just would have been more convenient."	**Drive Characteristic** The Drive to Defend against liabilities is not very important to the majority of nurses in PACU and ACU. Only 4 of the 16 PACU and ACU nurses interviewed noted the concern of defending from liabilities in charting. **Impact on System Acceptance and Use** The benefits of wireless computing pertaining to its impact on the ability to better defend oneself from liabilities because of being able to thoroughly document without having to rely on memory or manual charting, which is error-prone, was never emphasized to the PACU and ACU nurses. So perception of fit for this drive as it pertains to e-charting is not overwhelmingly substantiated by the data. **Supporting Data** HMC PACU Nurse E: "You are in this business because you care about people and you don't want to hurt them so it's really important that you have a record of everything but also because you need to cover your own self. If someone asks why you did it then you have to back it some way and you can't remember everything thing so having it in the system or on the printout is necessary for us. I don't want to get in trouble either." HMC ACU: No data

Open - Nonsecured to visitors - Unanesthesized patients - High distractions from other caregivers and other patients - Medium to high nurse to patient ration (i.e., high work volume)	**Drive Characteristic** High or necessary because of the conscious status of the patient. All of the 8 nurses interviewed in ACU noted the importance of bonding with the patient to ease anxiety and establish trust. **Impact on System Acceptance and Use** Bonding is the superior driver because of the patient's status. It is necessary to bond and establish trust with the patient to calm the patients' anxieties that if unattended impairs the nurses' abilities to render proper care. This in turn can impede services and slow patient throughput. Poor program design and numerous environmental distractions can hinder the nurses' ability to attend to the patient's needs, thus wireless computing or use of the system at the bedside becomes an impediment in the patient/caregiver relationship. Use is low under these circumstances because the nurses fear blemished their image with the patient (i.e., fear of appearing incompetent to patients due to the conscious patient's status). **Supporting Data** HMC ACU Nurse A: At first I would take them into the room because I was comfortable with… I noticed I wasn't making as much eye contact and I stopped bringing it into the room when the patient was conscious. When we are not making eye contact with the patient and making eye contact is crucial to easing the patient's nerves about their upcoming surgery. Our patients come in very nervous and we like to talk to them ask about their kids and let them get to know us. If they don't trust that you are going to take care of them they their anxiety goes up which is an emotion but this causes physical problems like blood pressure increase or nausea and you have to stabilize them before getting them ready for surgery so this delays the process. Having the computers there by the bedside kept us from doing our jobs to some degree. When I had that computer I noticed that I was too concerned about getting the information into the computer and printed out before the patient went to surgery. The program was so cumbersome that it made things too difficult and you felt too rushed to deal with the patient. I don't like that. We all said that the patient is our priority not that computer."	**Drive Characteristic** Moderate because the need to rely on documentation is not as crucial as in PACU because patients can provide or validate information like level of pain or confirmation of medications taken due to their conscious status. All of the 8 nurses interviewed mentioned the need to learn information about the patient and the varying methods for doing so (i.e., via the manual chart, asking the patient, or from the system). Since the system was deemed as a poor fit, the drive to learn about the patient using it was not superior. **Impact on System Acceptance and Use** Learning is the second to bonding because if the system is poor fit as in ACU the nurse can revert to gathering and validating information directly from the patient. Use was low and later non-existent because of low actual fit in this environment (i.e., inadequate design that did not incorporates charting by exception and caused the low patient/caregiver eye contact in light of high levels of distractions. **Supporting Data** HMC ACU Nurse B: "I felt like it always took my attention away from the patient. I didn't make eye contact because I would have to fiddle with the computer. I like computers but this system was so bad that it really made more work for us than anything. In fact, we went from having three sheets to six for just one patient. And the screens were arranged kinda weird so you would think you would out like items with like items but they were all over the place. It slowed us down so we stopped using them. I need to talk to the patient to make sure they are okay and calm them down a little so we can administer the anesthesia for the procedures. If I'm fumbling with the computer then I can't do that."	**Drive Characteristic** Moderate because the majority of nurses did not view the benefits of using the system to guard from liabilities unless they had been called to deposition in a legal suit and required to provide documentation of their patient interaction. Only 1 of the 8 ACU nurses interviewed noted any relationship between wireless computing and appeasing a drive to defend against liabilities and this 1 nurse was the unit manager and that personally designed the screens for the system with very little input form the unit. The data from the non-manager type nurses in the unit vehemently show her comments are not a true depiction of the impact of the technology in ACU). **Impact on System Acceptance and Use** Defending was not mentioned as a primary drive or concern in ACU. The ability to learn about and assess task efficiency and effectiveness of caregivers performing patient care is overrides the desire to defend from liabilities and the primary driver influencing perception of fit and system use. **Supporting Data** None

Medication Administration (observed on regular in-patient stay floors of VAMF)	**Drive Characteristic** The Drive to Bond is very important to assuring the patient that they are receiving the correct medications. All of the 4 nurses interviewed mentioned the impact of this drive in medication administration. **Impact on System Acceptance and Use** Nurses performing medication administration involved in this study initially perceived wireless computing as advantageous because it allows them to validate medication information as they are administering that gives them more confidence in assuring the patient that they are providing the correct medication. Having the system that provides wireless computing to information allows aids the caregiver serves as a mechanism to establish the patient/caregiver relationship because the patient can visually see there own prescriptions, which have been validated by a pharmacists, and compare that to the actual medication that the caregiver intends to administer. The system also allows the patient to view their own medical history, which includes effectiveness of previous medications. **Supporting Data** VAMF Floor Nurse B: "To me the patients seem more comfortable with us using the computer to give them the medications. They ask questions about what they are getting and you can show them what the doctor's ordered. Calm their nerves by showing them this and then saying and the pharmacist validated it and now I look at it a third time before I give it to them. They seem to like this idea. Actually with the computer you spend even more time with the patient sometimes. Since the process takes a little longer you end up spending more time in the patient's room. With the charting you it's easier and less distracting to do it right there at the bedside as opposed to back at the nurse's station."	**Drive Characteristic** The Drive to Learn is very important in medication administration because of the need to know what medications are valid prescriptions and the history of their effectiveness regarding the patient's condition. All of the 4 nurses interviewed mentioned the impact of this drive in medication administration. **Impact on System Acceptance and Use** Nurses performing medication administration involved in this study initially perceived wireless computing as advantageous because of the notion of being able learn about the patient's status and prescriptions ordered to treat the patient's condition.. Having wireless computing enabled nurses to learn pertinent information regarding who, what, and when meds are given at the point of care. **Supporting Data** VAMF Floor Nurse A: "…you can check prior orders and you have all the information you need about the patient right there at your fingertips. If you have any questions or concerns because you are still the person administering the meds, you can call the doctor or the pharmacy. You know who ordered what, when it was validated and who did it. If something doesn't make sense to you about the order when you go to give the med then it's now easier for you to find out if it's valid or not because you know who exactly to call and ask. All of that information is right there in the system. It just helps you not make any errors. It doesn't save anytime it's just so much safer and that's really what's important."	**Drive Characteristic** The Drive to Defend is very important in medication administration because of the need to ensure that the errors do not occur which can be detrimental to patient safety and even fatal. 3 of the 4 nurses noted the importance of defending from liabilities in medication administration. **Impact on System Acceptance and Use** Nurses performing medication administration involved in this study initially perceived wireless computing as advantageous because of the ability to record patient information that aids in establishing comprehensive documentation that serves as evidence to about the caregiver/patient interaction. This documentation can be used to defend the caregiver's actions if ever questioned for liability purposes. **Supporting Data** VAMF Floor Nurse C: "Using BCMA [barcode medication administration system] is the safest way to give meds though and it protects you as the nurse. I know that the physicians and the pharmacists have okayed these medications for me to give. I still make sure that they pass the common sense test but the system has so many alerts that you really don't have to worry about messing up and giving the wrong med if you follow the procedure."

Patient Triaging (observed in the Emergency Department of SVC)	**Drive Characteristic** The Drive to Bond is important when the patient is conscious to be able to calm the patient enough to gather abbreviated information about their condition in a short amount of time upon initial entry into the patient care system. In one regard, having access to historical information on patient's who have been previous patients at the hospital enables the triage nurse to reassure the patient that they (the caregivers) are cognizant of their pre-existing conditions, which allows the triage nurses to validate critical information that the patient may have forgotten to mention to the nurse. In this regard, the bulk of the onus is not on the patient to provide all information, which is often difficult for them considering their level of pain and inability to communicate. All 3 triage nurses interviewed believe that the ability to access information and not having to totally rely on the patient to provide needed information lessens the patient's frustration with them as nurses in the triage process. However, for triage the 3 nurses noted that gaining the information about prior care and medical history is more important that bonding at this initial assessment. **Impact on System Acceptance and Use** Nurses performing triage in the ED involved in this study initially perceived wireless computing as advantageous because it promised to allow them the ability to gather and process information about a patient upon initial entry into the patient care system at the patient's location (i.e., in ED waiting room, in critical care unit, or near EMS or patient vehicles), which would allows them more quality time triaging as opposed to processing data at the triage nurse station. For triage, the system observed fit the environment and did provide the needed mobility to triage patients at their physical location, which allowed the patients to be serviced faster (i.e., no extended waiting room stays for the patient). Additionally, having wireless computing allayed the problem of the triage nurse having to rely on memory, transcribe hurriedly written notes, and/or make excessive trips back and forth from a critical care patient's location to process data at the nurse triage stations that often added to the frustration of the nurse and the patient. The nurse could better assure the patient that existing patient data was known and that their current condition is appropriately annotated. **Supporting Data** SVC ED Triage Nurse A: "The nurses got really excited about it, even though people don't like change and the computer part scared us but it was a system that would make things legible and we wouldn't have to rewrite the same common data every time the patient came. We can go to the patient as opposed to waiting for the patients to come to us at the triage desk if needed. We still use the computers at the triage desk but I think we go to them it kind of makes them feel more comfortable. If we have critical patients we go to them anyway but at least we can take the system with us and do all of the triaging right there with the patient as opposed to scribbling it on some paper or just trying to remember stuff and then coming back to triage [the triage nurse station] to enter it... You know along the way from the patient's room or wherever they are back to triage [the nurse triage station] you might get interrupted numerous times and could easily forget things that then you have to go back to the patient once again. It was very frustrating for the patient and us. But now it's great because I can do it right at the there [the point of care]. Some of the family members get really upset because they think you can deal with the computer later and the urgency of taking care of the patient is more important. I think these same people would react the same if you manually triaged with a chart. But I reassure them that their family member can get better care if I assess correctly and the computer helps me do that. "	**Drive Characteristic** The Drive to Learn is very important in triaging because the purpose of this initial assessment is to gain information to assess the patient's current condition and view medical history to most effectively determine which area of the patient care system (i.e., acute or critical) is more amenable to their physical needs. All 3 triage nurses interviewed emphatically noted the necessity to learn about factors in the medical history (e.g., allergies, prevailing ailments, etc) that are critical to procedures taken by the attending nurse and/or physician during immediate care. **Impact on System Acceptance and Use** Nurses performing triage involved in this study initially perceived wireless computing as advantageous because of the notion of being able learn about the patient's status and historical medical information to properly make initial assessments and appropriately categorize the patient for treatment. Having wireless computing enabled nurses to learn pertinent information regarding the ailment at the point of care. **Supporting Data** SVC ED Triage Nurse A: "Some of the patients come in by rescue, or unconscious, or the old person that forgets and you cant' get the needed information to triage them. It would take us hours to look through records if they were a previous patient. Now you can look it up in the system and read down the list and confirm that they are still on certain medications or they had a procedure done in the past. We could read the charts and if we have to often make changes because the patient either forgets to tell you something or they didn't understand the question the first time. So you had a lot of scratch throughs, can catch information... they don't want to tell you that at triage... It's great for that because we have to know these things to figure out the best treatment."	**Drive Characteristic** The Drive to Defend is a concern because of the need to ensure that the errors do not occur, which can be detrimental to patient safety and/or delay the patient from receiving proper treatment because of inaccurate triage information. 2 of the 3 triage nurses interviewed noted that having wireless computing or the system helps to protect them from making liable actions. **Impact on System Acceptance and Use** Nurses performing triage involved in this study initially perceived wireless computing as advantageous because of the ability to record and access historical medical data that aids in establishing comprehensive documentation that serves as evidence to about the caregiver/patient interaction. This documentation can be used to defend the caregiver's actions if ever questioned for liability purposes. **Supporting Data** SVC ED Acute Care Nurse A: "It's just less papers to lose and less the chance of you leaving something out. You feel reassured that you can enter it right there with the system. The information is just so more accessible and legible, which keeps us from making mistakes in treatment… I am concerned about the automatic times that the system generates because sometimes treatment starts in the car and you've gotten the patient stabilized before any information is ever entered in the system but those things don't become an issue until somewhat gets sued."

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