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Approach to mobile information and communication for health care☆

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Summary Evidence suggests that inadequate access to information and ineffective communication are proximal causes of errors and other adverse events in-patient care. Within the context of reducing these proximal causes of errors, we explore the use of novel information-based approaches to improve information access and communication in health care settings. This paper describes the approaches for and the design of extensions to a clinical information system used to improve information access and communication at the point of care using information-based handheld wireless applications. These extensions include clinical and information resources, event monitoring, and a virtual whiteboard (VWB).

1. Introduction

Several studies have demonstrated that the lack of access to information during decision-making and ineffective communication among patient care team members are proximal causes of medical errors and other adverse events in-patient care [1—3]. We have designed and implemented extensions to our clinical information system in an attempt to address these causes.

We contend, with support from published studies, that many errors stem from one or both of two kinds of proximal causes: lack of information at the point of decision-making [1—3] and breakdown in communication for coordinating patient care team members [4—8]. By their nature, these problems should be responsive to information-based solutions (as opposed to, say, requiring advances in hardware technology or biomedicine) [7—12]. We are exploring the use of novel information-based approaches to improvement in information access and communication.

We sought solutions that reduce reliance on memory and support error-proofing. We considered interventions to be on a spectrum from computation to communication, and considered which interventions were appropriate for which tasks. Based on an analysis of the clinical information needs and communication patterns of nurses and physicians in the practice of in-patient care, we extended an existing Web-based clinical information system using institution-independent, hand-held wireless applications. We anticipate these applications will improve patient care by reducing proximal causes of medical errors and other adverse events.

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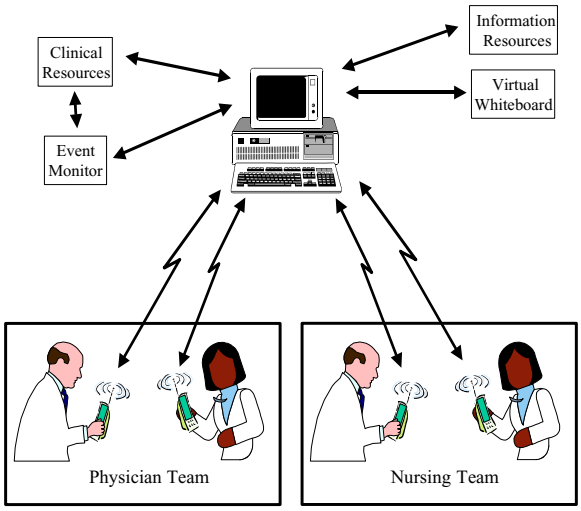

Fig. 1 Clinical information system extensions to support collaboration and information needs.

2. Approach

Our approach involves the introduction of new information technology into in-patient care settings in an attempt to improve access to information and communication (proximal causes of medical errors). The application consists of extensions to the existing clinical information system, WebCIS [13]. WebCIS is the Web-based clinical information system at New York-Presbyterian Hospital (NYPH) that enables clinicians to browse the content of their patients' medical records. These extensions include clinical and information resources, event monitoring, and a virtual whiteboard (VWB) (Fig. 1).

3. Information and communication needs studies

The initial step of our approach was to identify areas where WebCIS could be further improved within an error prevention framework. Each day, approximately, 2000 users use the system to view about 7000 patient records. These users include attendings, housestaff, nurses, students, and administrative staff. WebCIS is accessible through Web browsers running on computers at nursing stations and offices at NYPH as well as from off-campus locations. We conducted surveys, focus group sessions, and observational studies with resident housestaff, hospitalist attendings, and nurses with the intent of understanding the problem and planning the solutions [14,15].

The results of these studies showed that 68% of information needs remained unsatisfied or met with failure during teaching rounds. Similar results were found during walking rounds (64%). Physicians cited a majority of information needs related to patient specific data. Domain-specific information (e.g., guidelines and formulas) were mentioned by physicians but less frequently by nurses. The survey data suggested that both groups have significant difficulty in obtaining information mainly because of the time constraints. The results of the focus groups supported these findings. In the focus groups, physicians and nurses also emphasized that since the time to look up information is limited, efficient and relevant information sources are more useful.

The focus groups also showed that most of the participants were already using handheld devices, and commented on their practicality; particularly, for looking up drug information. Interns and residents identified Web sites, such as MD Consult, which supports searches across many textbooks as their preferred choice for domain-specific knowledge because of the ability to choose the information level on the fly. Hospitalists identified Up-To-Date as their preferred choice because it gave more focused and relevant search results with cited references to journal articles. Both groups rarely used Medline searches in the hospital setting stating that searches were too cumbersome and that they often did not have time to find the full text article in the library.

Communication difficulties identified by the groups focused around four main problems: a slow and inefficient paging system, inconsistent communication upon transfer of patient care, the need for feedback on order status, and the need for face-to-face communication where mistrust or disagreement in care plans existed. A common ''whiteboard'' area with patient problems, responsibilities, and tasks with check-off to identify completion was considered to be a potential solution to non-urgent communication issues regarding patients.

In addition to the studies described, we have used WebCIS log files to track who, what, where, when, and in what context (that is, what clinical activity) clinicians access on-line health information resources [16]. We accomplished this by studying clinicians' selections of links from the WebCIS ''health resources'' page. We examined 6 months of log files to identify 38,763 uses of resources by 2607 users. We were able to identify sterotypical usage patterns of information resources based on user type (e.g., attending physician, nurse, house officer, etc.), clinical context (e.g., reviewing laboratory results, medication orders, etc.), and resource (e.g., PubMed, Micromedex, Harrison's, etc.). A companion survey demonstrated that most

clinician access to these resources was through the health resources page (and hence, trackable through the log files). The users perceptions of their resource uses were validated through comparisons with their activity as recorded in the log files.

These preliminary studies provided the motivation for the development of the applications: clinical resources (PalmCIS), virtual whiteboard, event monitor, and information resources (infobuttons).

4. Clinical resources (PalmCIS)

PalmCIS (palm-based clinical information system) is an application that displays a set of patient information on a wireless handheld device. It is the wireless, palm-based extension to our current NYPH desktop clinical system (WebCIS) that is designed and formatted for use on a wireless hand-held device (WHHD) [17]. This extension provides NYPH clinicians with secure access to patient data anytime, anywhere, and includes access to data in the repository, alerts, and the virtual whiteboard, as well as many other commercially-available Web-based information resources. The WHHD can also provide access to locally stored information resources (such as ePocrates).

PalmCIS provides features that are intended to improve timely access to clinical information. In designing the system, we considered the unique features of the wireless environment such as screen size, input mechanism, and bandwidth.

PalmCIS is based on client—server architecture and is platform-independent. Therefore, it can be accessed from a variety of WHHDs. Client browsers that provide direct, SSL (secure socket layer) encryption such as the PalmSource Web Browser 2.0 can be used to interact securely with PalmCIS [18].

The server-side application of PalmCIS is a CGI program that interacts with the same clinical systems as WebCIS. These systems include the clinical data repository (CDR), medical entities dictionary (MED) and lightweight directory access protocol (LDAP) server. We have taken the following security measures: IP and user authorization, strong user authentication, session management, logging, and e-mail notification of successful and unsuccessful logins (Fig. 2). We have discussed the issues regarding the development and new technologies in a recent publication [19].

Once logged onto PalmCIS, users are presented with their patient list in a pull-down menu as well as an option to specify a patient's medical record number (MRN). Upon selection of a patient, users are provided with a concise view of their patients through presentation of a patient report. This report contains a summary of laboratory, cardiology, and radiology results for the last 2 days. For each result, the name and timestamp are displayed along with more essential information in a pull-down menu. For example, the values for sodium, potassium, bicarbonate, chloride, blood urea nitrogen, creatinine, glucose, and calcium are displayed for a ''basic metabolic panel'' laboratory result. Users have the option to view details of the results using the submit button containing a ''+'' that is found next to each result. Users can also obtain results prior to the previous day as well as other types of results (e.g., pharmacy reports, discharge summaries, and sign-out notes). Fig. 3 shows a few PalmCIS screens.

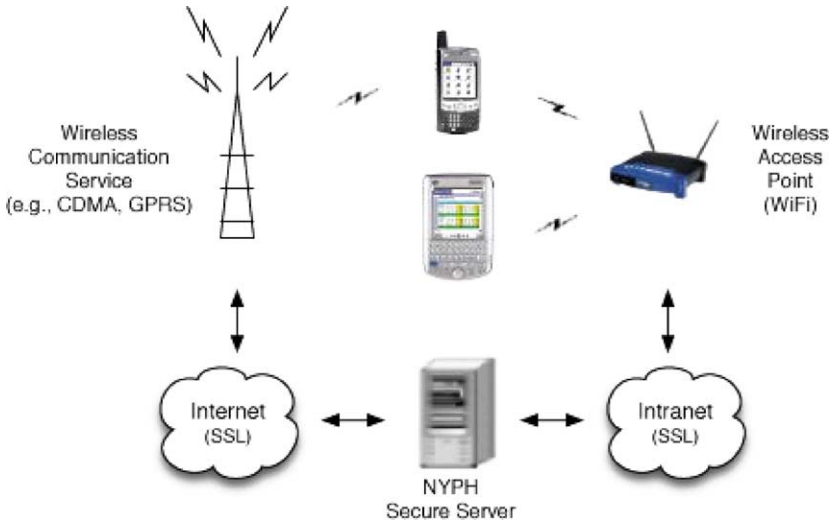

Fig. 2 PalmCIS architecture.

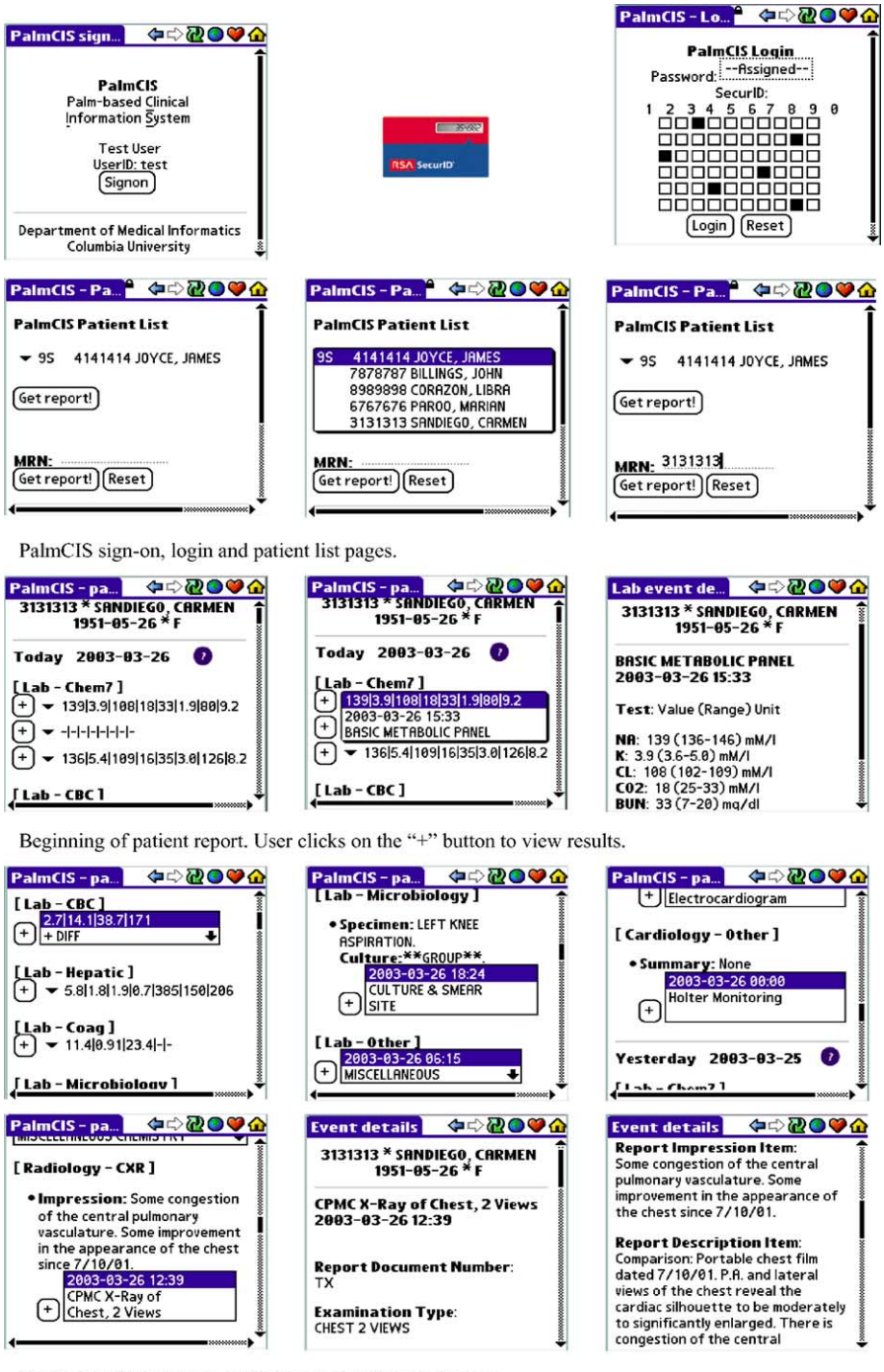

Fig. 3 Clinical resources (PalmCIS screenshots).

5. Virtual whiteboard

The virtual whiteboard is used for posting, routing, and tracking communications among nurses and physicians to address deficiencies in current channels used to coordinate care. It is intended to limit the number of paging interruptions by providing a mechanism for sending simple messages among providers asynchronously [20].

The VWB depends on two databases: one to keep track of health care team members assigned to particular patients and one to keep track of task requests. The team member assignment database is based on the current patient list capabilities in WebCIS (which allows users to maintain lists of patients assigned to teams and individuals) with features that allow assignment of specific roles for team members (resident, intern, and attending).

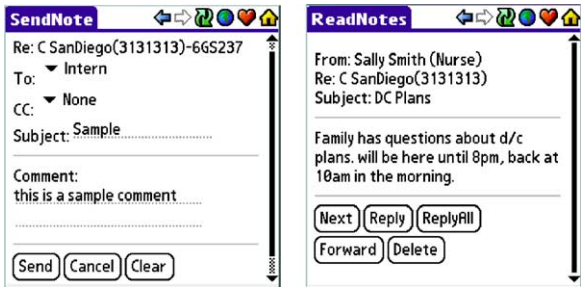

Fig. 4 Virtual whiteboard.

We designed a Web-based interface to maintain interns' schedules as they are entered each month by the Department of Medicine. Interns verify this schedule during the normal process of adding a patient to their primary list in WebCIS. Nurse—patient assignments are also captured by a Web-based interface at the beginning of each shift.

The task management database allows users to post specific tasks to patients' task lists, with assignment of the person responsible for carrying out the tasks, priority level of the tasks, and desire for acknowledgment. The VWB application provides a framework for handling a variety of tasks. The VWB handles priorities ranging from ''routine'' to ''urgent''. If a user has not acknowledged an assigned task within the time appropriate for the priority of the task, the sender is notified. For safety reasons, the VWB does not allow tasks to be assigned priorities of ''emergency'' or ''stat''; in such situations, users are directed to use the usual communication channels (e.g., the hospital paging system). Fig. 4 shows two screens of this application: reading and sending a message to the whiteboard.

6. Event monitoring

PalmCIS is also intended to provide timely palm-based notification of real-time alerts. The event monitor notifies clinicians about potential problems that may occur by checking in-coming clinical data and in providing computer-generated messages related to drug—disease contra-indications, drug-laboratory orders, and laboratory results. Event monitoring and alerting are implemented in WebCIS; however, they are still under development for PalmCIS. We expect to integrate laboratory, disease, and medication data alerts into a comprehensive wireless alerting system. We are focusing on alerts beyond those currently handled by order entry applications. When an alert condition is detected, an application formats the message and transmits it to the physicians and nurses responsible for the care of the relevant patient. For example, if a significant increase in serum creatinine is detected in a patient receiving a nephrotoxic medication or a renally excreted drug, an alert is sent to the physicians assigned to that patient and copied to the appropriate nurses.

7. Information resources (infobuttons)

Infobuttons are links between the clinical record system and on-line information resources that use patient data to automate retrievals of information in response to anticipated information needs [21]. On-line information resources include electronic documents and textbooks, databases, search engines, and expert systems. For example,

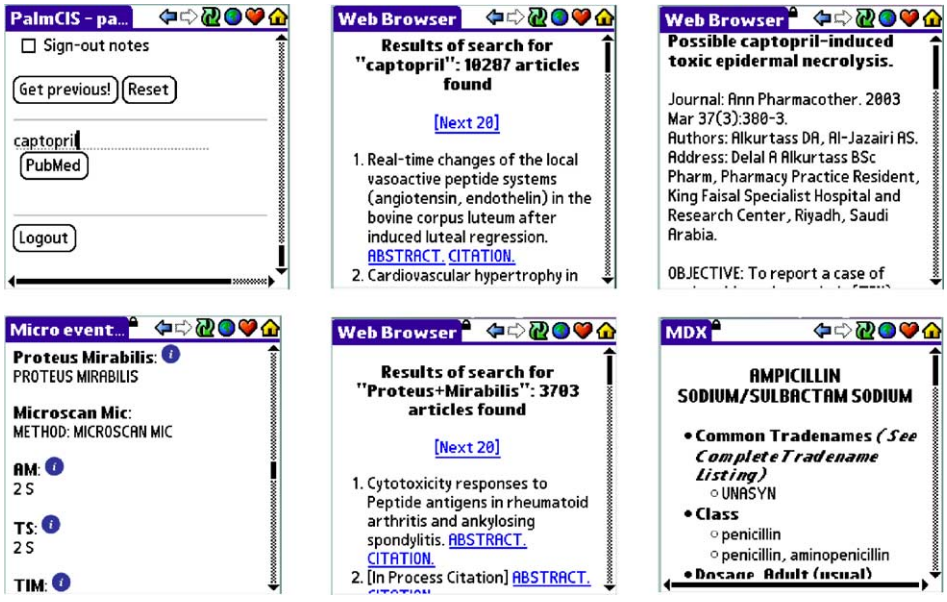

Fig. 5 Information resources (Medline search (top) and PalmCIS microbiology infobuttons (bottom)).

a laboratory result regarding a medication level could be mapped to national drug codes (NDC) or drug trade names to search the physicians desk reference (PDR) for prescribing information. Similarly, a term in a chest X-ray report might be linked to a clinical decision support system such as DXplain for more information about the differential diagnosis for findings in the report.

We have previously implemented and deployed a small number of infobuttons in the hospital clinical information system. Those infobuttons use patient data to automate retrieval from bibliographic (Medline) and pharmacology databases (Micromedex). The infobuttons currently implemented in PalmCIS retrieve information from the same databases. A filter was implemented to display only the relevant information retrieved from these databases. For example, icons, advertisement, and other links are removed. When displaying bibliographic information from Medline, the application initially offers a list of the articles retrieved. For each article, it is possible to retrieve the abstract alone or the full citation. When infobuttons are related to a particular medication that a patient is taking, a set of search categories is displayed (e.g., contra-indications and toxicity) making the automated retrieval more specific. An additional feature allows users to search Medline directly (Fig. 5). We are currently evaluating the possibility of linking patient data to electronic textbooks.

8. Discussion

We sought to identify the needs and perceptions of health care providers before starting development. That study provided us with significant information. For example, focus groups identified difficulties around four main problems: a slow and inefficient paging system, inconsistent communication upon transfer of patient care, the need for feedback on order status, and the need for face-to-face communication where mistrust or disagreement in care plans existed. A common ''whiteboard'' area with patient problems, responsibilities, and tasks with check-off to identify completion was considered to be a potential solution to non-urgent communication issues regarding patients.

The design and implementation process raised numerous issues; some common to all applications, such as security of sensitive information, while others are more specific to a particular application (e.g., asynchronous messaging in the VWB). Security issues were particularly important because of compliance with HIPAA and the use of wireless technology. For example, security and identification issues make current e-mail systems impractical for communication of clinical information or clinical alerts. Data should be sent over encrypted channels, have strong authentication and authorization, and have the capability for digital signatures to ensure messages are unaltered.

Evaluation of the user interface is an important step prior to full deployment. We, currently, have a group of clinicians using the system at the point of care. The user interface continues to evolve as we learn more about the clinicians' needs. In that regard, we designed a two-part survey containing questions to gather information regarding the usability of PalmCIS. The first part of the survey contained general information questions about the user's experience with WebCIS, the Kyocera QCP 6035 (device used by the clinicians) and PalmCIS. The second part asked more detailed questions about the user interface and functionality of PalmCIS. The one major issue that was commented on was the speed of the system over a cellular phone connection. There were requests for features currently found in WebCIS such as secondary patient lists, nursing station lists and lab summaries. The study is described in the article by Chen et al. [17]. In addition, we have been studying the log files of WebCIS to identify possible common patterns of use [22]. Results from this study suggest common information access behavior, which may allow prediction of what users may want to see next. This can potentially provide quicker access to needed information, leading to optimal use. We believe the results of these studies will help us to maximize functionality and improve user satisfaction with the applications.

In a review of handheld computing in medicine, Fischer et al. found that most use of handheld devices is to access medical literature and electronic pharmacopoeias for patient tracking, medical education, research, and e-prescribing as well as for specialty-specific uses [23]. Many institutions are using handheld devices to access patient data [24—28]. Others have developed alerting systems to deliver alerts and reminders via alphanumeric pagers [29]. To address the issue of delay between the time, laboratory data become available and when physicians review them, a real-time notification system has been implemented at Brigham and Women's Hospital [30]. Mobile computing is also being increasingly used for wireless access to Medline and other knowledge sources [31—33], data-entry for research studies [34], medical education support and training [35—37], and for writing prescriptions [38]. Recent studies have focused on the PDA usage patterns in the clinical setting [39—42] as well as barriers for the use of these

devices [43]. However, none of these studies has measured the impact of improved access to information on patient care, and none have studied the ability of these technologies to improve communication or collaboration among patient care team members.

Our main goal is to explore the use of novel information-based approaches to improve information access and communication. Following the pilot evaluation, we propose to use a randomized clinical trial to measure the impact of the applications on clinicians' information access and communication. Our hypotheses are that (a) the WHHD is a useful tool for health care providers in in-patient settings, (b) the WHHD improves access to information when compared to desk-bound technology, and (c) the WHHD improves communication between health care providers when compared to desk-bound technology.

9. Conclusions

We have designed and implemented extensions to a clinical information system that we believe will contribute to improving access to information as well as communication and collaboration among and between physicians and nurses. We believe that these improvements will ultimately reduce proximal causes of medical errors and adverse events. An evaluation of these applications in clinical settings is planned in order to determine their impact.

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