Electronic Patient Records in a Ubiquitous Setting

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ABSTRACT

Electronic patient records are emerging as the standard in hospitals. This paper will look at the advantages of ubiquitous computing and keeping electronic records, but also at the challenges for the user, who could be a nurse or doctor, these include the user experience and developing a context-aware system that adapts its behavior to the user's current location. Two patient record systems are discussed, including their implementation, goals, and issues with development. Security and reliability of electronic patient records will be looked at. Results are then given on how current electronic patient records have worked in practice across different health care systems.

Categories and Subject Descriptors

J.3 [**Life and Medical Sciences**]: Medical information systems; H.5 [**Information Interfaces and Presentation**]: General

General Terms

Design

Keywords

Electronic patient records, Electronic health records, Pervasive health care, Ubiquitous computing, Hospital information system

1. INTRODUCTION

Health records need to be accessible to multiple people, sometimes around the world, and they need to stay consistent and updated. A consulting doctor, someone from a different hospital who looks at your case providing medical advice, will need access to your records. If you are on vacation and injured, the practicing doctor who is treating you will need access to your records, and this access can be crucial and time dependent. Even within the same hospital over time your records need to be kept up to date in one central location. Having multiple copies of your history which could each be slightly different is a very dangerous possibility. For example if you recently found out that you are allergic to a medication, your doctor would need to know this so an allergic reaction does not occur.

Nurses require information about a patient at many different points in their schedule. The amount of information included within patient records can be daunting, and include drug dosage, past health problems, family health history, vitals over time of a stay, allergies, etc. When a nurse or doctor visits a patient they need access to this information, but patients are not stationary. Information about a patient needs to be accessible wherever the patient is: room, hallway, examination room, or operating room. A nurse is expected to write down patient's records multiple times, or to retrieve physical records whenever they are needed. The nurse writes all this information by hand during a patient's stay: when they first arrive, later on during testing, checking vitals throughout the day, etc. This information is often duplicated onto a bedside table record at each point. Information is also duplicated for computer records at some point in the day [9]. It can be challenging to keep patient records up to date and accessible if records are kept on paper, but if you shift documents to an electronic setting this task is very manageable. Goals of keeping electronic patient records include reduction in the duplication of work for nurses, ease of accessing information, and reduction of errors.

Next we will take an in depth look at two systems that are being developed, MobileWard (Section 2) and Ward-In-Hand (Section 3). Our study will include field tests by researchers and how users have responded to the systems. In section 4 we will look at the challenges that arise with electronic patient records (EPR) and accessing them in a secure, reliable fashion. Lastly, we will look at the effects that EPR are currently having in the health care world, including studies that look at whether EPR reduce the time nurses spend on paperwork and the positive effects that EPR have had on some hospitals (Section 5). The perseverance of paper records and why EPR are not the norm yet is also addressed.

2. MOBILEWARD

MobileWard is a ubiquitous tool to allow access to EPR throughout a hospital. The tool is a context-aware mobile system designed for use within the healthcare environment. MobileWard is designed for a PocketPC and uses its context-awareness to help solve the mobility, redundancy, and accessibility problems for records. MobileWard uses a Wireless

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Local Area Network (WLAN) to communicate with the overall computer system and keep records stored on a central server. With a portable device and synchronized information MobileWard looks to reduce work and errors within a hospital [9].

Studies have been carried out to see if MobileWard's performance fits expectations. The first study observed nurses conducting daily tasks with the help of MobileWard, as well as interviewing different staff members. The second study was laboratory-based and focused about their experience on the context-aware mobile EPR system [5]. Observations of nurses using MobileWard were at Frederikshavn Hospital, a regional hospital in Denmark. A full time ward was selected within the hospital with room for 24 patients. The study wanted to determine if a context-aware mobile EPR could support the nurses in their morning procedure [5]. During this time nurses make rounds to each of their assigned patients and do checkups. Many challenges were identified in the morning routine of a nurse. The patients are spread out throughout the ward, and the nurses need to be mobile to reach the patients. Data duplication also occurs during this time since nurses are moving around. First, nurses record vitals and patient statuses onto a clipboard, second, they copy them to the bedside record, thirdly, they could copy them to a hallway record, and lastly, onto a computer record at their workstation.

2.1 Ease of Use

MobileWard's interface design is meant to be simple and quick to use in all settings. A nurse can scan a patient's wrist band and record test results wherever the patient is. This information is then stored on the server. Other users of MobileWard can then access this information in real-time or at a later point anywhere in the hospital. Having patient records available via a desktop computer allows more freedom to work with the information and analyze it when needed and is all part of the ubiquitous system.

From the display of a pocket PC or tablet a nurse can view a patient's records while in their room. The screen can then dynamically change to show an overview of all the patients within a ward as a nurse walks into the hallway. Figure 1 shows two sample screens from a test system used by nurses. The details for a patient are displayed while in the patient's room, a summary status screen of patients in the ward is available while in the hallway. Each screen also shows status of patients or events through colors. As seen in Fig 1 if a patient has eaten, the message is green, while a patient not eating is something to be concerned about and is displayed in red to bring it to the attention of the attending physician. The current location is also shown at the top of the screen, and buttons are placed along the bottom to switch between views. A nurse can select an area of the screen to view a specific patient, or update a record.

2.2 Problems with MobileWard

There were 37 different usability issues identified by the studies in [5]. Using six hospital staff in both lab and field studies, they were able to identify problems relating to interaction, mobility, and context-awareness. Nurses could be uncomfortable with the keyboard layout, and thought some keys related to medical terms. Examples of medical terms were "tablets", "capsules", and "shift medication", which were confused with keys "Tab", "Caps", and "Shift" respectively. Nurses were also afraid that the handheld was spreading bacteria from one room to the next. Lastly, there were issues with the context-aware element. Often nurses were confused when the screen changed going from one room to the next. For example the screen would show an overview of all the patients when located in the hallway (left hand screen in Fig 1), and while in a room MobileWard would show more detailed information about the patient on the screen (right hand screen in Fig 1). The nurses did not understand why the screen switched between these views.

The context-awareness of MobileWard also had limitations in the information it shared. Nurses would feel that information was fragmented in the context it was shown. The nurses would want more information than shown, but the screen size was small. This is an issue with keeping the system small and portable, where limited screen sizes will reduce the information shared with the user on each display. A larger mobile device such as a tablet could be used to show more information, but can also be more difficult to hold and manage.

3. WARD-IN-HAND

In [7], Kjedlskov and Skov studied IMSS General Hospital to show four areas to focus on while developing an EPR system. They wanted a system to know its location, when to deliver information to a user, recognize roles as well as individuals, and lastly support communication of pertinent messages to staff. Including all this functionality in a mobile system requires a flexible structure. Ward-In-Hand tries to address this issue in a hospital setting, providing access to patient's records and hospital information in real-time. Much like MobileWard, Ward-In-Hand is another hand-held system using wireless networks within a hospital to be context-aware. Using a minimum of three wireless points within a hospital it is able to triangulate its position to provide the correct information at all times. With this system, though, the user has to request the information from the server, and the handheld device does not automatically update for its location.

3.1 Agents

Through the use of agents, the information management and timing management becomes easier. Agents were developed with Salsa (Simple Agent Library for Seamless Applications) and can act on the user's behalf, represent devices, or wrap a system's functionality [7]. Each agent performs a specific task assigned to it, for example the location-estimation agent is in all mobile devices and obtains the position. Agents include several components:

- a protocol that the agent uses to register with an agent directory;
- an interface through which the agent acquires knowledge or information;
- an instant messaging (IM) client through which users and agents interact by sending XML messages;
- and the subsystem that implements the agent's intelligence [7].

Using IM, Ward-In-Hand keeps its users, doctors, nurses, and hospital staff up to date on what is currently going on in

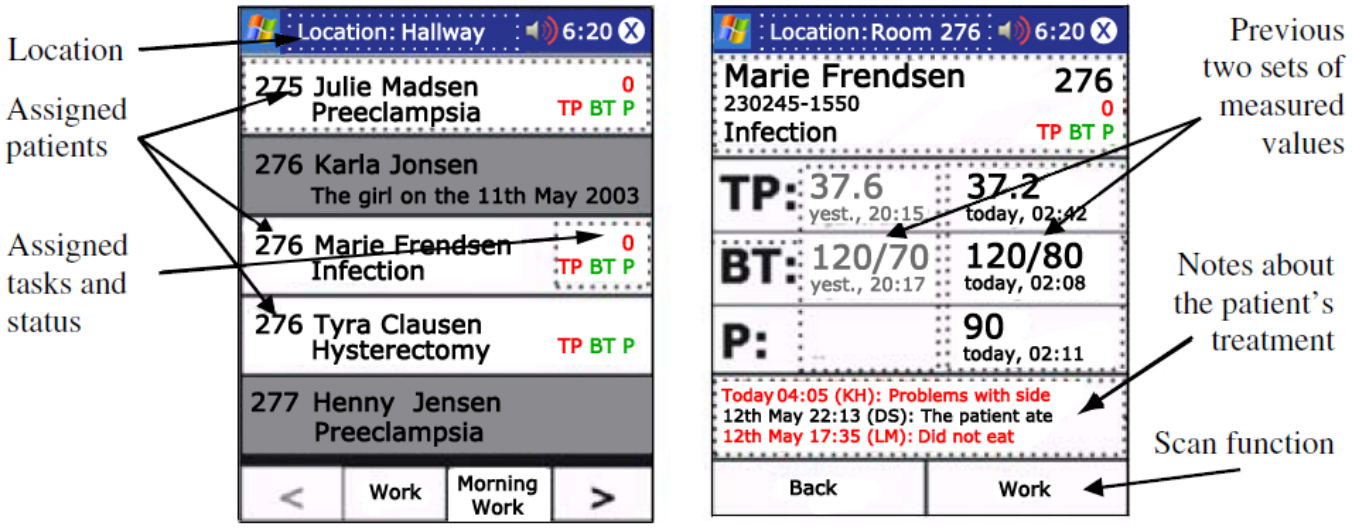

Figure 1: This shows the different display screens for MobileWard, with admitted patients (left) and information on a selected patient (right). Each screen is displayed depending on where the viewer currently is, if they are within a room, then they will see the info for an individual patient (right), while if they are in the hallway they will see a summary of admitted patients (left). Patient events and statuses are also color coded to give a quick view of how a patient is.

the hospital. For example it uses agents to monitor medical system information, and notice when results of a requested medical test are available. Then through use of more agents it can monitor a doctor's activities and decide when to send an IM notification [7].

3.2 Evaluation

In [7], Munoz presented two videos of Ward-In-Hand to 28 hospital staff, including doctors, nurses, and support staff. Staff were asked whether the videos represented realistic scenarios. According to hospital staff both scenarios from the videos seemed realistic. Table 1 clearly shows the results and it was a resounding "yes" from staff that they thought a system such as Ward-In-Hand would be useful. When asked whether or not they thought it would be helpful to know where others were in the hospital, 27/28 agreed or strongly agreed. Having messages delivered to them depending on where the staff was located would also be helpful in 27/28 cases. Also having the patient's record through a handheld computer would be useful in 27/28 cases. The final question asking if it would be distracting from their daily work to have messages delivered to them was less conclusive; 20/27 who answered said it would not be distracting, while three were not sure, and four said it could be distracting from their work. This showed that allowing the messages could be useful, and the time they were delivered was also important as staff could still find the messages distracting from other work.

4. SECURITY AND RELIABILITY OF EPR SYSTEMS

Imagine a patient walks into a hospital and is able to use their smartphone to upload insurance information and past medical records for the doctor. A function like this available in a hospital would help reduce inconsistency and the effort of keeping updated records, but the challenges of implementing a system like this across multiple hospitals are extensive. A high level of security including encryption, authentication, and access control are needed. Communication and a standard format between competing hospitals and insurance companies would also be needed [11]. The list of challenges is extensive, and to solve them all in detail would be difficult, so we will not be covering them all, but in this section we will bring them to the attention of the reader.

If a patient was in commute between hospitals, then the ability for ambulance staff to access and update patient records could be useful, but a larger system of communication would be needed, this will not be discussed much within this paper. Communication can be solved through a wide range of wireless technologies, each with their own problems. Cellular/PCS systems already cover a large portion of populated areas, and satellites can cover the rest but speed and reliability are big concerns using each of these. A system that covers such an expansive area is only needed for external monitoring of patients. Both MobileWard and Ward-In-Hand (discussed in sections 2 and 3 respectively) each use smaller WLAN instead [9, 7]. Use of radio frequency identification devices (RFID) is also a viable option is some cases for monitoring a small location as range issues are discussed in [11].

Looking at WLAN closer since that is what both systems (MobileWard and Ward-In-Hand) use we see problems facing WLAN. The frequency and medium that WLANs have to work with can be limiting in the hospital setting. With different materials used in hospitals it can be hard to receive signal at times. There are also other technologies within a hospital that can interfere with broadcasting. Increasing the number of access points can increase coverage but is still dependent on power and interference within the hospital [11].

	Strongly Disagree	Disagree	Slightly Disagree	Neither	Slightly Agree	Agree	Strongly Agree
It is useful to know who is in the hospital and where they are in relation to me	1	0	0	0	0	7	20
It is useful to send messages that depend on context for their delivery	1	0	0	0	1	7	19
It is useful to have access to the patient's medical record through a handheld computer	1	0	0	0	0	8	19
Receiving messages can distract me from my daily work*	9	9	2	3	3	0	1

*One person did not respond to this question

Table 1: Results from a questionnaire measuring user acceptance of scenarios and the system's context-aware features. In almost all cases staff replied that the information provided through Ward-In-Hand could be useful. There was still a concern about the messages still being distracting from daily task though [7].

WLAN are also made for traffic where delays are not critical, which can cause issues when it is relied on for patient information. Additional information about wireless connection and suggested ways to overcome these challenges can be found in [11, 6]. Further information about data encryption and suggested XML-based encryption for EPR can be found in [12].

5. REACTIONS TO EPR IN THE HEALTH CARE FIELD

Currently EPR is being used in hospitals throughout the United States and other parts of the world [4]. There are many different ways to implement an EPR system, and depending upon the size of the hospital EPR will require different infrastructure. In this section we will look at how some health care centers have adopted EPR, while others are still testing it.

5.1 Mental Workload

In [4] a study was done on a fully functional EPR system within a stroke unit. The system was in operation with over 26 million patient records and full IT support. Analysis of three major areas showed positive impacts for EPR. [4] looked at "clinicians' mental workload, overview, and need for exchanging information" and used the NASA task load index (TLX) to measure the mental workload on the staff. Staff would rate themselves from 0 (low stress level) to 100 (high stress level) at different points throughout the day, comparing TLX ratings when they used paper records or EPR. The tasks looked at were team conferences, ward rounds, and nursing handovers. Looking at the TLX rating from the nurses along with the amount of time each task took, gives a clear indication of the affect of EPR.

Table 2 shows the results from TLX testing after a team conference. Five of the six sub-scales show a significant improvement, with EPR all having a p score less than 0.05. [1] The only area where a staff member did not feel improvement was in the physical demand on themselves. This is understandable since EPR cannot change the physical environment. Nurses and doctors are still required to do almost the entire same physical task, such as taking tests and moving around the hospital [7].

Looking at all of the results from the staff reporting, we see benefits when EPR is used. Of the categories measured in [4], 20 of the 31 scales showed significant improvement when switching from using paper records to electronic records. The frustration level of a nurse during team conferences dropped substantially from 32.86 to 21.81. During ward rounds the mental workload also showed significant improvement ($p < 0.05$) in all categories measured. The categories are the same as shown in table 2 and dropped at least 22 points in each.

5.2 Paper Records Live On

Changing from paper records to electronic records is harder for some than others [8]. Saleem looked at integration factors within hospitals that are set up to use EPR, but where employees are still using paper [8]. Interviews with 20 staff from a hospital that fully implements EPR show categories where paper is used instead of the system in place (See Table 3). In two of the categories pointed out, efficiency and knowledge/skill/ease of use, 20 cases indicated that paper was the preferred method. Both categories are where EPR are supposed to excel and instead are huge hold ups [3].

Many of the issues that staff shared with EPR, and why they prefer paper records, are on preference or design of the system. The first category, efficiency, can possibly be explained since their ordering system for supplies might not be set up for electronic orders. The second category, knowledge/skill/ease of use, shows that it is easier to access data in printed form and can be explained by previous training and experience. Doctors know how to read and find the data when it is printed for them. If doctors were to be familiar with the user interface, they might be more comfortable accessing EPR. Doctors shared that they forget about a patient under the memory category. Ward-In-Hand tried to solve this problem with their messaging system informing doctors of patients and previously requested test. If a doctor does not receive a message from the system or a does not have a paper record in hand as a reminder they can forget about new walk-in patients. The last category for discussion is sensorimotor preferences, where doctors like to have paper to write on. They are not comfortable with writing on the screen, or typing. Other categories can be read in [8].

[1] A multiple variable significance test (Anova) with a confidence interval of 95% was used to compare each subscale. A p value less than 0.05 is considered to show significance

TLX Subscale	Paper Records		Electronic Records		Statistical test
	M	S.D.	M	S.D.	Significance, p
Mental demand	34.57	21.91	29.31	20.15	.048
Physical demand	18.86	14.61	18.89	18.64	.7
Temporal demand	40.00	23.42	33.06	20.88	.04
Effort	29.09	17.12	24.03	19.52	.04
Performance	34.71	22.26	22.67	21.88	.007
Frustration	32.86	26.63	21.81	19.86	.008
M, mean, S.D. standard deviation.(out of 100)					

Table 2: Mental workload for team conferences, N = 71 [4].

Category	Freq.	Description	Example(s)
Efficiency	20	Using a workflow process that improves actual or perceived.	"The emergency room uses pre-printed [paper] forms for orders... this paper 'workaround' is more efficient/expedient."
Knowledge/Skill/Ease of use	20	Training/support/experience/ease of finding needed information.	"Now we're trying to get doctors to view them [test results] in CPRS [instead of printed results]. But sometimes physicians will get frustrated and say where is it?"
Memory	17	Reminder about "old" or existing information.	"Without a sheet of paper, I sometimes forget about a [walk-in] patient."
Sensorimotor preferences	15	Preferred sensory input for task: "hear", "tangible", easily modified (ie. hand notes); mobility, something to "deliver".	"I like to have something to walk into the patient's room with"; "I hand write the labs down on paper... I can't write on the screen."
Freq.:Frequency of occurrence; CPRS:Computerized Patient Record System; BP:blood pressure.			

Table 3: Paper-based workarounds by category. Order of categories corresponds to the occurrence frequency across interview transcripts, beginning with the most frequent [8].

6. CONCLUSION

To implement a successful ubiquitous EPR in a hospital setting, good practices need to already exist [4]. If there is good work flow and a standard set up to record data currently then the adoption to electronic patient records can be an easy and beneficial transition. The decreased mental demand, effort, frustration, and increased performance all support this (see Table 2). It is evident that EPR systems are beneficial, to integrate them through a UI that is user friendly, and a system that is secure and reliable is important. Both MobileWard and Ward-In-Hand show positive effects within a hospital setting using mobile tools to access EPR, and there are other implementations available [2]. Possible research could include analyzing this mass amount of information that is stored within the hospital information system through data mining [10, 1]. Being able to access a patient's record in a remote setting throughout the world with electronic sharing, or having your doctor notified on their tablet of your latest test results while he is at your bedside can be extremely beneficial. Using EPR has the potential to help reduce medical errors, workload on hospital staffing, and increase the quality of medical care provided.

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