Development of a Personal Digital Assistant (PDA) Based Client/Server NICU Patient Data and Charting System

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ABSTRACT

Personal Digital Assistants (PDAs) offer clinicians the ability to enter and manage critical information at the point of care. Although PDAs have always been designed to be intuitive and easy to use, recent advances in technology have made them even more accessible. The ability to link data on a PDA (client) to a central database (server) allows for near-unlimited potential in developing point of care applications and systems for patient data management. Although many stand-alone systems exist for PDAs, none are designed to work in an integrated client/server environment.

This paper describes the design, software and hardware selection, and preliminary testing of a PDA based patient data and charting system for use in the University of Washington Neonatal Intensive Care Unit (NICU). This system will be the subject of a subsequent study to determine its impact on patient outcomes and clinician efficiency.

INTRODUCTION

Clinicians are becoming more accustomed to using portable technology in daily care. Automated wireless alerts have been used to prevent medical errors and alert clinicians to critical lab values as soon as they are available.[1] The University of Washington Family Practice program is now using handheld computers to document patient encounters, eliminating the old paper-based system.[2] The key benefit to these devices is that they allow clinicians to enter and access data at the point of care. Hence, many have started to recognize their potential in a variety of clinical settings. Nurses have started using Palm based systems as decision support tools, which aid in eliciting patient preferences at the bedside.[3] Others clinicians have used PDAs to access clinical information wirelessly and securely using Palm VIIs and secure web servers.[4] These examples, however, do not involve the integration of data into a central system, with sharing of data. The lack of a central server prevents clinicians from taking advantage of resources such as detailed formatting for notes and signout; it also does not allow for integration of data from central repositories with data acquired at the point of care.

More significantly, recent studies have documented the potential of PDAs to affect the quality of patient care.[5] With this in mind, we created an electronic charting system that combined the best of both worlds: the power and flexibility of a powerful PC based data repository with the portability and accessibility of a PDA. Although the example we describe within this text is a Neonatal Intensive Care Unit (NICU) system, the underlying issues are common to any site of care involving longitudinal care of a set of patients by interns and senior residents (or other teams of providers) in other ICU or inpatient settings.

The electronic medical record has been the focus of much study and development in recent years. Ultimately, a computer stored patient record system linked to a client PDA would impart many potential benefits for both patient and clinician.

REQUIREMENTS

Although the problems and needs of critically ill neonates and their medical records are unique, most of their issues apply to other longitudinal care settings. Changes in patient status and in patient care must be recorded in an accurately and promptly. The NICU (or other inpatient setting) process typically involves a great deal of repetition and inefficiency, with pen-and-paper recording of patient data on daily flow sheets and to-do lists, transcription of this data onto signout sheets and night time to-do lists, and transcription of this data into daily progress notes. The University of Washington (UW) NICU has tried to minimize redundant data collection and manual transcription by creating a computer-based database to save this information, allowing one data transcription task to generate daily progress note outlines, signouts, and to-do lists.

The UW system can be taken as a variation on the theme typical to most inpatient settings affiliated with residency training programs. During "prerounding", interns gather current patient variables, including vital signs, ventilator settings, feeds and fluids, and laboratory information. This information is recorded on preprinted data sheets and used during rounds for presentation. Later, senior residents update their records with this information using a Microsoft

Access (PC) database to generate reports that print patient progress notes. At the end of the day, residents prepare signout sheets, using their written records, and add overnight tasks (by hand) that need to be completed by the on-call residents. The Access database is effectively a flat file format (single table with one row per patient), and contains fields that keep track of demographic data, medications, problems, and tasks that need completion. Senior residents are responsible for keeping the database up-to-date. Differences in their timing and style of entry, however, make the information in the database, and generated reports, inconsistent from hour to hour and day to day.

Any new system must at least perform these same daily functions. The database programs must allow for easy collection of required patient data, at birth and on a daily basis. It must move this information both to and from the PDA and the PC based database. This database should also generate patient progress notes and sign-out, automatically updating the printouts with relevant data. Using PDAs, data is collected from bedside flowsheets and entered only once with all other documents generated automatically (e.g. rounding sheets, to-do lists, progress notes, signout sheets, templates for discharge summary).

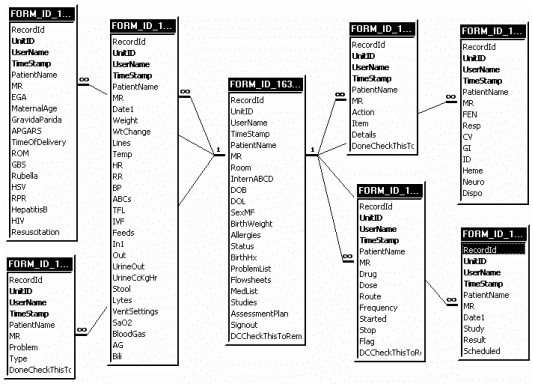

Figure 1 (Enlarge to 500% to view)

The charting system must also account for the intricacies of the residents' schedules. Patient records must be transferable from intern to intern as different doctors remain on call overnight. Different numbers of interns are working in the NICU from month to month, so patient re-assignment will often occur.

A relational model was deemed by the system designers to be the most effective (Figure 1). The main table includes the patient's name and medical record number (primary key). This table also contains personal demographic information. Other linked tables save each patient's problem list, medication list, long-term studies, birth history, signout, and daily assessment and plan.

The design also takes into account the important issues of security and data "ownership". Only one intern may "own" the data on his PDA at a time, so that different clinicians do not mistakenly overwrite each other's information. Password protection, both on the PDA and on the PC database, hampers unauthorized access in case the PDA is lost, stolen or accessed by unauthorized personnel. Information security remains a constant challenge, and the palm OS is no exception. Password protection will need to be refined and improved upon.[6]

HARDWARE SELECTION

A wide variety of handheld computers are available today. In order to obtain the most appropriate one, we studied the existing models and tested them in a number of categories.

As we began to consider our choices, we divided PDAs into three categories. First we compared the Palm OS based systems. After reviewing the technical specifications and abilities of these models, we narrowed the field to the Palm Pilot IIIxe and the Handspring Visor Deluxe. The Palm Vx, although smaller and comparable in memory and speed, was more expensive. The IIIxe and Visor were almost identical in terms of memory, speed, screen size, and abilities. We settled on the Handspring Visor because of its slightly lower price (at the time), its included USB cradle, its easily upgradeable memory, and the potential offered by its "springboard" expansion slot.

The second collection of PDAs we reviewed was the WinCE PPC machines. These PDAs run a compact version of Microsoft Windows with many of the same programs that would normally be found on desktop PC's. Most were about the same size and the Palm OS PDAs, and featured color screens (not available to Palm OS machines at the time). After comparing models, we chose the HP Jordana 680 as the representative of this class. (We recognize that at the time of publication, the Jordana 680 has been replaced with newer and more advanced models)

The final class of PDAs we considered was the WinCE Pro machines. These are larger PDAs that resemble notebook computers. They are larger than other PDAs, and often run PC based operating systems. The representative of this class that we chose was the VADEM Clio. This machine runs WinCE Pro on a portable "tablet". Used either with or without a keyboard, its touch sensitive screen

allows for a wide variety of options in programming and data control. With such a machine, there would be less conversion needed between the PDA and PC systems since both could operate Windows like programs.

On the other hand, we found the $999 price tag of these machines to be prohibitive. The larger size also made it unwieldy for interns to carry with them during their daily work. Finally, the handwriting recognition was far inferior to the Palm OS systems. These machines are compared in Table 1.

PDA Model	PDA Size (in)	PDA Wt	Screen Size	Screen Type	Price
Handspring Visor	4.8 x 3.0 x 0.7	5.4 oz	2.4 in	B&W	$249
HP Jordana 680	7.4 x 3.7 x 1.3	17.6 oz	6.5 in	Color	$675
Vadem Clio	8.8 x 11.3 x 1.0	51.2 oz	9.4 in	Color	$999

Table 1

The Jordana was much preferred in terms of size and portability. We also found its color screen to be quite clear and practical. Its weakness, like the Clio, lay in its poor/absent handwriting recognition. We also found it to be much slower than the comparable Palm system. Its price tag of $675 was more acceptable than the Clio, but still more expensive than the Visor.

The Palm OS PDAs have enjoyed unparalleled success in both the personal and professional marketplace. Palm based systems have accounted for over 75% of PDAs currently in use.[7] A random sampling of physicians in our medical system found that nearly all clinicians using PDAs were using Palm OS machines. The Handspring Visor was relatively inexpensive ($250 for the Deluxe model). Its hotsync software was compatible with both Windows and Macintosh platforms. The graffiti handwriting recognition software was the best available; it was easy to use, and remarkably accurate. The screen size was smaller and monochrome. Overall, we found the Handspring Visor to be faster, smaller, and easier to use than any other PDA available at the time.

For the PC side, we decided that a Windows based PC would meet our needs based on the ubiquitous deployment of such machines in the UW medical center. The Handspring Visor came with a USB cradle for easy synchronization with any Windows based machine. Most importantly, software for the PalmOS would work with databases that could be run on Windows platforms.

SOFTWARE SELECTION

Because PDAs have only recently achieved such wide acceptance, there has not been a great deal of time to develop software. Most companies creating Palm OS software are small and young. In fact, most of the more widely accepted database applications for the Palm OS are shareware, and sold only online.

Through internet searches and searches through internet resellers, we identified a number of potential database applications for use. These are detailed in Table 2. (We recognize that at the time of publication, some features and prices have changed)

Database	Relational Type	Password protection	Link to PC database	Price
HanDBase	Yes	Yes	Yes*	$19.99
ThinkDB	No	Yes	No	$19.99
MobileDB	No	Yes	Yes*	$14.95
JFile	No	No	No	$24.95
DbNow	No	Yes	Yes	$29.99
Pendragon Forms	Yes	Yes	Yes	$149.00
Satellite Forms	Yes	Yes	Yes	$795.00

Table 2 (* with middleware)

We evaluated five Palm based databases/data collection systems. ThinkDB and JFile were immediately excluded because they could not support the relational model. Such a model was preferred because it would allow for multiple tables of related, but distinct, information to be linked by chosen keys. The most promising application was HanDBase. This shareware program was powerful, and available for $20. It allowed users to create a fully relational database on the Palm, with over 20 different types of fields. HanDBase, however, was strictly a Palm OS program. It had no PC counterpart, and could not be linked to a PC database without some sort of conduit program (middleware).

Fortunately, there were a few vendors that offered such middleware. The first we tried was dbX from NixDev software. This software took HandDBase .pdb files from the Palm Backup folder and converted them into Microsoft Access format. There were some limitations with multiple users, as the program could not easily merge individual .pdb files into one Access database. This made it impossible to merge data from multiple interns' patients into a single database to generate a signout or to-do list for the resident covering all the patients in the NICU. There were

also some weaknesses in the conversion process, as the program did not automatically run after each hotsync, and therefore did not always recognize when new information was available. It also did not automatically detect links between database tables; each had to be loaded individually.

The next program we investigated was HanDJet, by Consult US. Like dbX, this program translated HanDBase .pdb files to Access format. HanDJet was more sophisticated than dbX in the way it handled linked .pdb files. It automatically recognized relationships and always loaded all the linked tables. Its weakness lay in its inability to join separate tables together easily. We also ran into difficulties when trying to reassign patients from one intern, and Visor, to another.

The remaining two options were Pendragon Forms and Satellite Forms. Both are powerful applications that allow the easy creation of "forms" on the PC that can then be transferred to the Visor. Pendragon Forms was significantly cheaper than Satellite Forms; we decided to try their software first.

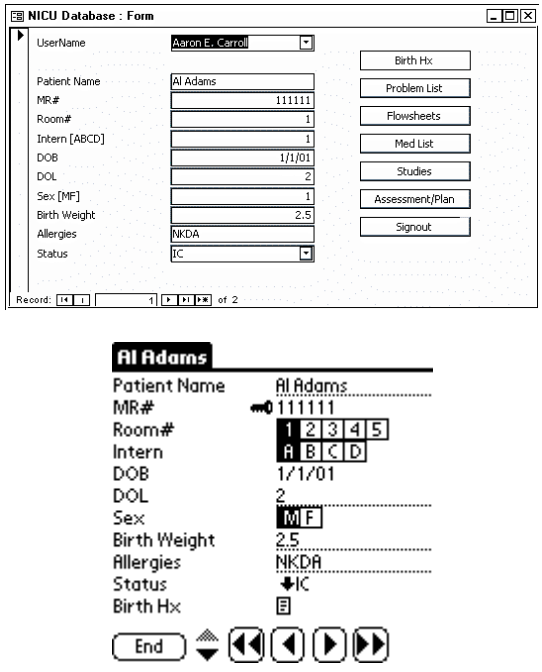

Figure 2

Pendragon Forms is a sophisticated commercial application that applies a modified client/server model to the PDA/PC relationship. The saved data is housed on the PC in a central database. Although it is easiest to use an Access database as the PC base, Pendragon Forms has the ability to hotsync to any ODBC compliant database.

IMPLEMENTATION

We implemented the patient record and charting system to meet the needs of the physicians working in the NICU. We used Handspring Visors as the handhelds into which all interns would enter information; Pendragon Forms links this information to the central database; Microsoft Access is the ODBC compliant database that houses all patient information. Preset forms allow Visors both to query the PC database for information and enter new information into the PDA (Figure 2).

Since Pendragon Forms is housed on the PC rather than the PDA, it allowed us to use the full power of the PC. We used Microsoft Access to set up the relationships between tables. We then designed a number of queries, forms, and reports to improve the system from a simple database to a sophisticated patient data and charting system. Using Visual Basic and DAO (Data Access Objects) we programmed routines to perform many tasks.

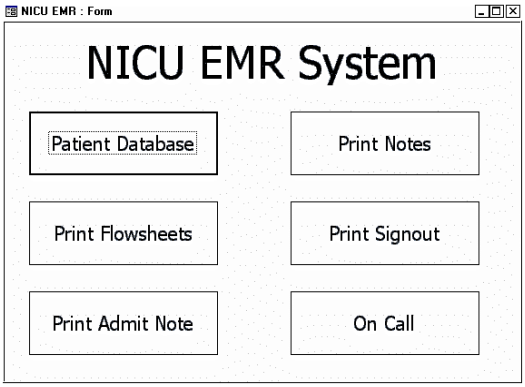

Figure 3

The intern is responsible for entering all data into the PDA. After hotsyncing, all information is transferred to Microsoft access and routed to the correct places in the database tables. The “Patient Database” action allows users to review and change patient data on the PC through easily understandable forms. (Figure 3) The “Print Notes” and “Print Admit Notes” actions generate reports that access the subset of data needed to satisfy charting requirements; the “Print Signout” action does the same for resident signout overnight. The “Print Flowsheets” action generates reports that allow residents and faculty to review the weekly progress of patients. The “On Call” form contains routines to shift data across PDAs for overnight coverage and intern reassignment.

DISCUSSION

There are many applications that have been developed to serve as electronic charting systems

both in the inpatient and outpatient settings.[8,9] Almost all, however, are made to exist on the desktop PC platform. There are few systems described in the literature that perform such functions as generating and printing progress notes, signout, and flowsheets. Even fewer allow information to be entered at the point of care on portable devices. Permitting entry wherever and whenever it is available allows for greater efficiency and significant error reduction.

Few systems have also been developed with such close ties between the developers and end-users. This point of care charting system was designed, developed, and tested by physicians who have worked in the NICU in both the intern, senior resident, and attending roles. We have an intimate knowledge of what is required by such a system, and how it can best be employed. At every step of development, we considered workflow and the role of the physician using the system, and discussed options and variables with residents who will use the system.

More importantly, although there are many charting systems, very few have actually been rigorously studied. During a Robert Wood Johnson Clinical Scholars Fellowship, this system will be the subject of a controlled trial that will investigate its effect on both significant patient outcomes, such as medical errors, and its ability to improve the efficiency and the experience of the physicians using it.

CONCLUSIONS

This PDA based electronic charting and workflow management system allows physicians to record patient information at the point of care, and later synchronize it to a central PC database. It is novel in both its abilities and its development. We used software and hardware that had not previously been used in so sophisticated a system. This system, with a total cost of less than $3000 (including hardware), is remarkably less expensive than almost any other such system. We also had the opportunity to have actual users develop every stage of the system, and were able to have other users outside the system offer suggestions and criticism.

It is our hope that the work we have done in selecting the individual components for our charting system will help others to create their own systems. We also hope that the development of our PDA based system will become a model for future development plans, such as integration with a centralized Electronic Medical Record system. We feel that one of the key factors to success was the intimate relationship between the developers and end-users. We also believe that the future rigorous studies to which we plan to subject this system will become the norm, as we subject our information tools to the same rigorous study that we do all other medical tools.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Michael Neufeld for his assistance in developing some of the specifics of the database. We would also like to acknowledge the University of Washington Department of Neonatology for their assistance and accommodation in developing this system. We would also like to acknowledge the contributions and suggestions of many of the University of Washington Pediatric residents in the creation of this system.

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