

The PDA as a Portal to Knowledge Sources in a Wireless Setting

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ABSTRACT

Two recent parallel developments, the widespread deployment of wireless networks and increased use of handheld devices like the personal digital assistant (PDA), have contributed to the development of mobile access to the Internet. Recent surveys show that approximately 25% or more of physicians use PDAs. Although used mainly for personal information management and static medical applications, PDAs have capabilities to connect to the Internet. We studied the use of handheld devices to access MEDLINE and other knowledge sources in a wireless setting.

INTRODUCTION

HEALTHCARE PRACTITIONERS in the 21st century face an unprecedented growth of medical information. Currently, MEDLINE contains over 11 million citations, with some 35,000 citations more added every month, including bibliographic citations and author abstracts from more than 4300 biomedical journals published in the United States and 70 other countries. Disease diagnosis and patient management have evolved rapidly, brought about by information discovered through molecular biology and the decoding of the human genome. New therapies, including specific disease-targeted drugs, are being developed rapidly based on cellular and molecular discoveries from these new technologies.

The practice of medicine is becoming more complex. The physician needs resources to access knowledge repositories at the point of care and need. Sackett and Straus¹ have shown that

allowing doctors easy access to evidence-based resources while making rounds increased the extent to which evidence was sought and incorporated into patient care decisions.

Two recent developments may help the clinician to access essential information at the point-of-need: handheld devices such as personal digital assistants (PDAs) and the increasing ability to connect to the Internet through wireless networks. These enabling technologies may have a positive impact on the mobile healthcare worker's ability to access electronic healthcare data and resources, and the practice of telemedicine.

PDA ownership among physicians is high. A Forrester Technographics Benchmark 2001 Survey² showed that 25% of physicians owned a PDA, whereas only 4% of nonphysicians did. The American Medical Association (AMA) reported³ that in 23% of physician practices someone in the office used a handheld device. Most used the devices for personal or office in-

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formation management, such as to keep a calendar or address and telephone list. Although the study did not specifically ask if the PDA user was a physician, the AMA believes this to be so. Among internists, the American College of Physicians–American Society of Internal Medicine (ACP-ASIM) survey⁴ showed that 47% of 489 member respondents used PDAs. The ACP-ASIM forecasts that the percentage of members who will use PDAs will increase to 67% by the end of 2002.

A PDA provides many advantages. It starts up quickly at the push of a button. It is convenient to carry around, fitting easily in a shirt pocket or handbag. Some devices can function for weeks of regular use after a quick battery recharge. PDAs are predicted to outsell conventional computers in the near future.⁵ Modules such as cameras, wireless modems, and extra memory can be added to extend the device's functionality and computing capacity.

The adoption of 802.11b wireless networks is increasing. According to Cahners In-Stat Group,⁶ sales of 802.11b access points grew 14% over the last quarter compared to the previous quarter of 2001 while the rest of the information technology field was in a slump. Among early adopters, the use of portable computers with wireless cards was 52%, second only to use of wireless telephones (78%). The decreasing cost of wireless equipment and ease of installation will further increase the use of wireless networks. Although security issues may preclude current deployment for medical data access, the use of wireless devices as a conduit to other types of essential information resources remains high. Some of these security concerns may be minimized through the use of infrared access stations, as we have tested in our setting.

Our research focused on technologies and resources that will provide the practicing clinician with access to knowledge resources at the point of need. We report here our experience in using PDAs in a wireless environment.

METHODS

We connected three wireless access points (Apple Airport Base Station, Cisco Aeronet 350 Wireless Access Point, and Linksys Etherfast

Wireless Access Point Cable/DSL router) to the local area network (LAN) in the department. Each of these devices was assigned a distinct Internet Protocol (IP) address. The devices were placed in different locations within the department to optimize signal acquisition. Infrared (IR) connection was established using Clarinet Systems EthIRLAN101 infrared port.

We also deployed two access points at the National Library of Medicine (NLM) exhibit area at AMIA 2001 Annual Symposium in Washington, D.C., and the American Medical Informatics Association (AMIA) 2002 Symposium in San Antonio, Texas. Wireless access to the Internet was provided to participants and exhibitors. We used one of these access points for live webcasts from the poster sessions using portable computers.

Testing was conducted mainly on three devices: Palm IIIc, Palm 505, and Handspring Visor Prism. Other PDA devices and emulators were also tested. The Visor Prism was equipped with a Xircom Springport Ethernet Module. A Palm modem for the Palm III series was also used to gain Internet access. For web browsing, we installed EudoraWeb, Blazer, and Avantgo browsers. Avantgo channels were downloaded through Avantgo's public server and an Avantgo M-Business server at the National Institutes of Health. Palm OS emulators were also used to test applications. Internet connection was accomplished through local serial synchronization to a desktop or portable computer via a PDA cradle, Springport wireless module, Palm modem, and IR device attached to a LAN. IR synchronization with portable computers was also done.

Documents in hypertext markup language (HTML) were developed using standard desktop text editors. The HTML files were transferred to web servers using Apache server software. Server access log files from August 28 to November 25, 2002 were analyzed using WebTrends. A user feedback form was downloaded each time the PDA synchronized to the server. Filled-out forms were sent back to the server anonymously and forwarded as email messages to the investigators.

PDA display size (the smallest screen size is 160 × 160 pixels) is a crucial factor in designing web pages. Also, as with desktop browsers, web pages are rendered differently by different

browsers in PDAs. For the Avantgo browser, a specific tag was used to ensure that the resulting HTML document was formatted correctly for the handheld device:

```
<META NAME="HandHeldFriendly"
  VALUE="true">
```

RESULTS

Several applications were developed: PubMed query with or without clinical "filters,"⁷ clinical trials search through www.ClinicalTrials.gov, physician's resources, community health care worker resources, patient resources, healthcare organization portal, and medical student resources.

Connecting to the Internet through an 802.11b wireless network and IR was achieved and reproduced consistently. 802.11b connection was accomplished while in motion, limited only by the availability of the reach of the radio signal. In our setting (indoors, thick concrete walls), this ranged from 50 ft in offices to 100 ft in open hallways. An IR link, however, was attainable only through line-of-sight access. The link to the LAN was restricted to a 15 degree arc on each side of the center and a maximum distance of 8 ft. Establishing an IR link took about 5 ± 5 s and retrieval of initial query results 20 ± 5 s. Once the wireless PDA had attached to the LAN, subsequent searches and abstract retrieval required 10 ± 5 s. A transient, rapid disruption of the IR beam, such as a person walking between the IR port and the PDA,

did not disconnect an established link. The IR link was maintained until the PDA turned off automatically after a preconfigured time (a maximum of 3 min inactivity). Similar time requirements were obtained with the Springport 802.11b wireless module, except that it was not limited by line-of-sight conditions.

PubMed query and clinical trials

We created a handheld-friendly query page to search PubMed using the text version of the Entrez retrieval system provided by the National Center for Biotechnology Information (NCBI). A search on "anthrax" using the clinical query mode yielded the result shown in Figure 1. The abstract was retrieved when the first article was selected. Links are provided to the full-text article and also to related articles. Similar results were obtained when EudoraWeb and Blazer browsers were used (the Avantgo browser is shown in the figures) except that EudoraWeb is a text-only browser. Its advantage is it does not require a proxy server, unlike Avantgo and Blazer. A clinical trials web page was patterned after www.ClinicalTrials.gov website. Information about clinical trials and the ability to search the database directly were provided. The Clinical Trials search page and results on a search for current clinical trials on "chronic myelocytic leukemia" are shown in Figure 2.

Physicians' resources

PDA tools for the physician, including continuing medical education, practice guidelines,



FIG. 1. L to R. The PDA-formatted PubMed search page, a search result on a clinical query on "anthrax," and a retrieved abstracts page. Abstracts may provide links to related articles and full-text articles.

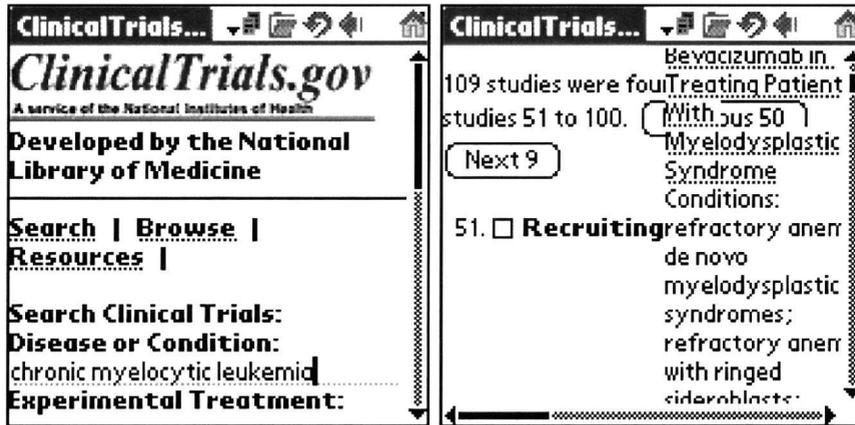


FIG. 2. The Clinical Trials search page shows an entry to search for “chronic myelocytic leukemia” and one of the clinical trials located.

and emergency procedures, were adapted from existing online resources. HTML files can be reformatted readily for the PDA, as we have done with a cricothyroidotomy procedure⁸ (Fig. 3).

Community healthcare personnel

PDA-formatted HTML pages were created for healthcare personnel traveling or assigned to distant locations. Reference information (Fig. 4) can be cached permanently in the user’s PDA. Updated information can be synchronized with the user’s PDA as needed. Data from survey forms (Fig. 5) can be synchronized directly with a central database server. Information from field studies and projects are immediately available to distant collaborators and project personnel.

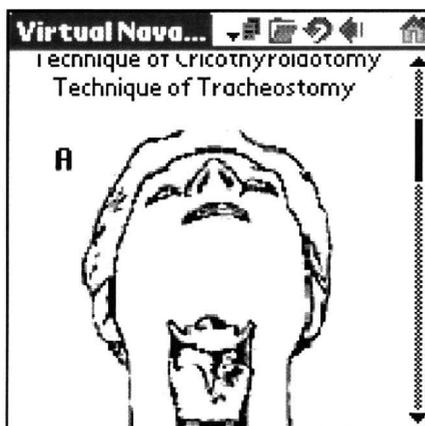


FIG. 3. An existing webpage reformatted for the PDA to illustrate an emergency procedure.

Server access log analysis

Access logs for the pilot testing period (August 28 to November 25, 2002) were analyzed (Table 1). An average of 620 web pages were viewed or downloaded daily for a total of 55,976 for the entire period. There were 594 unique users of the website. Among all visits, 59% accessed the server through Avantgo proxy servers, 26.2% downloaded PDA-formatted webpages via their organization’s Avantgo server, whereas 32.3% used Avantgo’s publicly available servers.

Web server activity ranged from 17% on Mondays to peak levels (22%) on Thursdays. Access on Saturdays and Sundays accounted for less than 3% each (1.16 and 2.70%, respectively). There was server activity at all hours of the day. During the period between 9 pm and 8 am, the percentage of each hourly period was less than 1% of total visits, averaging 25 users per hour (range, 8–45). There was an immediate rise to 3.5% (114 users) during the 8–9 am period that peaked at the 3–4 pm time period to 334 users.

Access log analysis showed that 208 server visitors performed clinical query⁷ searches. We are unable to determine how many users searched PubMed using the unfiltered search method, although we know that 2158 visitors accessed or downloaded the unfiltered search page.

User feedback

The evaluation form was viewed or downloaded 2985 times during the study period. Six-



FIG. 4. Laboratory procedures and illustrated directions on the preparation of oral rehydration solution can be cached on the PDA.

teen users provided feedback. Fourteen were Palm OS users (1 Sony, 1 Visor, the rest were Palm devices) and two PocketPC users. Three were attending physicians, one a veterinarian, one a software programmer in a medical school, and the rest were medical librarians. Of responders, all (13) considered themselves as very experienced in using the web. On a scale of 1 to 5, with 1 being "not experienced at all" to 5 being "very experienced," 10 reported as being very experienced in searching PubMed, and one each rated themselves as "4" and "3." Some of the responses were incomplete and only 11 provided a response on the overall usefulness of PubMed searching on a PDA. They were (Fig. 6): "extremely useful" 2, "very use-

ful" 4, "useful" 4, and "somewhat useful" 1. No one responded that it was "not useful."

DISCUSSION

The mobile physician practicing in a complex clinical environment needs immediate access to reference sources that will assist in the decisionmaking process at the point of need. Using patient care incident reports, Lindberg *et al.* wrote that rapid access to biomedical literature via MEDLINE can at times be critical to good patient care and can positively affect patient outcomes.¹³ Sackett and Straus¹ have shown that when resources are available, doctors will use them in decisionmaking. Wireless networks and handheld devices provide such as an environment. PDAs, because of their convenience, fit the requirement of a mobile work force.

Interface issues

The PDA developer must be cognizant of the device's display limitations: a 160 × 160 pixel maximum readable area in some devices. Vertical scrolling should be minimized and horizontal scrolling avoided. Device memory limitations dictate that the PDA webpage should be text heavy and image poor. Exceptions may be allowed for situations when the user may not have time to read text, such as in an emergency room environment. Another exception

The image shows a PDA screen with a form titled 'FORM 4B VT Follow-up Form'. The form contains the following fields and options: 'Study number VT', 'Date: July 31 2000', 'Staff number:', a section 'Check if collected:' with checkboxes for 'Hemoglobin', 'Malaria smear', and 'Blood for HIV DNA-PCR', and an 'Other:' field. At the bottom, there is a section 'Lab results of child's samples:'.

FIG. 5. Survey data can be synchronized directly to a database server.

TABLE 1. ANALYSIS OF ACCESS LOGS (AUGUST 28 TO NOVEMBER 25, 2002) OF PDA-FORMATTED WEBPAGES

Variable	N
Total PDA-formatted HTML pages viewed	55,976
Number of unique users	594
HTML pages downloaded to PDAs via proxy servers	32,466
Percent of total pages downloaded to PDAs	58.5%
Percentage of webpages downloaded via organization private synchronization server	26.2%
Percentage of webpages downloaded via Avantgo public synchronization server	32.3%
Number of clinical query searches to PubMed	208

might be when an image (Fig. 4) conveys the message more effectively.¹²

Information content

Reference resources are widely available on the Internet. The task of the developer is to re-purpose or reformat these resources for the wireless PDA setting. Because of variable operating platforms, the HTML format is the viable format for all devices. Many of these materials are already available on the Web. The adoption of eXtensible Markup Language and its related technologies (such as XSLT) as a cross-platform solution will facilitate information formatting as content and presentation become separate.

Connectivity and workflow

EudoraWeb and Blazer require real-time link to the Internet, but PubMed queries may still be performed even without a real-time connection to the Internet with the Avantgo browser. The browser has the ability to store

several searches that can be sent to PubMed during synchronization.

PDAs may be suitable for mobile public health personnel, especially those who connect to the Internet on an intermittent basis. Handheld devices are convenient for gathering data at the remote site. The electronic format prevents entry and transcription errors. Updated information can be sent to the remote site as needed.

User patterns of accessing PDA resources

The 3-month limited pilot study average of 620 webpages per day viewed or downloaded to the PDA was surprising, especially since we had directed our announcement of the pilot test to a limited number of users. We discovered later that the announcement made its way to websites and mailing lists read by medical librarians.

Another unforeseen finding was the percentage of users who accessed the pilot study server through Avantgo proxy servers. This indicates that the majority of those accessing the NLM pilot study server own a PDA, since only PDA users need to gain access through Avantgo proxy servers. This also implies that PDA ownership may even be higher than what current surveys suggest.²⁻⁴ Since we are unable to determine other non-Avantgo users from the access logs, total PDA users may actually be higher than 60% of webpages downloaded.

Server access mirrored daytime working hours, although there was server activity at all hours of the day. We were interested in determining whether user access patterns could be attributed to healthcare workers working the evening or night hours but we were unable to. Examination of domain names accessing the

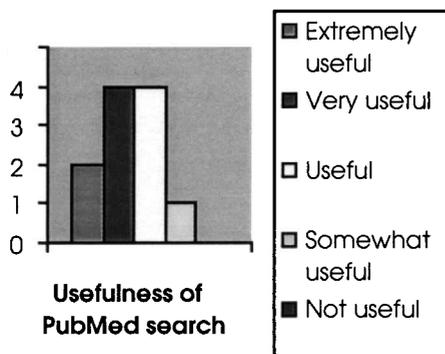


FIG. 6. Feedback from users on the overall usefulness of searching PubMed on a PDA ($n = 11$).

server activity after midnight revealed that these were coming from users in the West Coast and occasional users in Asia.

Feedback from pilot study

All users who responded through the feedback form rated access to PubMed overall as useful to extremely useful. The outcomes of the pilot study are being used to refine the application and to develop a more formal assessment of accessing PubMed at the point of care. We plan further study on methods of querying PubMed that will have greater clinical relevance.

Data security and PDAs

The Health Insurance Portability and Accountability Act (HIPAA) poses challenges that must be overcome before web-based applications for the PDA can be certified for clinical use. Concerns about wireless security^{10,11} must also be addressed in the healthcare area. Information between the wireless access point and the handheld device may be intercepted and the security and confidentiality of medical data compromised.

CONCLUSION

We have demonstrated that PDAs in a wireless environment can be used to access reference sources that are valuable at the point of care. Combined with other reference sources, such as clinical drug databases and decision support applications, the PDA is now the evidence cart. Initial response by clinicians and medical librarians was positive and enthusiastic. Clinical physicians find it a powerful resource in the practice of evidence-based medicine. It will also be a useful tool for decision support during ward rounds and case conferences. Although challenges in medical information security prevail, these may be minimized by emerging wireless technology based on other 802.11 standards and wideband technology.

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