Development of Evidence-Based Medicine Resources: Bridging Clinical Research to Medical Practice

Paul Fontelo
Office of High Performance Computing and Communications, Lister Hill National Center for Biomedical Communications, National Library of Medicine, Bethesda, Maryland
fontelo@nlm.nih.gov

Michael Ackerman
Office of High Performance Computing and Communications, Lister Hill National Center for Biomedical Communications, National Library of Medicine, Bethesda, Maryland

George Kim
Division of Health Sciences Informatics, Johns Hopkins University School of Medicine, Baltimore, Maryland

Abstract

We are developing resources for continuous and ubiquitous access to National Library of Medicine (NLM) information sources (MEDLINE, PubMed, and Clinical Trials) for the mobile physician and healthcare provider to support the practice of evidence-based medicine. We established wireless networks (802.11b, Infrared, Bluetooth) and created applications to search these databases. We also developed a content server with the main purpose of providing content to PDAs and handheld devices. We present our yearlong experience and evaluation of handheld devices, wireless access capabilities and analysis of log access data from servers. Interaction with users and online feedback will be discussed.

1. Introduction

The Clinical Research Roundtable was created in response to concerns that despite great expenditures by the National Institutes of Health and other funding organizations, advances in basic science and clinical research has not resulted in the delivery of better healthcare and formulation of health policy. This body, which had convened for about three years at the National Research Council reported their finding in the March 12 issue of the Journal of the American Medical Association.[1] The group identified two major obstacles or "translational blocks" in the process: 1) impedance to the translation of basic science discoveries into clinical studies, 2) a block in bringing the clinical studies into medical practice and health decision-making in systems of care. In an accompanying editorial, [2] Rosenberg suggested that the situation was tantamount to a national crisis requiring actions similar to the Manhattan project or the creation of the Department of Homeland Defense. He further suggested that a group of nationally prominent scientists and clinicians communicate to the President and members of Congress the dire medical consequences of continued lack of progress.

In their report, the Clinical Research Roundtable recommended: 1) that there be improvements in patient safety that would increase public confidence and participation in clinical trials; 2) development of medical information systems; 3) training highly motivated investigators and medical informaticians, and 4) adequate funding. There was reference to evidence-based decision support to clinicians, as part of the development information systems recommendation.

Basic and clinical research in the last decade has resulted in an unprecedented burgeoning of scientific information. Breakthroughs in human genomics and proteonomics, stem cell research, biomedical engineering, medical computing, molecular biology, and immunology are among the biggest contributors to the growth of biomedical information. Currently, MEDLINE contains close to 12 million citations,

around 40,000 citations are added monthly from bibliographic citations and author abstracts obtained from about 4,600 biomedical journals worldwide. Diagnostic methods have advanced quickly because of these discoveries. New treatment modalities, including drugs targeted to specific diseases are being developed rapidly based on cellular and molecular discoveries of cell DNA and protein function.

The management of this substantial increase in information, progress in developing new tests and innovative therapies pose a great challenge to the physician. Keeping updated on recent literature is a gargantuan task. Consider the following:

Number of journals	10,000
New articles a week	40,000
Time to read an article	30 mins

A physician who reads all day long for six weeks will already be a century behind.[3]

It is essential then that the clinician be equipped with resources to access information repositories and translate these to useful knowledge for decision support at the point-of-care. As Sackett and Straus[4] have demonstrated, 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.

Our prior research has shown[5] that two recent developments may help the clinician to access essential information at the point-of-need: 1) handheld devices such as a PDA; and 2) Internet access through wireless networks. These enabling technologies allow the mobile healthcare provider access to electronic healthcare data and information resources. With a PDA and a wireless network, a physician can read the latest abstracts, access full-text journals and other online resources from anywhere. Various filtering methods available through PubMed may narrow the search to clinically relevant journal articles.

The practice of evidence-based medicine (EBM) recommends that physicians obtain clinically useful information by personally searching, reading and critically appraising the medical literature. EBM is the conscientious, explicit and judicious use of current best evidence in making decisions regarding the care of individual patients.[6] It incorporates clinical knowledge and experience with clinically-oriented research in making decisions regarding a patient's diagnosis, treatment and management. The purpose of EBM is to provide the patient with the safest and most efficacious care.

Several pathways can be used to practice EBM. The quickest and most efficient is to ask a colleague. However, there is no assurance that the information obtained is current or reliable. One may read textbooks, but these maybe outdated. Searching personal collections is also acceptable, but this may be inadequate; updating personal collections can be very difficult. The best but most challenging is searching the research literature, essentially searching MEDLINE.

Practicing EBM by searching current evidence is neither easy nor convenient, especially for the independent practicing healthcare provider. After obtaining the search results and getting the articles, the task of critical appraisal of literature involves determining the validity of the study (design, bias, internal measurement validity) and deciding whether the clinical trial results are applicable to the patient. Although guidelines on the best approaches to accomplish this task are abundant,[6-16] this method is time consuming and unsuitable for the busy physician. It also requires many hours of practice before proficiency is achieved. Doctors need resources to sort through these sources quickly. Time constraints and the rigorous process often preclude the use of EBM in clinical practice. The medical literature can be challenging. Often, it is not written to meet the needs of the busy practitioner. Searching for relevant articles through hundreds of journals can be difficult.

If the process of obtaining information is hard, healthcare practitioners may not do it. According to Shaughnessy and Slawson[17-18] and as modified by Smith, [19-20] the usefulness of information is related to its relevance, validity, interactivity and ease of obtaining it. The more relevant, valid, interactive, and easier it is to get information, the more likely it will be sought.

$$\text{Utility of Information} = \frac{\text{Relevance} \times \text{validity} \times \text{interactivity}}{\text{Work to access}}$$

We present a continuation of our research on developing clinical resources to enable the mobile healthcare provider convenient access to PubMed and MEDLINE. It is our intent to encourage the practice of evidence-based medicine through easy access to MEDLINE and other NLM knowledge servers.

Methods:

PDA users may access 'certif.nlm.nih.gov' directly or indirectly (via proxy servers) depending on the Web browser used. Those who use the AvantGo browser must first go through, or 'synchronize' with AvantGo proxy servers. AvantGo proxy servers come in two general categories, public and private enterprise servers. Public servers are available to the general population after a registration process with AvantGo. Private enterprise servers are available only to those belonging to the organization. Optimized methods and experiments using Wi-Fi 802.11b, infrared and telephone modems to access the Internet with PDAs were established previously[5]. We also discussed PDA user interface and server features relevant to accessing MEDLINE via PDAs. In this study, our focus was adding Bluetooth connectivity to the Internet, testing with ARM-processor equipped Palm Tungsten devices and adding browsing features.

We added a Bluetooth Access Point (redM 1050AP) to the three existing 802.11b wireless access points (Apple Airport Base Station, Cisco Aeronet 350 Wireless Access Point and Linksys Wireless Access Point Cable / DSL Router) to the LAN. Palm devices, Tungsten T (Palm OS 5, integrated Bluetooth radio, Palm WebPro browser 1.0, AvantGo 5.2, build 65) and Tungsten C (Palm OS 5.2.1, built-in Wi-Fi 802.11b radio, Web Browser 2.0, AvantGo 5.2, build 65) were used for this phase of the project. Other staff members used PocketPC devices.

The search pages were modified to include the options to select searching for systematic reviews and retrieving abstracts of recent journals. A drop-down menu of 28 commonly read clinical journals and a searchable index of 122 core clinical journals were added. Just like the earlier version, searching was processed through CGI (common gateway interface) in the local server, and then forwarded to the PubMed servers. Systematic review and clinical queries are standard PubMed filters based on Haynes *et al*[21] and Shojania and Bero[22].

Server log access files were analyzed using Analog 5.3. As we previously reported, HTML documents were developed using standard desktop text editors like BBEdit. The HTML files were archived on a UNIX server running Apache 1.3.26.

Results:

Bluetooth connectivity and Palm Tungsten devices

Palm Tungsten T connection to the Bluetooth access point was established reproducibly. The link was disconnected after a minute of inactivity. Occasionally, the PDA had to be reset to re-establish a connection to the access point. Multiple tests in our department setting, (plasterboard walls, metal door frames) showed that the Bluetooth connectivity could be acquired to a maximum of 35 ft. Establishing a Bluetooth link took about 3 ±3 secs and retrieval of initial PubMed query result 10 ± 5 secs. Once the wireless PDA had attached to the LAN, subsequent searches and abstract retrieval required 5 ± 3 secs. The wireless connection was reproducible every time.

These results were similar to data obtained with Palm Tungsten C devices connecting to 802.11b access points. We found no interference problems between Bluetooth and 802.11b devices although they operate in the same 2.4 MHz frequencies.

Server Access Log Analysis

Analysis of access logs from August 28, 2002 to August 22, 2003 at 3-month intervals of PDA-formatted Web pages showed a total of more than 185,000 visits. 137,078 of the total or 73.8% were downloaded via PDAs.

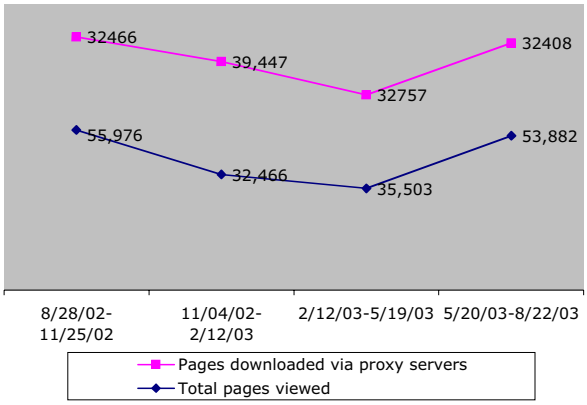

Figure 1. Comparison of yearlong total server visits and number of Web pages downloaded to PDAs via proxy servers.

Figure 2 shows the breakdown of server access between AvantGo public and private enterprise proxy

servers. These private enterprise servers were located in academic universities and at the NIH.

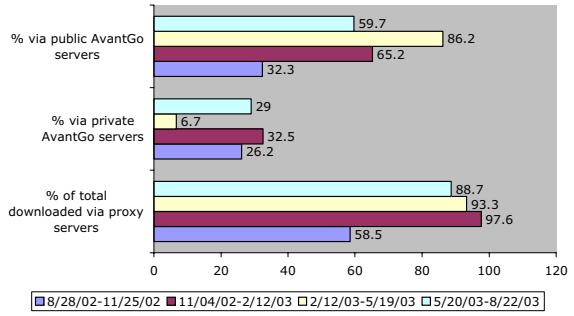

Figure 2. Percentage of total Web pages downloaded to AvantGo proxy servers.

Server access through public AvantGo servers was 2.5-fold higher than private enterprise AvantGo servers.

The number of PubMed/MEDLINE searches from the first to the fourth quarter were: 208, 144, 435 and 1261 respectively. Figure 3 summarizes these queries as percentages of total server visits.

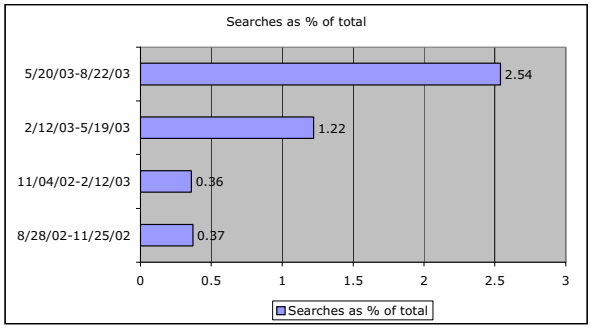

Figure 3. PubMed/MEDLINE searches compared to the total number of visits.

Feedback

Only 31 of the 1835 unique users of the service provided feedback, despite multiple requests and modification of the evaluation form to a simple checklist. Many of the feedback forms were not completed. The majority of evaluation forms (75%) were sent only after public access to this tool was announced in an NLM Technical Bulletin in July. Figure 4 summarizes user assessment on the overall usefulness of searching PubMed on a PDA.

Of the 31 responders, 5 were attending physicians, 3 resident physicians, one researcher and 7 medical librarians. Nine used Palm OS devices, 7 were PocketPC users and one responded as using another unspecified device. There were no Linux PDA users that responded during the study period.

The majority of users that provided feedback downloaded Web pages to their PDA via direct connection to their computer using USB (n=7) or serial (n=2) connection. Five used Wi-Fi, one a PDA phone combination, one a wireless modem and 2 reported accessing the server through Bluetooth.

There were 12 users who accessed the server through AvantGo browsers, 8 used Internet Explorer and one through EudoraWeb, a text-only browser. Two users selected the "other" category, but did not specify.

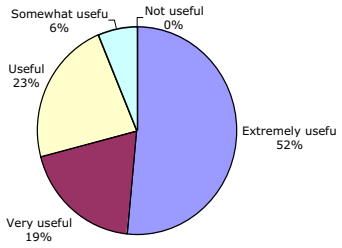

Figure 4. Feedback from users on the overall usefulness of searching PubMed on a PDA (n=31).

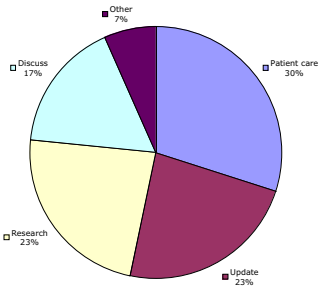

Figure 5. Motivation of responders who searched PubMed using PDA interface (n=29).

Discussion:

The availability of point of care tools in clinical medicine, although long recognized as essential to the practice of evidence-based medicine, has added significance in the light of the Clinical Research Roundtable report[1]. Availability of real-time access to decision-support tools is essential because clinicians will be more apt to use these resources if they are

convenient to for them to access,[4, 17-20] at the point of care.

Bluetooth connectivity

In our setting, Wi-Fi, infrared and Bluetooth connectivity were comparable. Ease of Internet access and download speeds were similar. It meets the 15-second window essential for user-tolerable quick access to decision-support tools at the point of care. There were no technical or interface impediments encountered when Internet access was established. Bluetooth connectivity adds another route to link to the Internet. With the increasing availability of 802.11b, infrared, Bluetooth access points and Bluetooth-enabled mobile telephones, healthcare providers now have several options.

For the mobile healthcare provider, the determining factor could be what Internet access modality is available in their clinical practice or what devices the healthcare practitioner uses. Signal reach will vary according to local conditions and can limit the use of handheld devices. Infrared access may be more suitable for those with data security concerns because of its line-of-sight feature. With infrared, the user is aware of the direction that the beam is pointed to, so it might afford greater control and security. Wi-Fi is multidirectional and may be less secure with current protocols. Bluetooth technology can be configured to require device authentication and "trust" that might confer added security over Wi-Fi. Bluetooth, also because of its shorter range may represent a security compromise between line-of-sight infrared and enterprise-wide 802.11 and Bluetooth technology. Another determining factor what type of network or device to use, would be what type of data or information is being sought or transmitted. We discussed other security and confidentiality concerns, such as HIPAA in our previous study.[4]

Server Access Log Analysis

Figure 1 shows total access and number of pages downloaded to PDAs in the year of study. We attribute some of the higher first quarter access to developers and local users' extensive testing of the server. The second and third quarter figures most likely reflect the decline in non-PDA users, as evidenced by the sharp rise in the method of accessing the server shown in Figure 2. The percentage of viewers who used a PDA to download pages changed from 58.5% in the first quarter, to mostly PDA in the second, third and fourth quarters (97.6, 93.3, 88.7% respectively.) This result may signify that users who continue to access the server are mostly PDA users. This data may be further supported by the observation in the server access logs of brief surges (1-3 days) in server visits through desktop browsers after announcements of the availability of the resource in mailing lists and continuous decrease soon after.

Incremental growth in the percentage of queries to PubMed compared to overall server access (0.37, 0.36, 1.22, 2.54%) is shown in Figure 3. The three-fold and seven-fold rise in the third and fourth quarters compared to the first two quarters, may be attributed to group list and meeting announcements and the July-August 2003 issue of the NLM Technical Bulletin publicizing the availability of the service to the general public. These changes may signify also that users who continue to utilize this resource are beginning to use it to as intended by the developers, to search recent medical literature through their PDAs in the clinical setting, to support the practice of evidence-based medicine.

We examined access to 'certif.nlm.nih.gov' based on the category of AvantGo proxy server (Figure 2.) Our review shows variability in the category of AvantGo proxy server accessed. However, except for a low point of 6.7% in the second quarter, access to private enterprise server was somewhat constant, between 26.2 to 32.5% of total proxy server access. Public AvantGo server access was more inconsistent, between 32.3 to 86.2%. Although we have no documented explanation for this data, daily visual inspections of access files have shown intermittent absence of connections from one or more of private enterprise servers stretching from a day to 2 weeks. This may be due to a malfunction of private enterprise servers. Private organizations may only have one synchronization server per organization. If it is not in service, there is no route of access for PDA synchronization via AvantGo browsers. AvantGo on the other hand, has a bank of synchronization servers; there is always a server available for PDA users to synchronize with.

User feedback

Although only 31 responses were received, more than 50% of users thought that this resource was extremely useful (Figure 4.) None of the responses indicated that this application was not useful.

We would like to have known why the users responded as they did, however, it is tedious to input text using a stylus. Writing lengthy text would likely discourage

users from responding. It difficult to list all possible reasons for rating the resource and we did not attempt to. In an early evaluation form, we provided space to add text, but received no responses. The feedback form was amended as a checklist that included only checkboxes and radio buttons. We plan to further explore the overall usefulness of this tool in the clinical setting.

Several questions on the use of the tool were received and resolved by email. Occasionally, a telephone call was required to resolve issues. Comments were also received by email. One user requested that a simpler URL be provided because of the difficulty in writing the current URL (http://certif.nlm.nih.gov:8080/nlm/) with stylus. Another responded that on top of its being freely available, there is nothing to download and take memory on the PDA. This user further suggested that mobile technology developers utilize the Web to provide services to PDA users. As expected, close to half of responders synchronize their PDAs though a direct connection to their computer. We were quite surprised to discover that more than half accessed the Internet by a wireless device (28% 802.11b, 11% Bluetooth, 6% each for PDA phone and wireless modem.) These numbers signify the increasing penetration of wireless devices in medical settings. It is highly likely that this trend will continue in the future, as newer devices incorporate wireless connectivity.

Medical librarians were well represented among the evaluation responders. In the early testing phase, medical librarians assisted in evaluating this resource. Informal partnerships and collaborations[22] were made with academic medical librarians and announcements were made on lists that medical librarians subscribe to. Medical library Web pages featured early versions. Medical libraries that provide hands-on sessions on the use of PDAs for clinical settings regularly hold PDA classes. It is not surprising then that they were among the highest population of users of the service. We continue to request input from medical librarians.

Figure 5 shows the motivation of responders for using a PDA to search PubMed/MEDLINE. One-third said, that they used this tool for patient care. Another 23% chose research, some of which could be related to searching information for patient care.

At best (fourth quarter access), only 1261 or 2.54% of Web server visits were for the purpose of searching PubMed among the 1835 unique users during this trial period. Although we have no data to indicate whether this has led to a change or applied to actual care of a patient, we are encouraged.

We will continue to evaluate this resource in its impact on the support of the practice of evidence-based medicine. The data after a yearlong observation period is encouraging.

Conclusion

We have tested Bluetooth as another method to access PubMed, MEDLINE and other NLM knowledge sources using PDAs and handheld devices in a wireless mode. Bluetooth was comparable to infrared, Wi-Fi or 802.11b in ease, speed and reliability of connectivity. A three to seven-fold increase in the number of clinical query searches was observed in the last two quarters of observation. PDA access through AvantGo public synchronization servers was 2.5 times greater than private enterprise servers. Responses from clinicians and medical librarians continue to be encouraging and constructive. We plan for this resource to be an integral part of the clinician's set of tools for evidence-based practice and decision support at the point of care. As such, it may help address one of the translational blocks identified by the Clinical Research Roundtable study by bringing clinical research to medical practice.

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