Meeting Clinician Information Needs by Integrating Access to the Medical Record and Knowledge Resources via the Web

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MINDscape is a web based integrated interface to diverse sources of clinical information including both patient specific information (electronic medical record) as well as medical knowledge (the "digital library") to provide "just in time" information at the point of care. It was developed at the University of Washington to meet clinical information needs both as identified locally and by a review of the literature. Beta testing by over 600 clinicians is in progress and medical centers wide access scheduled for Fall 1997. We describe the information needs we sought to meet and the ongoing evaluation approach we are taking to ensure the information needs of a diverse group of clinicians are met. The iterative evolution of the interface from prototype, to alpha to large scale beta testing is reported. Integration of information occurs at three levels: integration of information by patient, integration of information by provider, and integration of patient specific information with medical reference material and decision support tools.

INTRODUCTION

MINDscape is an integrated web based interface to the University of Washington (UW) clinical data repository (the Medical Information Networked Database system or MIND) and medical knowledge resources. Development has been driven by the philosophy of the University of Washington IAIMS program to create a comprehensive, integrated information access network. Specifically the goal of the IAIMS clinical group has been to bring "just in time, just what you need" decision information to the point of care in an integrated fashion[1,2].

The users of MINDscape are a diverse group of clinicians in multiple settings with differing information needs. Users include residents, nurses, fellows, nurse practitioners, and attendings. Settings range from off-site primary care clinics to hospital-based subspecialty wards in two major teaching hospitals: the University of Washington Medical Centers and Harborview Medical Center. Users also include referring providers in the WAMI area (Washington, Alaska, Montana, Idaho)[3].

Based on surveys and discussions, these clinicians have similar unmet information needs[4,5] to those summarized in a recent systematic review of the literature by Smith[6]. These needs fall into two categories - patient specific information and medical knowledge. Clinical information systems address the need for patient specific information (e.g. What medications is my patient taking?). The medical library addresses the need for access to knowledge resources (e.g. What are dosage and side effects of a certain drug?). Clinical decision making at the point of care requires access to both types of information[5] (e.g. Could my patient's abnormal creatinine be explained by a side effect of the drug they are on?). Furthermore clinicians need tools to facilitate managing groups of patients (e.g. Which of my inpatients has new abnormal lab values?). In an era of managed care, increased patient load and decreased clinician time, an integrated tool to access panels of patients, medical knowledge and patient specific information will be particularly valuable. We summarize below our 18 month project to develop the MINDscape application as such a tool.

METHODS - PHASE I

Concurrent development was undertaken in three parallel areas: A) web interface to patient data, B) summary view integrated by provider, and C) Internet accessible knowledge resources. Since the most successful and widely used informatics applications are those that meet a need (e.g. Medline[7], computerized laboratory information systems) each area was focused on meeting a specific information need identified at the UW and confirmed by the literature[4,5,6]. Ensuring needs were identified and met involved extensive participation by representative clinicians throughout the design and implementation process. Key collaborators included the IAIMS Clinical Informatics Knowledge Resources groups, the Health Sciences Libraries, and Medical Center Information Systems (MCIS).

The web based paradigm was chosen to provide a platform independent common front end to disparate databases and to permit rapid prototyping[8] for our iterative design approach. Platform independence was

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important since UW users (and referring providers) are approximately evenly divided among X-terminals, Macintosh and Windows platforms. The ability to provide a common interface via a flexible middle-layer to disparate legacy databases is important since the data displayed by MINDscape resides on multiple servers in a number of systems and databases including: INGRES, DECRAD, Intellus, Informix, Illustra, Mumps, Access, and various web servers.

A. Web Interface to Patient Data

First a "look and feel" prototype of the user interface was developed after reviewing existing Web interfaces to medical record systems[9,10]. Nine representative physicians were chosen to assist in an iterative testing and refining process. A text-based viewer had been used with the existing MIND clinical data repository but its use was limited by performance and interface issues. The prototype HTML interface was designed to address both of these concerns by a) querying and displaying only a small user-specified subset of patient information at a time and b) utilizing a graphical user interface with a "file folder" metaphor. To navigate within the medical record the user need only to point and click on tabs at the top of the screen corresponding to the major divisions of the chart: demographics, problems, laboratory, transcription, radiology, medications, immunizations, clinical reminders, visit history, findings, and procedures. Data was then displayed in a tabular form, with links both within and between folders. Within the laboratory folder clicking on the word "sodium" next to the result displays the trend for serum sodium over time. In the visit history folder clicking on the date of a hospitalization displays the discharge summary from the transcription folder.

The second step involved interfacing the HTML prototype to the MIND database to create a functioning tool for evaluation. MIND is a UW-developed production database containing the following information: patient demographics, insurance coverage, clinician selected problem list entries, ICD-9 diagnoses, all transcriptions, selected pharmacy records, allergies, immunizations, automatically generated clinical alerts, stay/visit data, CPT procedure codes, laboratory data, radiology reports. The MIND system consists of an Ingres relational database, DECRAD radiology system, SunQuest laboratory system, and Intellus transcription system and is being linked to the EMTEK and EPIC clinical information systems. A combination of Java applets and Common Gateway Interfaces (CGI) in C with embedded SQL was used to interface the web front end to MIND. Security was provided by Secure Socket Layer, session specific cookies and a custom database application to provide user authentication, manage passwords and log accesses by provider and by patient.

Thirty clinicians (nurses, residents, attendings) with multiple backgrounds (inpatient, outpatient, surgical, medical, subspecialty, primary care) were involved in a two month alpha test with e-mail feedback links to the developers. Detailed usage logs were kept. At the conclusion of the alpha testing an hour long meeting was held separately with each of the alpha testers using a structured questionnaire focusing on information needs unmet by the application and user interface issues. Additionally the application was demonstrated to large groups of clinicians, IAIMS staff, and MCIS staff to solicit open ended unstructured feedback.

B. Summary View Integrated by Provider

A prototype of the summary view of a group of patients for a given provider was developed and tested as a stand alone application. The implementation tools, evaluation methodology and test group were identical to the web view of the medical record. Inpatient and outpatient views were created. The views consisted of tables with rows corresponding to individual patients cared for by a single provider. The columns for the inpatient view included: name, patient id number, age, last inpatient visit, last outpatient visit, summary of laboratory activity since admission with hypertext links directly into the web view of the laboratory folder for that patient. The columns for the outpatient view were similar but included primary diagnosis and provider on last outpatient visit and showed laboratory activity since last outpatient visit rather than since admission.

C. Internet Accessible Knowledge Resources

A large number of Web accessible medical reference resources were and continue to be developed at UW. A limited subset was targeted for initial integration into the web view of the medical record. We in particular focused on access to MEDLINE, drug reference information, laboratory reference information, and clinical guidelines given the types of medical reference information needs previously identified[4,5,6,7]. A UW Federated Drug Reference database[11] and a locally developed web accessible laboratory reference manual both offered the potential to integrate with the electronic medical record since both were developed for external linking. The University of Washington Physicians Practice Plan in collaboration with the IAIMS group developed locally reviewed web guidelines for common

conditions of high morbidity and prevalence (e.g. diabetes, hypertension).

RESULTS PHASE I

The alpha version of the Web view of the medical record was successfully deployed to the alpha test clinicians but was deemed to be not ready for widespread implementation. Key areas identified for improvement were response time, user interface refinement, and functionality. Specific examples of user interface issues included need for interface consistency across different views of the medical record (e.g. problem list view and medication list view) and on-line context sensitive help. Specific examples of needed functionality were the ability to view a summary of data linked with a visit or hospitalization (e.g. labs, findings, procedures, medications, radiology, transcriptions associated with one visit on one screen) and the desire for more flexibility in viewing lab results.

The prototype version of the summary view integrated by provider was well received but felt to be in need of significant improvement. Specifically, these included more columns of data (e.g. radiology and transcription activity), a single application that would permit access to either a provider panel or a single patient's record, and more ways of specifying inpatient views (e.g. primary care providers wanted to be able to access their inpatients in a panel even if they were neither the current inpatient attending nor the admitting attending).

Integrated Internet accessible knowledge resources seen by the alpha test group were restricted to the laboratory reference manual and the drug reference. The linkage from the medication list to the drug reference database was identified as needing improvement (often rather than a one to one link the search resulted in a one to many link). The test users almost uniformly found these links and the ease of access from within the medical record to be very important. They expressed a strong desire to expand the linkages to other electronic information resources such as MEDLINE and additional clinical guidelines (both of which were already accessible on-line but required separate log-in access).

METHODS PHASE II

The focus of the second phase was creating the single integrated MINDscape interface based on the results of the phase I evaluation by: A) refining and integrating the individual projects of the first phase, B) expanding the number of knowledge resources and reference materials.

A. Alpha Test Issues Addressed

To improve system performance the server architecture was redesigned to use multiple parallel upgraded web servers, the database server was upgraded and database tables were re-indexed based on the SQL queries required by MINDscape. A single CGI application was written to merge functions of the provider view and the patient view. The overall user interface was overhauled to make it more intuitive to use with a straightforward consistent interface logic across all views and folders. Extensive on-line help functions were added. An automatically generated inpatient and outpatient visit summary function was added with hypertext links to more detailed views. Options for viewing lab results were expanded to include viewing of predefined and custom panels of labs over time (e.g. a renal transplant panel). The ability to reformat views for printing clean hard copy was added. The MIND database and the MINDscape application were expanded to provide tabs and views for pathology results and referring provider contact information. The inpatient and outpatient provider profiles were revised to include more summary information per patient. Multiple inpatient provider views were created: inpatients you are currently attending on, inpatients you admitted, inpatients for whom you are the primary ambulatory care provider. The MINDscape application was reviewed on an ongoing basis by the original alpha test group. A prototype access restriction mechanism to permit referring providers to access MINDscape records only for the patients they have referred to the UW was implemented.

B. Expanded Integration of Knowledge Resources

Existing linkages from the medical record to medical reference material were refined and many new linkages were added. We adopted the international symbol for information - a white "i" on a blue background - for hypertext links to knowledge resources. The problems with linkages from MINDscape to the UW FDR drug reference[11] were resolved by using the unique drug code in the MIND database as the search key for the Informix based FDR database with a backup free text search. The interface to the Mumps based laboratory reference manual was similarly refined. By passing insurance information to FDR from MINDscape and integrating a table of insurance company formularies into FDR it has been possible to flag drugs not on the formulary of the patient's insurance company . A large number of additional context dependent linkages were created including the following. A link in the demographic folder to cultural reference materials in HTML was

added (EthnoMed[12]). From the problems folder non-specific linkages were added to an HTML database of web accessible reference material (HealthLinks[13] and to Medline via the experimental National Center for Biotechnology Information PubMed interface[14] and a custom UW forms interface. Specific linkages from individual problems on the problem list to the respective HTML UW clinical guideline were maintained in a table in the MIND database. Automated linkages with parameter passing from entries in the problem list to Medline via PubMed were provided but without automated mapping from UW problem list vocabulary to UMLS or MeSH. Context specific links were provided to UW Healthlinks[13] wherever possible (e.g. from the radiology folder to a list of links to web accessible radiology reference and teaching material). The computational logic behind the automated clinical alerts based on HEDIS measures was displayed in the reminders folder. Specific links were created from providers names listed in patient records in the database to contact information for that provider maintained in a separate database. Work is ongoing linking to a library of patient educational material currently maintained in an Access database.

Prior to production deployment a large scale beta test of MINDscape is being performed. The purpose is to ensure our technical solutions are scaleable to the two medical centers and to ensure that the user interface and functionality in fact meet the needs of the majority of clinicians in the Medical Centers. In addition to an evaluation using the tools developed in Phase I, we are working closely with health services research faculty and the UW Center for Cost Outcomes Research to attempt to devise a methodology to evaluate the degree to which MINDscape meets clinicians needs and improves patient care throughout the region.

PRELIMINARY RESULTS PHASE II

At this time (July, 1997) the large scale beta test of MINDscape is nearing completion. The test groups feel that MINDscape is ready for full-scale implementation. Preliminary feedback from the beta test group suggests that meeting the information needs of the selected representative alpha test group is in fact generalizing to a larger cross section of the University of Washington Medical Centers. There is a tremendous amount of enthusiasm and heavy use of the application and its components with acceptable system response times (based on usage logs and network monitoring). Preliminary feedback also suggests that there is a significant amount of synergy between the three components of the application. In contrast to the paper system where they had only a list of their appointments for the day clinicians report the MINDscape system is helping them deliver better care by permitting them to easily access their next appointment's medical record (particularly important when the paper chart is missing, which occurs up to 20% of visits) and by bringing knowledge resources such as clinical guidelines to the point of care.

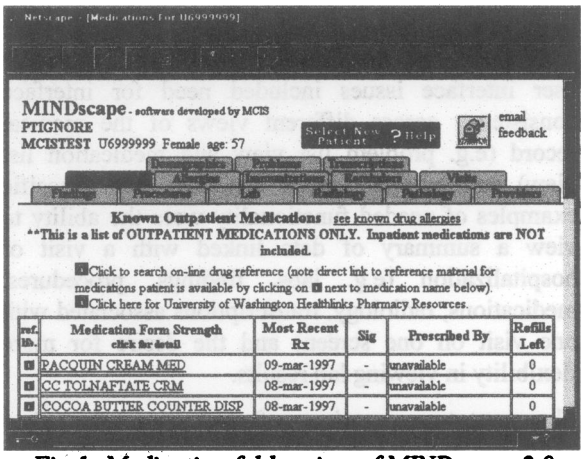

Fig.1: Medication folder view of MINDscape 2.0 with (i) links to knowledge resources including the UW Federated Drug Reference[11]

DISCUSSION

MINDscape is a good first step toward meeting the clinical information needs identified by many researchers[4,5,6] by integrating access to patient specific information with simultaneous access to relevant medical knowledge. Collaboration between informatics researchers, clinicians, librarians and medical center information systems personnel has been important to its successful implementation so far. Our approach to web access to a clinical data repository is similar to that taken by many others before us[8,9,10] but adapted to our local environment - in particular using the web to integrate access to a number of "best of breed" clinical systems. Similarly our approach of integrating access to information is built on work done by others[15]. Our goal has been to extend this work to create a full scale production system that provides a critical mass of functionality that will permit the widespread adoption of the MINDscape solution. One key piece has been the extensive involvement by many representative clinicians at all stages of the design which so far appears to have permitted us to generalize our solution across the UW Medical Centers.

To fully meet clinicians patient-specific information needs we plan to expand the MIND database and MINDscape interface to address current limitations.

We are working on Java based data entry and correction to permit clinicians to add to and update key components of the MIND database. UMLS tools are being integrated to address some of the difficulties inherent to the decentralized entry of problem lists and procedures. Refinements to the laboratory data interface(currently batched daily) will include real-time access and microbiology results. Access to radiology images is being tested on a limited basis. A number of clinicians have requested structured note entry to replace dictation. Finally, secure e-mail[16] will be integrated into MINDscape to address the evolving communication needs of both providers and patients.

To meet reference information needs we are working on automating and streamlining linkages to a growing number of web-enabled knowledge resources. To be scaleable and maintainable, references both internal and external to MINDscape will need to be described using a restricted medical vocabulary. In addition, to create automated linkages from MINDscape some formal specification of interface protocols to these external references will need to be created.

Finally, evaluation of the impact of a broad system such as MINDscape is posing significant challenges to standard evaluation approaches. Ongoing collaborations with experts in clinical research and evaluation in conjunction with the Bench to Bedside and Beyond Regional Telemedicine Evaluation contract will hopefully resolve some of these issues.

CONCLUSION

The Web in general and the MINDscape application in particular permit the creation of a clinician desktop that has the potential to provide a critical mass of key functionality via a single interface at the point of care. Though we have achieved a critical mass of functionality coupled a large and interested user population it is clear that more functionality is needed on the medical record side and more knowledge resources need to be integrated to fully meet the information needs of UW clinicians at the point of care. The approach we have taken using standard technologies has scaled within our institution and may be generalizeable to other organizations. We feel key factors to our success have been the extensive collaboration between informatics researchers, clinicians, librarians and information systems staff working across political and geographical boundaries.

Acknowledgments

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