A New Instrument for Medical Decision Support and Education: The Stanford Health Information Network for Education

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ABSTRACT.

The information needs of physicians are complex and ever increasing in a world of rapidly expanding medical knowledge and a practice environment where physicians are required to know and do more with shrinking resources. Current strategies for providing clinical decision support and continuing medical education have failed, in part, because they have not provided timely, easy access to information that is current, integrated with other information and the physician’s workflow, and relevant to specific questions that occur during the patient encounter. Meeting these challenges involves understanding the nature of medical knowledge, the different information needs of physicians, the clinical decision-making process, and the constraints of the physician’s work environment, as well as the traditional barriers to physician education. We explore the nature of some of these challenges and propose one solution in the form of a highly integrated web-based technology – The Stanford Health Information Network for Education (SHINE).

THE PROBLEM.

Meeting the information needs of physicians in their world of rapidly expanding knowledge and changing practice environments is difficult. Many questions that arise frequently remain unanswered despite the fact that answers can be had from textbooks, reference manuals, reviews, research papers and medical experts that would improve the quality of clinical decisions [1-3]. The reasons for this failure to answer questions that are derived from the patient encounter stem from the barriers to accessing and using information and the cost of breaching these barriers. Medical knowledge is vast, rapidly expanding, and scattered across the medical literature. The doubling time of medical information is currently about 19 years with medical knowledge increasing four-fold during a professional’s lifetime [4]. Medical knowledge resides in repositories that are spatially, functionally, and structurally diverse and searching for medical information is costly in terms of time, money, and effort. Often the answers to medical questions that are needed to deliver optimal patient care, even though they exist, are simply not accessible [1]. Medical libraries, for example, are not readily available to the majority of physicians and when they are, the time and effort of using them is often too great. Similarly, medical experts are not readily accessible. In a recent local survey, the textbooks available to physicians in their workplace were often more than 10 years old and quick access to current information was limited to chance encounters with colleagues in the hallway[5].

When encountering a question that occurs in the context of patient care, the physician can be faced with having to determine the relative cost of not answering the question – an expected-value decision problem. Often this amounts to a tradeoff between not delivering optimal patient care and the cost of obtaining information. Huth refers to this behavior as the “cost/benefit model of physician information seeking” [6]. If in the physician’s estimate, the costs to the patient are small or the costs of obtaining information are high, the physician may be prone to tolerate ignorance. However, costs hidden both to the patient and the physician/institution may not be taken into account: for example, costs to the patient may occur far into the future (whose present value is discounted), and costs to the physician/institution may result from a failure to alter an improper medical practice or from unnecessary referrals to subspecialists.

The signal-to-noise ratio of journal contents is often too low for raw articles to be useful in daily practice [4]. Physicians need information that is specific to the question asked and applicable to clinical practice [7]. The data must be delivered quickly and effortlessly in a way that is seamlessly
integrated into the workflow. It is this “just in time” approach that has been advocated as a means of incorporating scientific evidence into clinical decisions at the time that they are made[8]. The failure to provide timely answers has largely accounted for the failure of current information technologies to meet the information needs of physicians. We will explore some design issues that have contributed to this failure. There is convincing evidence that removing the barriers to accessing clinically relevant information could significantly improve the extent to which physicians’ information needs are met [7] and it seems likely that data that improves decision making will improve clinical outcomes.

Just as important as the need for information that occurs during the patient encounter is the need for continuing medical education (CME). State licensing boards have recognized this need and established requirements that must be met for physicians to maintain licensure. Unfortunately, CME is frequently no more successful in meeting physicians’ long term educational needs than are current information technologies (IT) in meeting immediate needs [9]. Traditional CME methods have been largely didactic in nature, often structured around conferences, and divorced from medical practice. The effectiveness of CME is inherently compromised because experts choose topics that they presume but are not certain should be important to the intended audience [10]. The most effective CME methods have used practice-enabling or reinforcing methods [11]. Much of the failure to link CME more closely with medical practice has resulted from the general failure of IT in the physician’s workplace and the regulatory decision to not allow self-initiated learning for the majority of physicians’ category I CME credit 1. A “practice-learning” model of CME has been proposed where CME becomes a means of improving patient outcomes through enhanced physician performance and is no longer an activity that is separate and discrete from patient care [10].

The Stanford Health Information Network for Education (SHINE) was conceived to address both issues of immediate (decision support) and long term (CME) information needs [5]. It makes available a core collection of medical content that includes textbooks, pharmaceutical databases, a bibliographic database, consensus statements and guidelines, full-text online journals, a differential-diagnosis expert system, reviews of clinical topics, and streaming video. All of this content can be accessed with a single, unified, web-based, intuitive interface and, more importantly, search capability. Searches are distributed in parallel among different resources by a “knowledge broker” and results from all sources are returned simultaneously in a format that is intended to optimize clinical utility (Figure 1). A metathesaurus allows the user to navigate through a concept space in order to maximize precision and recall. Searches and information retrieval steps are logged and are accessible to the user, making reconstruction of searches and results simple and instantaneous. SHINE will support teleconsultation through email and videoconferencing with tools that enhance data sharing. Development is currently underway to integrate the SHINE information tool with an electronic medical record (EMR) that will make it possible for the user to flow seamlessly between clinical practice and a learning environment and brings together a clinical alerting system with the authority of the medical literature.

INFORMATION NEEDS AND AVAILABILITY.

The information needs of physicians can be conceptually divided among those that are local, pertaining to a particular patient or institution, or global, pertaining to areas of generalizable medical knowledge. Forsythe, et. al. refer to this as a distinction between general and specific information and between global and local knowledge [12]. We offer a further distinction based on the criticality of time and importance of information. Decisions to pursue and efforts to obtain information will differ between information that is either time critical or important and information that is neither. Local information that pertains to the patient consists of the history and physical, and results of laboratory tests and studies. Local information that pertains to the institution includes specific policies and procedures such as clinical pathways, drug formularies, and reminders. Global information is everything else and consists primarily of the medical knowledge base of the physician that is generally applicable to all patients regardless of institution or geographic location. The manner in which medical information is made available to the physician must be sensitive to each of these distinctions. Global information that is required to make a decision in the near present time, e.g., what test to order, what diagnosis to consider or what treatment to prescribe, becomes inaccessible if the physician must travel to a medical library, or even interrupt a patient encounter to walk down the hall to a computer. Even more fundamental issues of context, such as a simple, intuitive interface

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1 The highest category of credit awarded by the ACCME (Accreditation Council for Continuing Medical Education) that is required for state licensure.
for information that is available electronically, and the ability to quickly find specific answers to questions that may require traversing multiple diverse resources can be strong determinants of whether information will be sought. The information returned also must have a high signal to noise ratio, that is, be focused and applicable. Curly, et. al. have found that traditional information venues often fail because information is not easily available or applicable[13]. Gorman further demonstrated that the decision to even pursue information can depend on the urgency (time criticality + importance) of the patient’s problem and the expectation that a definitive answer to the question exists [3]. Shaughnessy et al. have described the “usefulness” of medical information as being equal to the (relevance x validity) / work to access [14].

Traditionally, local information is gathered from the patient during the encounter, from the medical chart, hospital information system (when available), and the physician’s memory of hospital-specific guidelines, policies and procedures. Frequently handbooks, paper or electronic, are available to assist the physician with the latter. Global information is usually obtained during the physician’s training and subsequently, from textbooks, journal articles, colleagues, didactic sessions, assorted databases, and often fragmented learning experiences. Assisting the physician with local information needs has been the intent, with varying degrees of success, of efforts to develop an electronic medical record (EMR). Efforts to offer computerized solutions to the physician’s global information needs that reduce the time, effort, and expense of obtaining information have produced a number of important applications that represent significant advances. These include MEDLINE, a bibliographic database of the medical literature from the National Library of Medicine, and its recent web-based incarnation, PubMed, as well as electronic forms of traditional textbooks and journals, many with added functionality such as search engines. More recently many web-based versions of these

Figure 1. The user interface.
applications have appeared. Nevertheless, the success of these efforts are notably variable. Where they have failed, more often than not, they have been insensitive to the aforementioned determinants of physician’s information requirements.

Another reason that systems intended to meet the information needs of physicians fail is that they often do not account for the relationship between global and local information needs. Many information needs require the physician to synthesize global information, e.g., the results of a randomized trial, and translate it into terms that are locally meaningful, e.g., apply it to a specific patient, clinical situation, or formulary. The physician must first distill the significance (and applicability) of the study as well as be aware of patient characteristics that may affect its application (local knowledge). The assimilation process is frequently frustrated by the disparate nature of information systems that provide global knowledge (e.g. MEDLINE) and those that provide local knowledge (e.g., the hospital information system or electronic medical record).

Two problems present themselves. The first is the gap between the medical literature, clinical studies in particular, and the heuristics required to deliver patient care. One attempt to bridge this gap is the creation of clinical practice guidelines (CPG). CPGs are attempts to distill the meaning of the global literature on a clinical problem into a heuristic that allows the physician to direct patient care. Such guidelines are authored by government agencies, professional societies, and healthcare institutions. Some of the more well known examples include the federal Agency for Health Care Policy and Research (AHCPR), the NIH consensus statements, and the Cochrane Collaboration [15, 16]. Practice guidelines that are created by healthcare institutions are a step further removed from those that are created by a consensus of experts and may reflect biases that are peculiar to the institution (e.g., financial) and not necessarily in the best interests of the patient. In general, practice guidelines vary widely in their quality, authority, and applicability. The ultimate arbiter is the medical literature itself, and integrating it with the guidelines is crucial to the acceptance of such guidelines by medical practitioners. Information technologies that facilitate this integration at the point of care without interfering with the workflow of the healthcare provider are likely to be the most successful.

The second problem is one of applying a medical heuristic or practice guideline to a particular patient (Forsythe’s specific information [12]). This involves having information about a specific patient that bears on the application of the rule. An example of this might be knowledge of the renal function of a patient that would bear upon the use of a drug that was excreted through the kidneys or an interaction with another drug. This sort of information is contained within the patient’s medical record. Thus, the essential goal of a medical information system would be to integrate the medical literature, practice guidelines, and the electronic patient record and deliver it in a way that would be seamlessly available to the healthcare provider at the point of care. The failure to do so may explain why most of the questions that are generated in the minds of physicians during the patient encounter go unanswered [4].

DESIGNING MEDICAL INFORMATION SYSTEMS TO MEET GLOBAL INFORMATION NEEDS – USEFULNESS AND USABILITY.

In an important book, The Problem with Computers [17], Thomas Landauer observes that, despite massive outlays for information technology since 1973, there has been a downturn of productivity growth and a lack of correlation of business success with widespread computerization. He calls this phenomenon the “productivity paradox” and attributes it to a failure to design well for usefulness and usability which, in turn, is due to a resistance to evaluate the actual effectiveness of computer systems and a lack of feedback that cripples the normal process of technical improvement. “Usefulness” refers to the ability of a technology to perform useful functions; “usability” refers to the way (ease) with which those functions are performed. Understanding each of these depends on a careful analysis of the task that needs to be performed and the people performing it. He proposes a solution that he calls “user centered design and development” (UCD) that depends on evaluative feedback.

As an example of the failure of information technology to produce an increase in productivity that results from a more proximal failure to understand the task to be performed, Landauer cites an experiment by Gould [18] that was subsequently repeated by Stuart Card of Xerox PARC. In this experiment letters were prepared either by hand and given to professional typists or by the authors using a text editor, with little difference in total costs between the groups. Landauer observes that computers are often deployed in a way that shifts who does the labor, in the economic interest of one of the parties but not necessarily the sum. Similar
failures are cited in the realm of computer-aided instruction. In each case, the flaw stems from the failure to understand the task to be performed and the process of designing the technology to perform that task. Software is commonly designed by programmers who do not carefully analyze the task, never observe the end-user, and “add and subtract features and functions reflecting their own fantasies of what the job is like and under the assumption that the users are people just like them” [17]. Unfortunately the designer/programmer is rarely the user!

Nowhere is the failure to apply the principles of usefulness and usability more apparent than in the design of medical information systems. Specifically, this translates into a failure to understand the way in which physicians think, the information they need, and the tasks they must perform. Many medical information systems have been created for managing both global and local medical information, yet they have not been adopted by most physicians who continue to practice medicine without them. Medical informatics has been dominated by a concern for the technology without formal efforts to understand the needs of physicians [4]. This is a fundamental flaw that must be overcome to allow a chance at success! The technology must serve the physician, not the reverse. Even when information is valid and relevant, it must be delivered in such a way as to be usable. The data must bear directly on issues of workflow, speed, and user interface design. An information system that is down the hall, requires multiple passwords, excessive entry of information by the physician, and the need to sift through a large amount of irrelevant information, clearly is not designed with usability in mind and is destined to fail.

It is unfortunately a rare occurrence for a software designer to directly observe a healthcare provider taking care of a patient. Landauer’s “user-centered design and development” is one solution to this problem. A system that is both useful and usable would be one that was able to access, search, integrate, and deliver medical information from diverse medical resources that included textbooks, the journal literature, medical reviews, practice guidelines, a drug database and the electronic medical record, in the context of a patient encounter, with minimal effort and interruption of the workflow. Such a system might also bring the expertise of academic medical experts to the practitioner during a “virtual” encounter.

**THE STANFORD HEALTH INFORMATION NETWORK FOR EDUCATION.**

**System architecture**

**Overview.** SHINE is structured as a client-server system overlaid on the world wide web. Its functionality includes the ability to query multiple content collections through a single formulation and view the results in a common interface as well as query or browse a single collection (Figure 1). It also includes specialized tools such as the medical diagnosis program, DXplain [19, 20] and the ability of the user to save query results to an electronic notebook or reconstruct searches through a logging system. Commands or requests, such as for query, browsing, or notebook functions activate separate functional capabilities of the server. In order to integrate distributed and heterogeneous resources into one seamless application, SHINE uses a mediator and wrapper-based architecture that is common to many data integration projects. Resources are wrapped into a CORBA object query service model [21, 22] that allows all information resources to have the same application interface (API). The mediator translates the user query (global) into the local searching syntaxes required by the individual databases. Where possible, different resources have been transformed into a consistent SGML document type definition (DTD) that specifies the tags (fields) of the SHINE metafile and are maintained in an Oracle database. The mediator is accessible through the HTTP protocol so that SHINE can be accessed through a web interface (Figure 2).

**Query Formulation and Concept Mapping.** User queries are sent to the Language Processing Service component that includes the SHINE metathesaurus. The SHINE metathesaurus uses the UMLS (Unified Medical Language System) metathesaurus of the National Library of Medicine [23] as a source of common ontologies. The SHINE metathesaurus allows the user to navigate in a concept space either automatically or manually as a way of refining a search. Search refinement occurs by calling a Java applet that is passed synonyms and concepts related to the original query. The user may navigate around the concept space to refine and alter the search. The mediator then parses the queries into the syntax of the local databases.

The SHINE Language Processing Service must help the user search over two basic classes of information: that indexed by assignment of controlled vocabulary terms (e.g., MEDLINE) and that indexed
based on its textual content (e.g., medical textbooks). By making connections among a proliferation of controlled medical vocabularies, the UMLS project provides a source of knowledge vital to searching multiple instances of both classes of information. Resources with assigned indexing based on a controlled vocabulary included in the UMLS can be quickly integrated into SHINE simply by translating user queries into the required vocabulary and search syntax.

When using the UMLS for free-text searching, the nature of user queries into the system drives the implementation: typical queries consist of phrases of fewer than ten words. While we intend to monitor system usage to track common queries and create more complete topic descriptions (similar to those used in Text Retrieval Conference [24]), these posited ‘common queries’ have yet to emerge. Information retrieval cannon [25] subordinates the query as simply a tool for finding relevant terms that can then be integrated into relevance feedback ‘super query’. Such a service will be offered within SHINE, but there is concern that the cost of the initial browsing for a relevant document among the results of a poor search may drive the cost of information above the threshold of usefulness to the practitioner.

Hearst provides evidence that short queries can be effective information search tools, especially if they are formulated according to two simple constraints [26]: 1) the query must be composed of a conjunct of disjunctions of topics and 2) proximity constraints must be applied within the corpus. For the first constraint, we apply knowledge encoded in the UMLS. The corpus of phrases contained within the UMLS first is searched to identify candidate topics. These topics are pruned to find a set that covers the query expression while introducing the fewest new terms. Topics are considered pair-wise to calculate their minimum nodal distance within the UMLS conceptual hierarchy (this is not a strict hierarchy, thus there is not one ‘true’ distance between two topics). Topics are clustered into proximal groups that make up the disjunctive sets which are then conjoined into a new query. We use a fine document granularity to satisfy the latter constraint.

This query is presented to the user, who may navigate the conceptual hierarchy or modify the topic grouping to better represent the original information-seeking context. This method can also be used to refine a query based on its preliminary search performance, adding synonyms and/or decreasing topic specificity to increase recall or increasing specificity to enhance precision. This could potentially be done automatically before presenting search results to the user. In addition, indices used within specific resources can be applied to the system to identify the most appropriate UMLS vocabulary for searching. In the end, the SHINE Language Processing System strives to improve access to medical information by searching on conceptual content rather than linguistic expression.

The SHINE Document Object Model. The document object consists of the object ID, type, and content attributes. The model allows for information sharing as well as the dynamic display of documents. A content object consists of a granule of information that is searched and displayed. The level of granulation differs somewhat among the different resources but is chosen in a way that makes conceptual sense. A granule in a textbook might be a subsection whereas a granule in a guideline might
consist of the entire guideline. The display of returned documents consists of a hypertext outline that preserves the context of the information and allows the user to quickly focus down on the relevant piece of information. The way that a document is displayed is extremely important and requires much thought. A document style that is appropriate for the printed page is not necessarily appropriate for the computer screen [17]. We also recognized that increasing the signal-to-noise ratio was an essential part of both usefulness and usability. Returning too much information can be as problematic as not returning enough.

Hypertext linking of documents is an essential part of the navigation and integration within SHINE. It was our goal to present an unbroken chain of evidence to the primary care provider. Recognizing that the “atoms” from which most medical knowledge is constructed consist of journal articles, we have created direct hypertext links from all references within the document resources to NLM’s MEDLINE database. Once in the MEDLINE database, the user can “update” references quickly, in the sense of finding more current articles related to the original citations, using MEDLINE’s PubMed “related articles” search engine that uses a statistical matching algorithm to find similar articles [27]. When the full text articles are available, as some are, for example, through Stanford University’s HighWire Press, the user is able to go directly from the citation to the full text. References that are contained within a single database (MEDLINE) provide a way of conveniently linking any resources that contain a subset of those references. Development is under way at SHINE to link documents at a more fundamental, conceptual level.

The Electronic Notebook. SHINE provides a Java-based electronic notebook for saving, annotating, organizing, and archiving query results from any location. The notebook also allows users to share documents, notes, and email. Tools are currently being developed that will allow the user to share patient data, including DICOM-compliant images, to facilitate consultation among physicians. The notebook (with the log) is also an essential component of the SHINE CME server. Following AMA (American Medical Association) and ACCME (Accreditation Council for Continuing Medical Education) review of our concept of learner-initiated learning, physicians may be awarded continuing medical education credit for submitting evidence of answering questions that occur in the context of patient care (see below).

The User Log. The SHINE user log automatically captures each of the user’s interactions with the system. This includes the questions asked, the results returned, and precisely which results the user examined. In this way, the trajectory of the user through the system (and through an information space) can be studied and reconstructed by the user, the administrator/researcher/educator and content owner. The log thus provides useful information about the use patterns and learning efficiency of the physician, and the value of particular resources. With the electronic notebook, the log becomes a means of awarding CME credit for user-initiated learning.

Remote Medical Consultation. When users are unable to answer questions with the integrated databases of SHINE, they will be able to consult with medical experts at academic medical centers. This consultation capability will include e-mail at one end of the spectrum and real-time videoconferencing at the other. Both will use tools that have been designed to share medical data including a whiteboard and the ability to send images that conform to current radiological standards (DICOM3).

A new paradigm for CME. Continuing medical education that is based on a didactic model that is divorced from medical practice is ineffective [28],[9],[11]. Moreover, the questions that frequently occur in the course of caring for patients often go unanswered [4]. We have endeavored to answer both of these inadequacies by proposing a new model for CME in which users initiate learning by answering questions that occur during patient care. This is an application of the “just-in-time” information delivery model proposed by Chueh and Barnett to CME where education occurs in the context of a real patient problem [8]. SHINE meets the tactical information needs of the physician by providing quick answers to questions that occur during the patient encounter. This may involve being presented with a guideline, diagnostic strategy, or quick review. It is usually impractical, however, for substantive learning to occur during the patient encounter because of time constraints (a typical twenty minute encounter during which time most of the physicians attention must be focused on the patient). But by coupling the integrated resources and the “just-in-time” information delivery that SHINE provides with the means to archive and reconstruct searches through the log and notebook functions at the user’s convenience, SHINE enables the user to directly link learning with clinical practice.
In-depth learning occurs when the user, starting from the question that was asked during the patient encounter, studies the entire result set and acquires a comprehensive understanding of the subject. This is what Barnes calls the “Practice-Learning Model” for CME [10]. As an example, if a physician were seeing a patient with a chief complaint of fatigue and suspected that the patient might have obstructive sleep apnea (obstruction of the airway with cessation of breathing during sleep), they could perform a search for “obstructive sleep apnea” on SHINE. The results set would include several cursory reviews that included diagnostic and treatment algorithms, as well as several very sophisticated full-text journal articles and textbook chapters. In the context of the patient encounter, the physician needs to know what to do next, i.e., he/she must decide how to confirm or exclude the diagnosis or how to initiate treatment. Generally, this means that they need a “rule of thumb” in the immediate context of the patient encounter. They may obtain from a quick review (the Stanford Primary Care Teaching Modules, for example) or a practice guideline.

Reviewing these does not constitute in depth learning of the sort that is expected for CME. For that, the physician must assimilate a thorough body of knowledge concerning this subject. Such assimilation might involve starting with several textbook chapters followed by several full-length journal articles that would give the physician a thorough understanding of the presentation, epidemiology, pathophysiology, work-up, and treatment of obstructive sleep apnea. Since each result set is saved to the physician’s personal electronic notebook, this may be done whenever and wherever it is most convenient, after the patient encounter has been completed. Having accomplished this, the physician would either describe how this learning has altered their practice or request a set of questions that would pertain to the body of knowledge that they had assimilated. These questions would be obtained using the same matching algorithm that associates different elements from the various SHINE resources. The key here is that learning occurs when an information need is identified by the learner and a clinical decision must be made. Learning is more efficient, patient care is improved, and the learner is motivated by having important questions answered with minimal effort and earns CME credit in the process. An unbroken chain of information is thus created that starts with the patient, produces a practical answer that facilitates a clinical decision, and ends with a thorough review of the medical literature. Medical practice becomes evidence-based!

Joining global and local information needs – integration with an electronic medical record

Over the past several decades, computerized systems have evolved that capture and distribute “local” patient information. Most of these systems provide some sort of results reporting for laboratory and test data as well as billing information. To varying degrees, many of them also capture aspects of the clinical encounter through transcribed or scanned provider notes and keep track of lists of medications, medical problems, drug interactions and other patient data. Those that are limited to results reporting are often called “clinical information systems”. More sophisticated systems that attempt to replace the paper-based medical record are called “electronic medical records” (EMRs) or “computerized patient records” (CPRs). Some systems provide the ability to enter orders electronically and are linked to “event engines” that alert physicians to drug interactions, the inappropriate use of a test, or a preferred clinical guideline. These systems have been shown to reduce costs and improve care [29-32]. Experience with these alerting systems, however, has demonstrated an understandable reluctance, on the part of many physicians, to follow some recommendations that are “pushed” to them without the evidence from the medical literature that supports them.

Non-compliance with alerts and guidelines and errors that result from incorrect or inadequate medical knowledge are very costly both to the patient and to the institution [33, 34]. Moreover, the absence of connections between guidelines/recommendations and peer-reviewed medical literature impedes the goals of “evidence-based medicine” initiatives that promote basing medical practice on evidence. Notable attempts have been made to link the electronic patient record with the journal literature [35-40], and are reviewed elsewhere [41].

We are currently working to integrate the SHINE system with a well known electronic medical record that contains an event engine that generates alerts and reminders based on patient data (e.g., laboratory values and test results) and electronic order entry. As an example, when a physician enters an order for an antibiotic, the current system may prompt the physician to choose a different antibiotic or dose, based on a lab value (e.g., serum creatinine), a diagnosis, a drug interaction, or the availability of an equally efficacious but less expensive alternative. What is lacking in such a system is the immediate availability of evidence that supports these alerts and guidelines. Once integrated with SHINE, the same physician will be confronted with a query result set
that supports the guideline (It is assumed that guidelines that are not supported by the medical literature will be removed). This represents the final phase of integration of SHINE into the physician’s workflow. Thus the physician is not only able to receive answers to queries that they themselves generate, but also to queries that are generated by the EMR event engine in response to patient data and physician order entry. If non-compliance with alerts and guidelines occurs, as early experience suggests, because authoritative and relevant support from the literature is not readily available to the physician, then integrating the support (through SHINE) should increase compliance while educating physicians. “Just-in-time” information delivery for decision support is linked to “just-in-time” education. Moreover, requiring such support to be present for guidelines and alerts also forces the institutions that foster them to be vigilant in their authorship and ensure that they are, in fact, evidence-based.

Clinical Evaluation

A crucial part of designing any system is evaluative feedback from the end-users [17]. The features built into SHINE suggest that it might represent a significant advance in end-user information retrieval and high-quality electronic content. However, to determine the value of such an integrated resource tool, it needs to be tested empirically. An evaluation is underway to determine if practitioners can use it to answer clinical questions and whether they will use it to pursue these questions during patient care. The specific goals of the evaluation are as follows:

- Determine whether physicians can use SHINE to answer clinically derived questions more correctly than in its absence.
- Test the hypothesis that SHINE encourages practitioners to pursue more medical knowledge questions in actual clinical environments.
- Determine the extent to which physicians are satisfied with the answers to their clinical questions found using SHINE.

Two types of studies have been designed to meet these goals. A “two pass” study will test the first hypothesis, whether practitioners can use SHINE to answer clinical questions. A set of 200 clinical questions has been collected through interviews with community-based, primary care physicians after actual patient encounters. Physicians will attempt to answer these questions first without and then with SHINE. A third-party review panel will determine correct answers to the questions. Physician performance will be measured in terms of the number of correct answers with and without the information resource.

Whether physicians will use SHINE in the course of treating patients will be determined in a “field” study. In several primary care practice sites, physicians’ baseline rate of question asking, information pursuit, and satisfaction with answers will be measured before SHINE is introduced. Several instruments including interviews, observation, and diaries will be used to collect this data. SHINE will then be introduced to the field clinics and tested to assure optimal system performance in these community environments. After a period of several weeks, the rates of question asking, pursuit, and answer satisfaction will again be measured using the same techniques. These studies draw upon the expertise and prior experience of Friedman who is collaborating to evaluate SHINE [42].

While the most important endpoint for a medical intervention is a reduction in morbidity or mortality, meeting the above goals will determine the extent to which a highly usable information system affects clinical questions. We logically suspect that if more clinical questions are pursued and correctly answered, patients will fare better. Such outcome studies are the subject of future research.

CONCLUSIONS AND FUTURE DIRECTIONS

With SHINE, we have endeavored to understand and create a system that addresses the information and continuing educational needs of the physician. These needs are complex and can be understood only in the context of the physicians' workflow, medical decision process, and the changing state of medical knowledge. The on-going evolution of client-server technologies, particularly those that are web-based, continues to remove traditional barriers and create new possibilities for sharing and integrating information. Many challenges remain. Much of the effort that is currently required to create and maintain a system such as ours is expended in the process of converting existing knowledge resources, such as textbooks, to a form that can be easily integrated with other resources (including electronic patient records) for searching and electronic distribution. As emerging standards for electronic mark-up such as XML (extensible markup language) are more widely adopted, integration will be greatly simplified and the ability to search documents (that are tagged at a conceptual level), will be enhanced. Other
challenges are cultural and will involve creating new business models that allow content providers to more easily embrace electronic publishing and facilitate the integration of different resources. It is our hope that continued research and development in this area will ultimately benefit patients by enabling physicians to more adeptly gather, assimilate, and apply medical knowledge to clinical practice.

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