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Invited Paper

Targeting and Structuring Information Resource Use: A Path Toward Informed Clinical Decisions

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Abstract

A core skill for all physicians to master is that of information manager. Despite a rapidly expanding set of electronic and print-based information resources, clinicians continue to answer their clinical queries predominantly through informal or formal consultation. Even as new tools are brought to market, the majority of them present information in a rigid fashion, presenting cumbersome user interfaces and inflexible data presentation. The need to rethink the structure of electronic information is paramount to improving the use of evidence at the bedside. As new tools are developed and educators teach clinicians to use them, the context for use of information resources must be considered, with special attention to physician workflow, following the three paths outlined in this article. The process will be facilitated greatly by promoting evidence-based practice for the care of patients in the hospital and clinic setting.

Key Words: Evidence-based medicine, information storage and retrieval, medical informatics, natural language processing

Introduction

The approach to an overview of electronic information resources available to practicing clinicians could proceed in two directions: a panoply of the latest and most sophisticated tools that exist on the market or a focus on the use of information and how it relates to the structure and the manner in which we teach and train clinicians to use these tools. The title of this article was chosen carefully to reflect the latter priority. That is, the future direction for these resources should not be producing more of the same; rather, the resources need to do a better job of delivering knowledge to physicians while they work, requiring a fairly extensive set of reforms. They should be targeted to different needs, based on the clinical context of physicians' work and structured in intelligent ways that pay attention to physician workflow and skills. What follows is a roadmap that has the potential to improve evidence-based medical practice among clinicians.

Current State

"Build it and they will come," a line from one of the premier sports movies of all time, *Field of Dreams,* infers that merely creating a baseball field would guarantee that a historic team would attend and play on it. Unfortunately, many information resource technology corporations have adopted this strategy, building a plethora of tools, attempting to target different niches for practicing clinicians. Many of the tools are used infrequently at best. Why? Consider the drive to build

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professional baseball stadiums as a means of revitalizing downtown urban areas. The mere novelty initially attracts many fans because most of these stadiums set attendance records during their first year of operations. But as the novelty wears off, the fans stop coming, discouraged by a poor on-field product. Similarly, physicians purchase tools but then often fail to use them in clinical situations if their information needs are not met.

Doctors are besieged with information and information tools. They have large numbers of clinical questions and little time to acquire and assimilate answers. The resources include *MEDLINE*, one of the staples, comprising nearly 4,200 journals, with 7,300 citations added per week. Yet beyond *MEDLINE* is where clinicians frequently attempt to answer their questions, including electronic textbooks, summary resources, clinical practice guidelines, and evidence-based summaries. Add to this the myriad multiple formats within which these resources are presented: print, personal computer based, locally housed on institutional servers, Web based, or on handheld devices. In the end, faced with choices, physicians largely have their clinical queries answered through personal consultation or referrals.[1] One must wonder whether the reason for this discordance is the way in which information is structured.

The structure of the information may be part of the reason, but the tendency to use personal consultation rather than information resources may have its roots in training. In a survey of trainees and academic clinicians in the United Kingdom, the average amount of reading time varied significantly by experience.[2] Medical students reported spending the greatest amount of time in self-directed reading (90 minutes per week) compared with residents (20 minutes) and attending physicians (45 minutes). More striking, however, was the number of trainees who reported spending no time in this endeavor (up to 75% for early house officers).

One might postulate that some of these early learners focused their information-seeking behavior at the point of care. A second study attempted to answer this question by observing internal medicine resident behavior in their continuity clinics.[3] Using direct observation, structured and unstructured interviews, and audiotaped recordings of resident and clinic mentor encounters, the investigators found that residents were least likely to report using electronic or print-based information resources to answer clinical questions and were more likely to ask colleagues or consultants. Direct observation revealed that residents overestimated their use of electronic resources, obtaining answers for their most important clinical questions from computer-based sources only 7% of the time. Indeed, in this study, 58% of questions were answered directly by the clinic attending, without active searching beyond the mentoring context.

The Roadmap: Three Paths to Better Clinical Decisions

Successful adoption of technology in fields outside medicine often depends on explicit attention to the users' workflow. Reflecting on findings in the study by Tilburt et al.,[3] the need for efficient information exchange and quick decision making (as is necessary in the outpatient setting) may encourage learners to have their clinical questions answered by their attending physician, a colleague, or a consultant. However, other factors are likely involved, all pointing to tremendous variability in the clinical work context: variability in the clinical settings themselves, in the way that physicians express their knowledge deficits,[4] in the types of information and the amount of information that they need at any given point in time, and in their skills in interpreting the information. Such variability suggests that to promote better use of these resources, they must be restructured with flexibility: within the user interface and in how the information is delivered. This initial step would create tools that pay attention to physicians' needs and may make the information more likely to be used.

Two clinical scenarios follow, which were designed not only to highlight the complex and variable information needs that practicing clinicians

express but also to show how variable characteristics of the setting mandate equal attention to physician information retrieval skills (Table 1).

Scenario 1 describes a hospitalist physician who has admitted 12 patients on call and is trying to triage the last four, who simultaneously came to her service. One patient has a pulmonary embolism, and the physician is wondering whether she can administer subcutaneous low-molecular-weight heparin instead of intravenous unfractionated heparin, thereby allowing the patient to be discharged home in the morning. This represents a fairly acute, specific information need at the point of care, which will have significant short-term management implications.

Scenario 2 paints a different picture, describing a family physician working up a 6-month-old infant with suspected failure to thrive, having questions between visits on the most appropriate, effective diagnostic approach for this child. There is less of a time constraint in this case, requiring more general information needs to help manage the child's case.

Although these two instances paint different contexts, could a single information resource meet both physicians' needs? And if one such resource existed, would it completely solve both practitioners' dilemmas? The roadmap to be described advocates three paths: two in which information is restructured and one that pays attention to the user context and the setting to create a more informed and skilled physician-consumer of information.

Paths 1 and 2: Restructuring the Information: Input and Output

The drive among many to improve evidence-based practice has resulted in the adoption of the Information Cycle as a framework to influence physician behavior. First advocated by Drs. Brian Haynes and Gordon Guyatt and then refined by the Society for General Internal Medicine's Evidence-Based Medicine (EBM) Task Force, this sequential series of microskills has been used to structure EBM teaching to learners and as a way to guide information resource use at the point of care (Figure 1).[2] Using this model, clinicians are instructed to create a structured clinical question at the outset, based on the patient at hand (ask), which also points to the most optimal information resource to search (acquire). Review of the search yield reveals multiple results, the validity of which must be assessed by the clinician (appraise). The clinician then chooses the information that best applies to the patient being cared for. However, many clinicians have not found this framework to be a practical approach to answering their information needs. Fundamentally, the success of each step requires success at each of the previous steps. Selection of an ineffective resource may result in invalid information and inappropriate application of the information to the patient's case. Asking an unstructured clinical question can lead to inappropriate resource selection. Equally important, following this structure has the potential to disrupt

Table 1 Clinical Scenarios

Scenario	Description
1	A hospitalist physician has admitted 12 patients on call at night and is trying to triage the last 4 who came to her service simultaneously. One of them is a 52-year-old woman with the diagnosis of pulmonary embolism. She is not hypoxic, and the physician wonders if she can administer subcutaneous low-molecular-weight heparin instead of unfractionated heparin, thereby allowing her to be discharged home in the morning.
2	A family physician is in the midst of a work-up of a 6-month-old infant with suspected failure to thrive. On his last visit with the child, her growth parameters have fallen below the 10th percentile on all measurements. Between visits, he wonders what appropriate, effective diagnostic approach he should initiate in this baby at her next visit in 5 days.

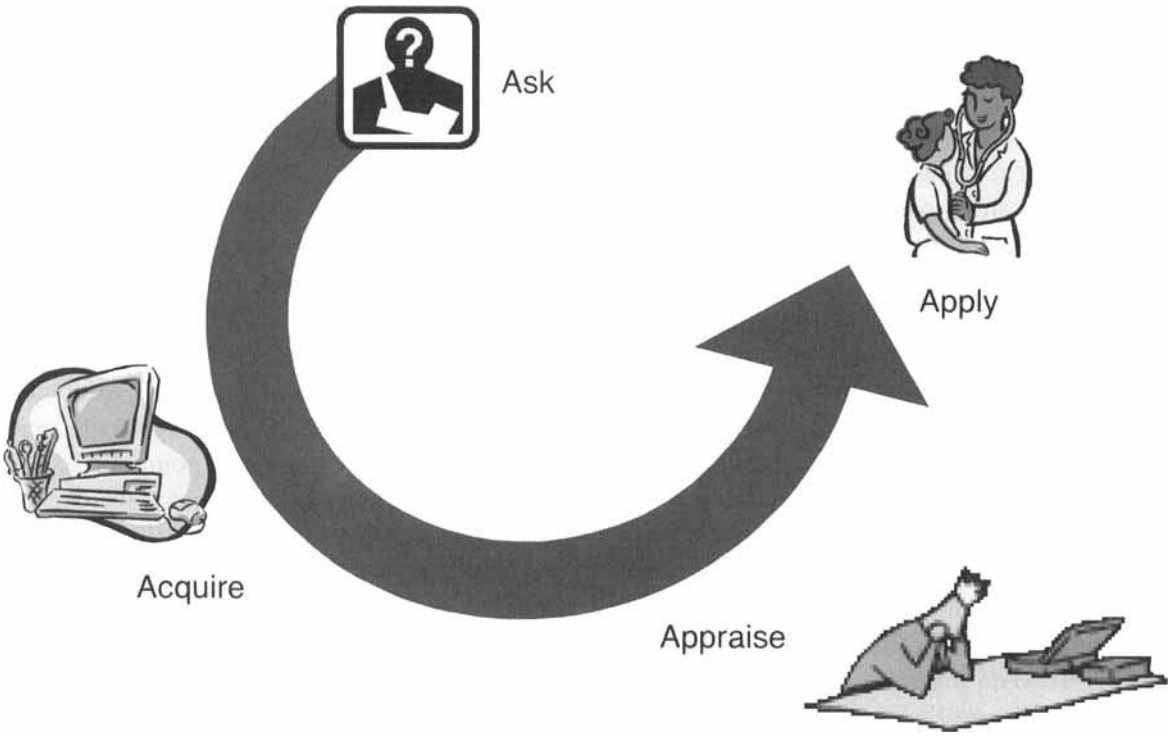

Figure 1 The Information Cycle. Four sequential steps involved in promoting evidence-based practice behavior among practicing clinicians. Adapted from the Society for General Internal Medicine's Evidence-Based Medicine Task Force.

workflow. Typical workflow-related barriers that clinicians encounter as they attempt to complete each skill within the Information Cycle are detailed in Table 2.

Indeed, recognizing the difficulties clinicians face when they attempt to practice EBM, leaders in this field are attempting to address the common criticisms and misconceptions of this framework.[5] For example, many current educators recognize that the paradigm may not apply to situations in which physicians improve their knowledge to care for patients whom they have not yet seen ("just-in-case" as opposed to "just-in-time" information retrieval). In addition, many have recognized that all steps within the cycle do not need to be completed at one sitting. Some have proposed that information for practicing clinicians should take the form of preappraised resources, essentially eliminating the need for physicians to perform sophisticated critical appraisal. On the other hand, suggestions to reduce structure and improve workflow may create other challenges in knowledge and resource organization.

Expanding on the next steps in the first case scenario may illustrate these dilemmas that clinicians face. The hospitalist practitioner, looking for information on the effectiveness of low-molecular-weight heparin in the treatment of pulmonary embolism, has multiple resources at her fingertips. She first explores *MD-Consult*,[6] a resource that interfaces with electronic textbooks, journals, and practice guidelines simultaneously. Using the key words "low-molecular-weight heparin" and "pulmonary embolism," she retrieves 2 textbooks and 504 primary journal studies. Proceeding to *Up-to-Date*,[7] a hypertext-linked Web-based source of information, her simple search is forced to proceed in three steps, resulting in 98 potential topics. *The American College of Physicians (ACP) Journal Club*[8] is her next choice, a preappraised evidence-

Table 2 Barriers to Effective Implementation of the Evidence-Based Medicine Information Cycle

Step in the Information Cycle	Barrier
Apply	Weighing all of the values (society, patient, physician)
	Personalizing the information
Appraisal	Time to assess the strength of the information
	Performing numeric calculations and other data extraction
	Assessing if there is remaining uncertainty
Acquire	Where is the information located?
	How can the resource be efficiently and effectively searched?
	Scanning the search yield for the optimal information
Ask	What information is actually needed?
	Structuring the query to determine the ideal category of resources and to drive an effective search

based review of recent primary studies, which yields 35 matches. As another source at her fingertips, she then turns to *Clinical Evidence*,[9] which is organized by clinical questions but results in text-based paragraphs that might be difficult to search through to find her answer in the limited time she has. Finally, when turning to a primary source of information, specifically *MEDLINE*, her searching requires a complex set of skills, including an understanding of Boolean logic, medical subject headings, and hierarchical search strategies. In summary, the clinician in scenario 1 has faced complex user interfaces, rigid search engines, often irrelevant and large search yields, and minimal guidance to prioritize search yields.

Path 1: input flexibility. Improving resources' ability to accept various forms of physician input must be one step toward improving their use and utility. The progress in natural language interpretation has accelerated rapidly outside the medical industry but can be applied easily in health care informatics. Syntactic and semantic analysis of sentence structures is at its most sophisticated level, with some of the foundational work being accomplished at Stanford University, MIT, and the University of Cambridge. An example of a flexible user interface that exists on the Internet currently is *Ask Jeeves.com.*[10] This site was developed to interpret basic English sentence and question structure to provide relevant search yields. As an illustration, the question "When will Mars be closest to Earth?" yields a direct link from *Ask Jeeves.com* to an article on *Space.com*, which provides the exact answer: August 27, 2003.[11] More striking, typing in the question "Is low-molecular-weight heparin effective in pulmonary embolism?" provides direct links to a structured overview of studies that address this question[12] and to a sentinel primary study to answer this question from the *New England Journal of Medicine.*[13] Although there is no assurance of the validity or sufficiency of information retrieved from this general search of the Internet, the user interface provides a less intimidating mechanism for clinicians to express their information needs.

Integration of the concepts and algorithms behind *Ask Jeeves.com* (and other sites like it) seems logical for specific health information resources. "*SUMSearch*," a meta–search engine for health information resources, developed out of the University of Texas in San Antonio, has partnered with the National Library of Medicine to develop semantic and analytic techniques in natural language processing for physician questions.[14] The goal is to create a search engine that will allow English queries to drive the search of reliable medical information resources effectively, providing clinicians with a practical tool that requires minimal training to use. Other search

interfaces (such as *PubMed* and *Up-To-Date*) should follow suit.

Path 2: output flexibility. Improving the user interface does not obviate the need to structure information output in a way that is usable for the practicing clinician. Both case scenarios feature physicians facing different information needs in disparate situations. For example, one might imagine that the hospitalist in scenario 1 requires a quick, preappraised bottom line answer to her question about low-molecular-weight heparin and pulmonary embolism. By contrast, the pediatrician in scenario 2 is looking for a general evidence-based approach, likely with more detailed information, contained in longer text passages. As "smart" resources accept more flexible input, should they not be designed to help both practitioners' information needs?

A framework that may guide this approach to output flexibility can be found in the EBM literature. Haynes developed a hierarchical categorization strategy for information resources, presenting it as the Evidence Pyramid, depicted in Figure 2.[15] The pyramid organizes information resources according to two distinct but related factors: the extent to which primary data are presented in isolation or combined with other data to provide more statistically robust conclusions and the extent to which the recommendations are integrated within physician workflow tasks. As an example, the lowest level of the pyramid contains "studies," composed of primary data sources, including clinical trials and cohort and case-control journal articles. Above this level are "Syntheses," characterized by systematic consolidation of primary studies, often using statistical techniques, such as meta-analysis. On top of this level are "Synopses," containing bottom-line recommendations in abstract form, extracting information from various syntheses in a systematic, evidence-based manner. At the highest level, "Systems," recommendations from multiple data sources, are presented to physicians completely integrated within steps they take to care for patients; for example, within physician order entry systems or as part of hospital-wide formularies.

Using this hierarchy, one can imagine that physicians may select the depth to which different levels of evidence can be accepted based on the amount of time they spend to enact a patient-care decision, their own skill set to assess information validity, and the extent to which they have access to multiple resources. For example, in scenario 1, the hospitalist would likely prefer to use a system or a synopsis to answer her query and simultaneously care for her patient, whereas the general practitioner in scenario 2 may wish to review syntheses or primary studies to help him decide on the optimal work-up for failure to thrive in a child.

The Evidence Pyramid outlines a schematic for helping clinicians sort through the extensive choices in information technology. However, the question might arise as to whether a single resource can be structured to deliver all four levels of information, targeted to the physician's needs. A resource attempting to provide this type of output flexibility is *Evidence-Based On Call*, developed in the United Kingdom.[16] Using an electronic user interface that allows the clinician to retrieve more detailed information with a single mouse click, this resource presents studies, syntheses, and synopses in one context. As an illustration, the clinician in the first scenario uses "pulmonary embolism" as a search term in this resource, and the first screen on retrieval recommends the following: "Use a low molecular weight heparin (LMWH) and warfarin." By clicking on an icon adjacent to that statement, the clinician finds a second screen, revealing that "LMWH is as safe and as effective as heparin, and no monitoring is needed." Finally, if the clinician wishes to see the primary studies, another mouse click brings up a third screen, which presents a clinical trial that support the previous statements.[17] Note that the clinician can drill as deep as he or she wishes to go. Physicians express different information needs during different points of their workday; use of such a resource can facilitate the effortless targeting of the information to the need. Currently, few other resources are structured in this manner.

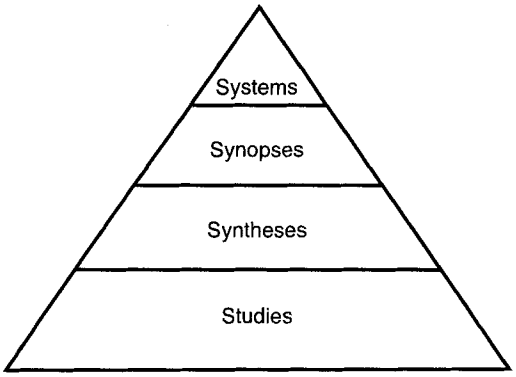

Figure 2 The Evidence Pyramid. Depiction of a hierarchical structure of evidence, with higher levels representing more summarized data and more integration within physician workflow. Reproduced with permission from ACP Journal Club.[15]

Path 3: Focus on the Teaching Context to Promote Mindfulness

Restructuring information to promote flexibility will enhance the utility of these resources; however, whereas proceeding down the first path will require no further training for clinicians, hierarchical output from flexible resources requires crucial skills presently not held by many clinicians. In other words, it will not be enough to focus on the resources themselves, but teaching clinicians to be mindful of their information needs, their practice context, and their individual set of skills will pave the path to targeted, effective use of these resources.

Educators are discovering that physicians find themselves in multiple information consumer roles during the workday, as demonstrated in the scenarios presented herein. Some advocate terms to reflect these roles and their relationship to evidence and information, such as "replicator," "user," and "doer" (S. E. Straus and M. Gerrity, personal communication, 2003).

When practicing in a replicator mode, for example, the clinician exhibits minimal time to look at evidence-based summaries, just requires bottom-line information supported by systematic clinical research, and will implement it immediately at the point of care. A clinician who chooses to practice as a user of information may access preappraised evidence summaries to try to help answer his or her questions (such as those found in the *ACP Journal Club*). Finally, a clinician with advanced skills, and perhaps more available time, may assume the role of doer, critically appraising and analyzing information for himself or herself.

A clinician is unlikely to adopt only one of these roles for his or her entire career. Instead, physicians switch roles depending on the clinical circumstance and their own skill set. They may even practice in all three roles at different points in the workday. In the absence of the perfect resource that effortlessly fulfills all information needs, clinicians must be trained to recognize their knowledge gaps and their information management skill set so that they may better target the information resource that is most likely to fill that need. In essence, this final path outlines the fact that clinicians must become trained to be reflective in their information use, asking them to be able to identify what role they assume at a given moment (e.g., replicator, doer, user), guiding them to the resource best suited to the role, and understanding whether they are able to interpret and apply the information provided. This can be accomplished by asking clinicians to ask themselves two simple questions for each query: "Am I looking for general or specific information?" and "Should I be looking for bottom line, preappraised, or primary evidence-based information?" The answers to these questions can directly interface with the Evidence Pyramid. Essentially, the answers to these questions can be combined with the hierarchical organization of information,

Lessons for Practice

- Improving the use of evidence-based resources requires restructuring the information and retraining physicians.
- Three paths to improving the use of information resources at the point of care are as follows:
  - Structure information resources to accept natural language queries.
  - Allow for flexible, user-directed, evidence-based output searched and delivered flexibly and based on the needs of the clinician.
  - Train users to be mindful of their information needs, with respect to amount and type, and of their own skill sets.

leading to an appropriate resource on which the physician can focus his or her initial search efforts.

But what defines an "appropriate" resource, and which ones belong in the pyramid? Many claim to be evidence based, but the lack of standardization of this label leaves this a less than reliable term. Potentially acceptable characteristics of an evidence-based resource may include information that is (1) based on systematic searches of the literature, (2) externally peer reviewed, and (3) presented in a format that conveys the strength of its scientific underpinnings, among other traits. Yet no standards have been created to help clinicians identify the resources that offer more reliable recommendations. As such, physicians must first become aware of sound examples of information tools that reside at each level of the Evidence Pyramid, informed by reasonable published criteria (e.g., those presented and reviewed in the *ACP Journal Club's* "Resource Corner"). Once aware, they can be more certain of the information they extract from these tools.

For example, in scenario 1, the hospitalist physician may see her role as a replicator of evidence. She is pressured by the other admissions she must evaluate and triage and needs to make a rapid decision about initial therapy for her patient with a pulmonary embolism. When she answers the two questions above, she realizes that she is looking for very specific information and that she seeks only a bottom-line answer. As such, one could assert that the best way to meet her information resource needs would be to interact with a computerized physician order entry system (at the top of the pyramid) that delivers knowledge to her as she writes the orders for this patient. As she types in "heparin," for example, the system knows that the patient has a pulmonary embolism, and, automatically, it suggests low-molecular-weight heparin as a treatment option. In scenario 2, the family physician's role may be one of a user of evidence, with more time to reflect and construct a diagnostic strategy for his patient with failure to thrive. When answering the two questions above, he states that he is looking for more general information about the clinical condition, and he may be willing to look at preappraised summaries of the evidence to inform his strategy. Using the pyramid, he would proceed down to the Syntheses level and, as such, may be interested in an evidence-based review article or a systematic synthesis of the literature on failure to thrive in children.

As the final step, both clinicians would need to know the specific examples of resources within each category in the pyramid. For example, if interested in a synthesis, a clinician would go to the *Cochrane Library*,[18] *Clinical Evidence*, or perhaps a practice guideline. Those interested in a synopsis could use *Evidence-Based On Call*, certain personal digital assistant resources, or *ACP Journal Club*.

Convergence of All Paths: Information Utopia

In the ideal information world, searching for data to inform clinical decisions would be both a passive and an active process. At the passive level,

relevant knowledge would be integrated seamlessly within the clinical encounter; any workflow action would stimulate knowledge delivery relevant to that encounter. In addition, there would be a small number of flexible resources that would be required to fulfill all knowledge needs. However, the active components to this behavioral pattern would capitalize on physicians' desire to be active learners and practitioners. Ultimately, the final decisions are made actively and collaboratively with their patients, balancing the information retrieved with society, patient, personal, and professional values.

But information utopia is not yet a reality; thus, the three paths just described represent individual steps to promote more efficient and effective use of existing electronic resources, leading the medical profession toward a more streamlined, standardized approach to the management of information. Following this roadmap should create a more informed information consumer—a crucial step toward the ultimate goal of improving evidence-based practice for patients.

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