INFORMATION RESOURCES

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The Evolution of Electronic Medical Records

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Abstract: No clinical computing topic is being given more attention than that of electronic medical records. Health care organizations, finding that they do not have systems adequate for answering questions crucial to strategic planning and for remaining competitive with other provider groups, are looking to information technologies for help. Many institutions are developing integrated clinical workstations, which provide a single point of entry for access to patient-related, administrative, and research information. At the heart of the evolving clinical workstation lies the medical record in a new incarnation: electronic, accessible, confidential, secure, acceptable to clinicians and patients, and integrated with other, non–patient-specific information. The author describes the problems associated with paper-based record keeping and the promise of the electronic medical record, emphasizing the areas of clinical trials and decision support. He then discusses the issues that must be addressed and the requirements that must be met if electronic medical record systems are to move beyond intranet environments within single health systems or practices and to integrate with regional, national, and international resources via the Internet.

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Stories about the "information revolution" fill our newspapers and popular magazines, and our children show an uncanny ability to make use of computers as routine tools for study and entertainment. Similarly, computers have become omnipresent in hospital wards and outpatient offices. Yet many have observed that the health care system has been slow to understand information technology, to embrace it for its unique practical and strategic capabilities, and to incorporate it effectively into the work environment.

It is remarkable that the first microprocessors, which enabled personal computers, did not appear until the late 1970s, and the World Wide Web is only about five years old. This dizzying rate of change, combined with equally pervasive and revolutionary changes in almost all health care systems during the past decade, makes it difficult for health care planners and institutional managers to try to deal with both issues at once. Yet many now believe that the two topics are inextricably related and that planning for the new health care environments of the 21st century requires a deep understanding of the role that information technology is likely to play in those environments.

No clinical computing topic is gaining more attention than electronic medical records. Health care organizations are finding that they often do not have in place systems that allow them to answer questions that are crucially important for strategic planning and for better understanding how they compare with competing provider groups in their communities or regions. Furthermore, the inefficiencies and frustrations associated with the use of paper-based medical records have become increasingly clear.[1]

ELECTRONIC HEALTH RECORDS: ANTICIPATING THE FUTURE

Many health care institutions are seeking to develop integrated clinical workstations. These are single entry points into a medical world in which computational tools assist not only with clinical matters (results reporting, order entry, access to transcribed reports, telemedicine applications, and decision support), but also with administrative and financial topics (admission–discharge–transfer, materials management, personnel, payroll), research (outcomes analysis, quality assurance, clinical trials, implementation of pathways and protocols), scholarly information (digital libraries, bibliographic searches, drug information databases), and even office automation (spreadsheets, word processors). At the heart of the evolving clinical workstation lies the medical record in a new incarnation: electronic, accessible, confidential, secure, acceptable to clinicians and patients, and integrated with other, non–patient-specific information.

Inadequacy of the Traditional Paper Record

The paper-based medical record is woefully inadequate for meeting the needs of modern medicine. It arose in the 19th century as a highly personalized "lab notebook" that clinicians could use to record their observations and plans so that they could be reminded of pertinent details when they next saw that same patient. There were no bureaucratic requirements, no assumptions that the record would be used to support communication among varied providers of care, and remarkably few data or test results to fill up the record's pages. The record that met the needs of clinicians a century ago has struggled mightily to adjust over the decades so as to accommodate to new requirements as health care and medicine have changed.

Despite the need for a new record-keeping paradigm, most organizations have found it challenging to try to move to a paperless, computer-based clinical record. It forces us to ask the question "What *is* a health record in the modern world? Are the available products and systems well matched with the modern notions of a comprehensive health record?" Companies offer medical-record products, yet the packages are limited in their capabilities and seldom seem to meet the full range of needs defined within our health care organizations.

The difficulty in automating medical records is best appreciated if one analyzes the *processes* associated with the creation and use of such records, rather than thinking of the record as an object that can be moved around as needed within an institution. For example, on the data-input side, the medical record requires the integration of processes for data capture and for merging information from diverse sources. In order to be useful, the record also must provide facile mechanisms for displaying needed data, for analyzing them, and for sharing them among different kinds of individuals (including secondary users of the record who are not involved in direct patient care). Thus the computer-based medical record is best viewed not as an object or a product, but rather as a set of processes that an organization must put into place, supported by technology. Implementing electronic records is inherently a process-automation and systems-integration task, and thus systems that function well in one environment often do not transfer well to others in which institutional processes and traditions may have evolved in different ways.

The Medical Record and Clinical Trials

The arguments for automating medical records are nicely summarized in several works, including the Institute of Medicine's report on computer-based patient records.[1] One argument that warrants emphasis for academic medical centers is the importance of the electronic record in supporting clinical trials. We are constrained today by a terribly clumsy method for acquiring the data needed for clinical trials, generally relying on manual capture of information onto datasheets that are later transcribed into computer databases for statistical analysis. The approach is labor intensive, fraught with opportunities for error, and increasingly difficult to defend in light of the high costs associated with randomized prospective research protocols.

The use of electronic medical records offers many advantages for carrying out clinical research. Most obviously, it helps to eliminate the manual tasks of extracting data from charts or filling out specialized datasheets. The data needed for a study can be derived directly from the electronic record, making research-data collection a byproduct of routine clinical record keeping. But other advantages accrue as well. For example, the electronic record can help to identify patients who are eligible for a study, and can ensure adherence to a complex protocol whose logic depends on currently available data about that patient. We are also seeing the development of novel authoring environments for clinical-trial protocols that can help to assure that the data elements needed for the trial are compatible with the local electronic record system.

Integrated Decision Support and Guidance

Another theme in the changing world of health care is the increasing investment in the creation of clinical guidelines and pathways, generally in an effort to reduce practice variability and to develop consensus approaches to recurring management problems. Several government and professional organizations, as well as individual provider groups, have invested heavily in guideline development, often putting an emphasis on using clear evidence from the literature, rather than relying on expert opinion alone, as the basis for the advisory materials. Despite the success in creating such evidence-based guidelines, there is a growing recognition that we need better methods for delivering this information to the point of care. Computer-based tools for implementing such guidelines, and integrating them with the electronic medical record, present a potential means for making high-quality advice available in the routine clinical setting.

Recurring Issues That Must Be Addressed

There are at least four major issues that have consistently constrained our efforts to build effective medical record systems: (1) the need for standardized clinical terminology; (2) concerns about data privacy, confidentiality, and security; (3) challenges of data entry by physicians; and (4) difficulties associated with the integration of record systems with other information resources in the health care setting. I

briefly discuss the first three of these items and then spend the rest of this paper discussing the fourth, emphasizing the remarkable opportunities afforded by wide-area networking and the Internet.

Standards for Clinical Terminology

The richness and variety of medical concepts are currently major barriers to formulating a widely accepted and standardized clinical vocabulary that is suitable for encoding patient-specific information in the electronic medical record. Evolving standards exist in niche areas (e.g., ICD10, CPT, SNOMED, Read Codes, NANDA, DICOM, and the like), but none is yet sufficiently accepted or comprehensive to meet the full needs of the electronic health record. The National Library of Medicine has sought to provide some coherence to the situation by creating the Unified Medical Language System,[2] a composite of some 40 vocabularies that in 1998 contained close to 500,000 biomedical concepts and over one million terms to describe them.

Security, Privacy, and Confidentiality

Many are concerned that storing patient-specific information in computers will lead to the inappropriate release and use of such data. A 1997 publication of the National Research Council (NRC) of the National Academy of Sciences in Washington, D.C., addressed these issues in great detail.[3] The NRC appropriately recommended policies and procedures for protecting the confidentiality and security of clinical data in computers. It pointed out, however, that the major vulnerabilities are related to inappropriate use of patient-specific information by health workers who have access to those data as part of their regular work. Seen in this light, such risks are as great or greater when data are stored in paper charts.

Data Entry by Physicians

Integrating computer use with the workflow of busy clinicians is inherently challenging, but when such use requires data entry by physicians, few systems have been successfully adopted. As a result, many record-system developers have sought to allow the physicians to use other methods for data entry, such as dictating notes for online transcription or filling out coded data forms that are later transcribed or scanned into the computer. With the introduction of newer point-and-click technologies, or pen-based selection methods, we are seeing systems that promise to be more attractive to clinicians. Some researchers are performing carefully designed studies in an effort to determine what kinds of interactive features are likely to be both attractive to clinicians and efficient in terms of time requirements.[4]

Integrating the Patient Record with Other Information Resources in the Organization

Physicians are "horizontal" users of information technology.[5] That is, rather than becoming "power users" of a narrowly defined software package, they access a wide variety of systems and resources. Thus routine use of computers, and of electronic medical records, will be most easily achieved if the computing environment offers physicians a critical mass of services that are both smoothly integrated and useful for essentially every patient encounter.

With the introduction of networked systems within our health care organizations, there are new opportunities to integrate a wide variety of resources through single clinical workstations. The nature of the integration tasks is illustrated in Figure 1, in which various workstations are shown at the upper left (machines for use by patients, clinicians, or clerical staff) connected to an enterprise network, or "intranet." In such an environment, diverse clinical, financial, and administrative databases all need to be accessed and integrated, typically by using networks to tie them together and a variety of standards for sharing data among them. Essential to this model is the clinical database (or clinical data repository), a central resource that gathers and integrates clinical data from diverse sources such as the chemistry laboratory, pharmacy, radiology department, and microbiology laboratory. This clinical database provides the nidus for what can evolve into an electronic medical record as more and more clinical data become available in electronic form and are added to it.

The trend toward the enterprise-intranet model of the health record, illustrated in Figure 1, now seems reasonably well accepted. It is therefore important to ask what the medical record will become after it has been effectively implemented on computer systems and new opportunities for its enhancement become increasingly clear to us. One way to anticipate the changes that are likely to occur is to consider the potential roles of wide-area networking and the Internet.

Extending the Record Beyond Single Institutions

The Internet began in the late 1960s as a U.S. research activity funded by the Advanced Research Projects Agency (ARPA) of the Department of Defense. Initially known as the ARPAnet, the network began as a novel mechanism for allowing a handful of defense-related mainframe computers, located mostly at academic institutions or in the defense industry, to share data files with each other. As the technology matured, its value for non-military research activities was recognized, and by 1973 the first medically related research computer had been added to the network. During the 1980s the technology began to be developed in other parts of the

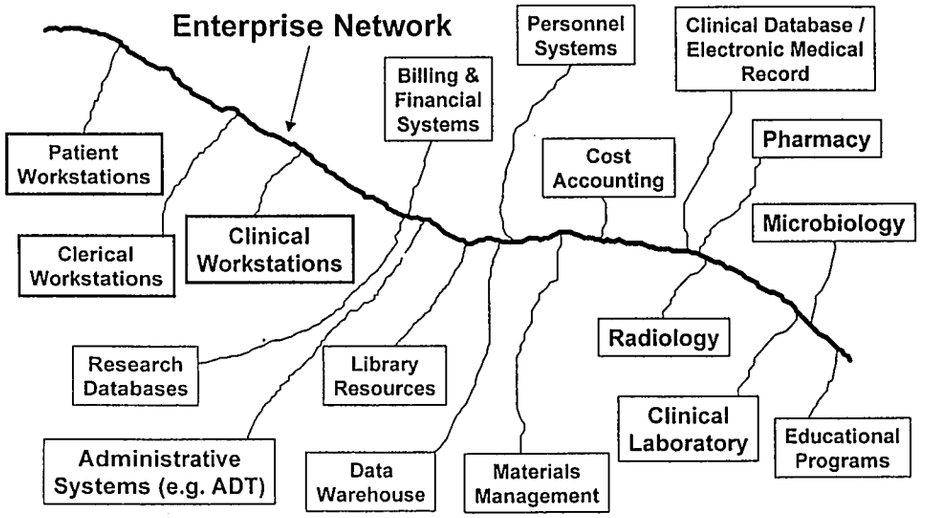

Figure 1. The enterprise "intranet," in which single clinical workstations (outlined in bold in the upper left), and various clinical departments and resources are connected by an enterprise network or intranet.

world and the National Science Foundation took over the task of running the principal high-speed backbone network in the United States. The first hospitals, mostly academic centers, began to be connected to what had by then become known as the Internet, and in a major policy move it was decided to allow commercial organizations to join the network as well. By April 1995 the Internet in the United States had become a fully commercialized operation, no longer depending on the U.S. government to support even the major backbone connections.

The societal impact of this communication phenomenon cannot be overstated, especially given the international growth in the number of connected machines, and thus of connected people, over the past five years. Countries that once were isolated from information of potential social, scientific, or political importance to their citizens are now finding new options for bringing timely information to the desktop machines of individuals who have Internet connections.

Envisioning the Enterprise Internet

Although we should always expect a medical record to be populated with data about a specific patient, in the electronic implementation of such records we may also expect to find data regarding populations of patients, integrated access to the biomedical literature, and interactive environments for offering clinical guidelines, or frank consultative advice. We can envision a world in which the enterprise *intranet* of Figure 1 is seamlessly connected to the full *Internet* beyond, with integrated access to a wide variety of information sources that are geographically distributed well beyond our local institutions (see Figure 2). To the extent that an individual's medical records are maintained in compatible electronic formats at all the institutions where they have been seen, the Internet provides the potential of creating "virtual medical records," the electronic compilation of a patient's health data from all the settings in which he or she has been seen. Although such a concept raises important issues related to patient privacy and confidentiality, there are technical and policy measures that can be taken to help to assure that such virtual records are kept secure but also are available at times of medical need.[3]

Implications for Patients

As the number of Internet users continues to grow (recent estimates suggest there are more than 76 million users in the United States alone), it is not surprising that increasing numbers of patients, as well as healthy individuals, are turning to the Internet for health information. Most physicians have by now encountered at least one patient who came to an appointment armed with a question, or a stack of laser-printed pages, that arose from medically related searches on the World Wide Web. The companies that provide search engines for the Internet report that medically related sites are among the most popular. As a result, physicians and other care providers must be prepared to deal with information that patients discover on the Web and bring with them when they seek care from clinicians. Some of the information is timely and excellent; in this sense physicians can often learn about innovations from their patients and will increasingly need to be open to the kinds of questions that this

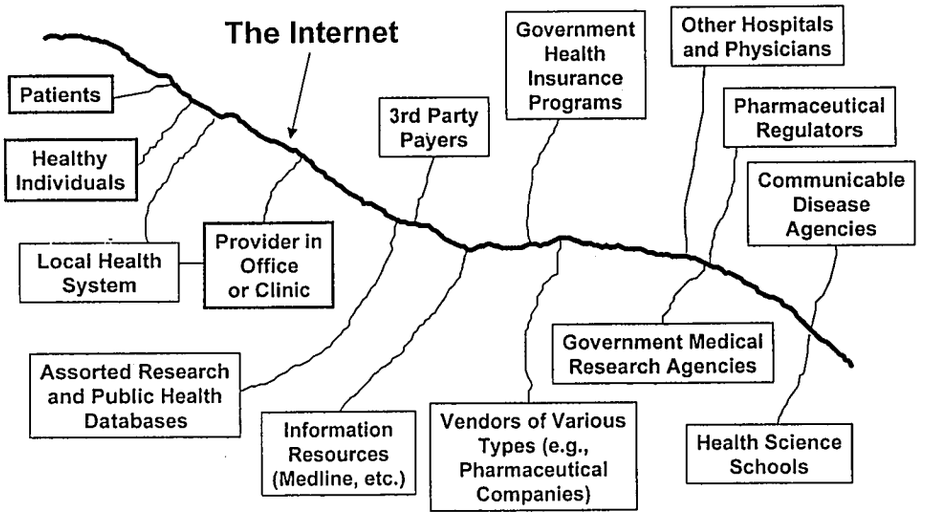

Figure 2. The global health-information infrastructure, in which the enterprise intranet of Figure 1 is seamlessly connected to the full Internet and to resources beyond the enterprise's own patients, local hospitals, and providers.

enhanced access to information will generate from patients in their practices. On the other hand, much of the health information on the Web lacks peer review or is purely anecdotal. People who lack medical training can be misled by such information.

In a more positive light, the new communication technologies offer us creative ways to interact with our patients and to provide better care. Years ago medicine adopted the telephone as a standard vehicle for facilitating patient care, and we now take this kind of interaction with patients for granted. If we extend the audio channel to include our visual sense as well, the notion of telemedicine emerges. Although there are major challenges to be overcome before telemedicine is likely to be extensively adopted for direct patient care,[6] there are specialized settings in which it is already proving to be successful and cost-effective (for example, international medicine, teleradiology, and video-based care of patients in state and federal prisons).

A potentially more practical concept in the short term is to use computers and the Internet as the basis for communication between patients and providers. For example, there has been rapid growth in the use of electronic mail as a mechanism for avoiding telephone tag and allowing simple questions to be answered asynchronously. Still largely experimental, but extremely promising, are methods based upon the technology of the World Wide Web. Examples include Web-based facilities for disease management (e.g., see Caresoft, Inc., <http://www.caresoft.com/> or Healthdesk, Inc., <http://www.healthdesk.com/>). Patients log in to a private Web site, provide information about the status of their chronic diseases (for example, blood glucose readings in diabetes), and later obtain feedback from their physicians or from disease managers who seek to keep the patients healthy at home.

Requirements for Achieving the Vision

Realizing the vision described above will depend on at least three factors: an enhanced Internet; better education and training for health care providers; and changes in the management and organization of health care institutions.

The Next-Generation Internet

The comprehensive electronic medical record system I have proposed here will require an Internet with much higher bandwidth and reliability, a faster response time, and financial models that make the applications cost-effective and practical. Major research efforts are under way to address some of these concerns, including the federal Next Generation Internet activity in the United States (see <http://www.ccic.gov/ngi/>). In addition, academic institutions have banded together in a consortium designed to create new testbeds for high-bandwidth communications in support of research and education. Recently incorporated as the University Consortium for Advanced Internet Development (UCAID; see <http://www.ucaid.org/>), their initial effort builds on existing federally funded or experimental networks and is known as *Internet 2*. Exploratory efforts that continue to push the state of the art in Internet technology

all have significant implications for the future of health care delivery in general and of the computer-based health record in particular.[7]

Education and Training

There is a difference between computer literacy (familiarity with computers and their routine uses in our society) and knowledge of the role that computing and communications technology can and should play in our health care system. We are generally doing a poor job of training future clinicians in the latter area, and are thereby leaving them poorly equipped for the challenges and opportunities they will face in the rapidly changing practice environments that surround them.[8] We need more medical informatics training programs, expansion of existing programs, plus support for junior faculty in health science schools who may wish to seek additional training in this area.

Organizational and Management Change

Finally, there needs to be a greater understanding among health care leaders regarding the role of process reengineering in successful software implementation. Health care provides some of the most complex organizational structures in society, and it is simplistic to assume that off-the-shelf products will be smoothly introduced into a new institution without major analysis, redesign, and cooperative joint-development efforts. Underinvestment and a failure to understand the requirements for changing the process of care as new technology is introduced, as well as problems with technical leadership and planning, account for many of the frustrating experiences that health care organizations report regarding their efforts to use computers more effectively in support of patient care and provider productivity.

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References

1. Institute of Medicine. The Computer-Based Patient Record: An Essential Technology for Health Care. Washington, DC: National Academy Press, 1991 (revised 1997).
2. Lindberg D, Humphreys B. The Unified Medical Language System. Meth Info Med. 1993;32:281–91.
3. National Research Council. For The Record: Protecting Electronic Health Information. Washington, DC: National Academy Press, 1997.
4. Poon A, Fagan L, Shortliffe E. The PEN-Ivory project: exploring user–interface design for the selection of items from large controlled vocabularies of medicine. J Am Med Informat Assoc. 1996;3:168–83.
5. Greenes RA, Shortliffe EH. Medical informatics: an emerging academic discipline and institutional priority. JAMA. 1990;263:1114–20.
6. Grigsby J, Sanders J. Telemedicine: where it is and where it's going. Ann Intern Med. 1998;129:123–27.
7. Shortliffe E. Health care and the Next Generation Internet (editorial). Ann Intern Med. 1998;129(July 15):138–40.
8. Shortliffe E. Medical informatics meets medical education. JAMA. 1995;273:1061–5.