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Canopy Computing: Using the Web in Clinical Practice

[Special Communication]

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Abstract

The rain forest canopy is a seamless web through which arboreal creatures efficiently move to reach the edible fruits without any attention to the individual trees. Individual health care computer systems are rich with patient data, but rather than a canopy linking all the trees in the forest, the data "fruit" come from a diverse forest of individual computer "trees"-laboratory systems, word processing systems, pharmacy systems, and the like. These different sources of patient information are difficult or impossible to reach by individual physicians, especially from

their offices. The World Wide Web and other standardization technology provide physicians and their institutions the tools needed for seamless and secure access to their patients' data and to medical information, when and where they need it. We and others have adopted these tools to combine independent sources of clinical data. Physicians who assist in the purchase of clinical information systems should demand products in their practice settings that are Web enabled, use standard coding systems, and communicate with other computer systems via broadly accepted protocols.

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WITHIN the rain forest, trees and other vegetation create a canopy, an interwoven system of plant life that provides a rich habitat for birds, insects, and other animals that need never forage on the forest floor. From the ground, the forest is a collection of individual trees. From the canopy, it is a seamless web.

PATIENT DATA: THE FOREST OR THE TREES? [↗](#)

Health care computer systems are rich with patient data, but rather than a seamless web, their "fruit" or data come from a diverse forest of individual "trees" or computer systems. For example, electrocardiographs (ECGs) carry ECG tracings, word processing systems discharge summaries and operative reports, laboratory systems produce laboratory results, pharmacy systems organize prescription records, and radiology systems produce images and their interpretations. Hordes of other specialty systems carry obstetrical ultrasound, spirometry, electroencephalography, cytology, and endoscopy results. [\[1\]](#) Consequently, even at a single encounter, one patient's data scatter over multiple separate trees. Over the years, as the patient visits multiple physicians and institutions, the trees may fill a forest.

Today, at best, physicians and health care organizations work with their computer and computer systems from the forest floor, accessing each tree to reach the information at the treetop. Obtaining laboratory information requires the use of the laboratory computer, accessing billing information can require driving to the office to log in to the office computer. Even when computer systems are linked, it often is a cumbersome process and because of organizational boundaries, many computer systems are off limits altogether.

Computer systems unrelated to immediate patient care also beckon physicians, such as programs that access the bibliographic citations on the National Library of Medicine's MEDLINE system, medical textbooks, pharmacology databases, Medicaid eligibility files, and more. These databases also may exist in many separate trees.

UNIFYING DATA: THE ELECTRONIC MEDICAL RECORD [↗](#)

Electronic medical record (EMR) systems provide a way to unify the data from these many information sources. They organize diverse clinical information and can eliminate filing costs, illegible notes, and lost charts. [\[2\]](#) They can save physicians time by serving as a unified collection of reports and results. They can also improve care by detecting dangerous trends and possible oversights. [\[3,4\]](#) Finally, EMR systems provide a basis for outcomes management [\[5\]](#) and a database for epidemiological studies. [\[6-10\]](#)

Such systems have been built and used for many years, [11-16] but their adoption in clinical practice has been slow, in large part because combining differently coded clinical data from many computer systems is as difficult for system integrators as it is for individual physicians. Even an item as simple as a serum glucose concentration may be coded "SGLU" in one system and "325" in another. To combine patient data from many sources, an organization must invest considerable resources to translate the codes and formats from the many source systems into a single approach for the EMR system.

What physicians need are tools that can easily join all of the separate sources of clinical information into one canopy where physicians and other authorized professionals can reach their patients' data when and where they need them. Like arboreal animals, authorized users would only have to climb into the canopy once to reach all of the information pertinent to a particular patient.

The World Wide Web offers most of the tools needed to create this ideal. The tools are defined as technical standards from the Internet Engineering Task Force. [17] These standards are remarkable for their (1) breadth, which is more than 2000 for subjects ranging from network address assignment to e-mail address assignment and from browser displays to security; (2) price, which is free from <http://www.isi.edu/rfc-editor/categories/rfc-standard.html>; and (3) development, which is by geographically dispersed academic and industrial collaboratives who produce products that fit together.

These Internet standards provide the ropes and netting needed to access multiple computer systems at the canopy level of clinical systems where the information resides. Armed with a Web browser, an authorized user could, in principle, access all modes of clinical information including (1) text data, such as echocardiogram reports; (2) graphical tracings, such as ECGs; (3) images, such as radiograph films; and (4) sound recordings, such as physician dictation. Moreover, a user on a Web browser can access any Web-enabled clinical system to which he or she has access rights. Not only is all of the information accessible from one system, but that system can be accessed by an authorized user from anywhere in the world.

Privacy issues are paramount in any access to patient data. The Internet Web standards provide the tools needed to provide strict control over who can access what records. They provide unbreakable (for all practical purposes) encryption mechanisms (128-bit key) for hiding all meaning as patient data move from source computer to user. Other Web standards provide the tools for transmitting clinical information from producing systems (eg, laboratories to the EMR system). [18] Of course, individual source computer systems must also enforce the strict security policies they would enforce as stand-alone systems. [19]

ONE COMMON LANGUAGE ↕

The hypertext markup language (HTML) [20] is the most familiar Internet standard because it defines the face of the Web to most users. The pages that a user sees on a browser are simply rendered HTML documents. HTML is also the most relevant language to this discussion because it offers so much of the capability needed to unify computer systems.

The extra muscle in HTML files compared with standard word processing documents comes from the tags (special text strings) that define many aspects of the presentation of the text that follows them. These tags also control scripts, applets, tables, forms, and multimedia anchors that give Web documents even more power. The HTML scripts and applets are little computer

programs embedded in an HTML document that can be used to verify the input, generate special displays, and generate new HTML documents. HTML tables are ideal for presenting clinical flow sheets, and HTML forms can request information from the browser user and thus provide mechanisms for capturing clinical data. Anchors provide hypertext links to other documents that may reside on any Web server. Hospital discharge summaries, head computed tomographic (CT) scan images, dictated notes, or motion cardiac echocardiograms are all "documents" that can be accessed by Web browsers. Institutions can bind many independent information sources into the canopy of one HTML browser and reach such sources anywhere on the Internet if needed.

Since HTML documents from any number of different applications can be intermingled on one browser screen, the browser on a workstation can provide user-side integration of separate functions provided by independent systems. Further, it is relatively easy to "wrap" (add a layer of program code on top of the existing program that makes it operate on a browser) legacy systems (older medical information systems that run on mainframes and minicomputers), especially those that transmit entire screens to a terminal in HTML browser technology.

On the horizon is an even more powerful markup language, the extensible markup language (XML), [21] which has been anointed as the browser markup code of the future by the committee that establishes Web browser standards. An XML document has the same general look as an HTML document, but with XML, developers can invent new tags for entirely new purposes, eg, the definition of 3-dimensional chemical structures [22] that can be displayed on a browser, or for defining clinical record structures. Indeed, Health Level Seven (HL7), a nonprofit standards development organization, is considering XML as the syntax for sending all of its messages.

CRAFTING THE CANOPY [↗](#)

What we have described so far does not provide all of the tools we need for seamless access to many different clinical data sources. Such systems would usually still ask users to identify themselves and the patient in question, inhibiting smooth transition from one data source to another. However, with moderate modifications to the cooperating systems, such context information can be passed around securely with existing Internet capabilities. So it is possible for larger organizations to create a unified canopy by making such changes according to their internal conventions.

However, true standards are being developed for passing such context between completely independent programs. For example, the Clinical Context Object Workgroup (<http://www.mcis.duke.edu:80/standards/ccow>), an ad hoc consortium organization that includes such companies as Microsoft (Seattle, Wash) and Hewlett Packard (Andover, Mass), is defining standards for identifying the user and the patient across many independent programs. The computer industry at large is also developing standards for authenticating the user just once during multiple programming applications. So eventually, context passing mechanisms will come with all clinical software.

The Internet does not provide the specifications about how to ship clinical information between separate systems, for example, for sending microbiology susceptibilities from a laboratory system to a pharmacy system for optimizing antibiotic choice and dose. However, most of these needed specifications have been developed by the HL7 organization (<http://www.MCIS.duke.edu/standards/HL7/>) and its collaborators. Health Level Seven version

2.3 [23] is a 600-page standard for the structure and content of clinical messages that has been approved by the American National Standards Institute, New York, NY. The Logical Observation Identifier Names and Codes Committee, a collaborator of HL7, [24,25] which has been supported by the Agency for Health Policy Research, Rockville, Md, the John A. Hartford Foundation, New York, NY, and the National Library of Medicine, Bethesda, Md, provides universal codes for identifying tests, clinical measurements, and report section headings within HL7 messages. Codes from the Logical Observation, Identifiers, Names and Codes Committee are available at no cost (<http://www.mcis.duke.edu/standards/termcode/loinc.htm>). Codes for identifying symptoms, findings, problems, organisms, and the many other items that are reported as values in reports are available from the Systematized Nomenclature of Medicine (SNOMED). [26] So most of the tools we need for building the canopy are in place.

EMRs IN PRACTICE

The process of building Web-based clinical systems is well under way. Almost every large system vendor now offers, or promises, Web-based medical record systems. A number of academic medical centers including the University of California, San Diego, [27] Columbia Presbyterian, New York, NY, [28] University of Minnesota, Minneapolis, [29] University of Missouri, Columbia, [30] University of Washington, Seattle [31] Partners of Boston, Boston, Mass, [32] Care Group of Boston, [33] University of Wisconsin, Madison, [34] Children's Hospital of Boston, [35] Mayo Clinics, [36] and Centre Hospitalier, Rennes, France, [37] have wrapped their EMR in browser technology.

The Regenstrief Medical Record System (RMRS) EMR, which serves Wishard Memorial Hospital and Clarian Health Partners (formerly Indiana University and Methodist Hospitals), both in Indianapolis, has been in operation for more than 25 years. It is thus, by definition, a legacy system that could benefit from the fresh look of the graphical browser interface and take advantage of the web structure to integrate with other clinical systems.

The RMRS carries all transcribed dictations, laboratory tests, orders, diagnostic study reports, and patient encounter data. [38] We use it here as a case study of the advantages of Web-based clinical software. Until recently, users would access our EMRs through "dumb" (conventional) VT100 terminals. In April 1995, we began to wrap the RMRS in Web technology. Although the process took 18 months to complete, much time was spent waiting for the Web technology to mature. The RMRS EMR now supports both dumb terminals and browser output simultaneously (users on dumb terminals, see the old approach and those on PC workstations, see the Web) but only the browser version allows physicians to go the next step and blend in other applications, access medical textbooks and literature, and present voice recordings and diagnostic images.

ACCESSING PATIENT DATA

The RMRS presents patient data in many views: new observations, flow sheets, and full narrative reports, such as radiology reports, discharge summaries, and orders. Specialty snapshots, which are customized arrays of clinical data relevant to a specialty or subspecialty, are also available. Specialty snapshot show only the impressions of diagnostic reports, such as magnetic resonance imaging scans and CT scans. However, they are associated with HTML anchors that provide links to the full report and diagnostic images, respectively. So, through browser technology, a user can click on the report icon (the small box with vertical lines) or the image icon (the bone) and see the full report or the radiologic image, respectively. Anchors also link to sound recordings (recorded dictation), to ECG tracings, and soon to color photographs of

dermatologic lesions and motion cardiac echocardiograms. Multimedia hypertext meets the needs of physicians by eliminating the time-consuming pursuit of test results, films, and records or worse, the all-too-frequent inability to access these data when they are needed the most.

This level of integration with clinical systems for patient data does require programming and cooperation from the source systems. To create the browser linkage between the diagnostic text report and its source image, the image producer must deliver to the EMR an HL7 result message that links the dictated report record to the address of the image on the picture archiving system. Such messages can be sent by encrypted e-mail and other mechanisms. The details can be found in the HL7 implementation guide. [39]

With browser technology we can yoke many independently developed programs together to achieve a single function. For example, when a physician clicks on the image icon next to the head CT scan report, the RMRS displays (through HTML) a set of thumbnail images of the CT scan slices (Figure 1). When the physician clicks on a specific thumbnail, say slice 5, the browser sends a request to a picture archiving system (AGFA Ltd, Ridgefield Park, NJ). The picture archiving system then returns the specific slice requested through another clinical standard called Digital Imaging and Communications in Medicine. [40]

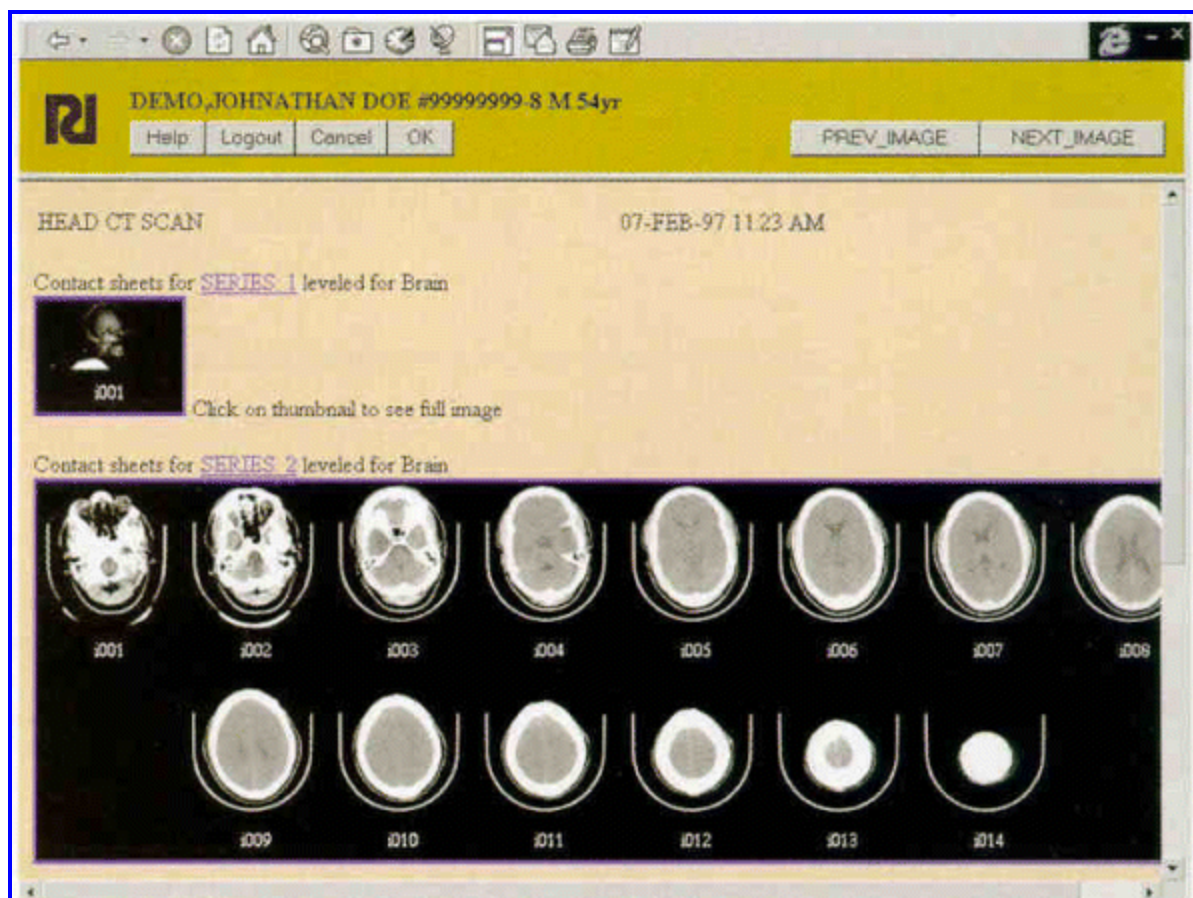


Figure 1.-Thumbnail images of CT scan slices displayed through a Web browser on the Regenstrief Medical Record System EMR.

Analogously, when a user clicks on a tracing icon next to an ECG impression, the computer fetches the full ECG tracing in a compressed format and yet another commercial program

(LINKTools, Link Medical, Norwood, Mass) decompresses the ECG tracing and prints it to the video terminal or laser printer. When we record and compress speech input entered into the browser, we use a plug-in (VoxWare, Princeton, NJ) that converts the usual 8000 bytes/s digitized speech to 180 bytes/s. We are engaged in early pilot tests with voice recognition systems that can take speech dictated into the computer and translate it directly into printed words without a transcriptionist, allowing physicians to dictate reports of patient encounters with immediate entry into the EMR system.

Web technology also helps break down the organizational barriers that put some data off limits. In a project supported by the National Library of Medicine, the 5 major hospitals in Indianapolis, Ind, will deposit key laboratory and encounter information in a shared central computer. Each hospital will have its own physical database, but has agreed to allow emergency department physicians from any of the participating hospitals to use these data to care for emergency patients under limited circumstances. The Boston Collaborative provides another example of such Web-based emergency department data sharing for emergency care. [41]

INFORMATION WHEN AND WHERE YOU NEED IT

The browser also makes it easy to provide the electronic knowledge sources at the canopy level, which is something that was difficult before Web technology. With a single mouse click, a physician using the RMRS to review a patient's medical record can access PubMed, which is a Web-based subset of the National Library of Medicine's MEDLINE database, OVID (Murray, Utah), which is an electronic information aggregator in the biomedical sciences literature, and/or MD Consult (St Louis, Mo), which is a Web-based medical information service funded by 2 publishers. Most of the Web-based EMR systems mentioned in this article provide the same or similar access to knowledge sources. Physicians can access a whole library of medical knowledge without leaving their workstation or losing their place in a patient's electronic chart. Furthermore, almost no programming work is needed to interface Web-based knowledge sources to a Web-enabled EMR system.

Researchers at the Columbia University Department of Medical Informatics, New York, NY, [28] provide another illustrative example. They have applied browser technology to their sophisticated EMR system, which captures data from more than 30 different clinical systems, including laboratory, radiology, and spirometry measures performed by patients in their home. The Columbia EMR system carries more than 300 million rows of information (where a radiology report may occupy many rows) and is used by more than 5000 different care providers. The Web version of this is the Columbia Information System (CIS) Web. (Figure 2) shows a CIS Web browser screen used to retrieve ECG results. The capabilities of their system are similar to those of the RMRS but they have gone much further regarding the ideal of ubiquitous access. An authorized Columbia physician can access the Web version of the EMR system from anywhere.

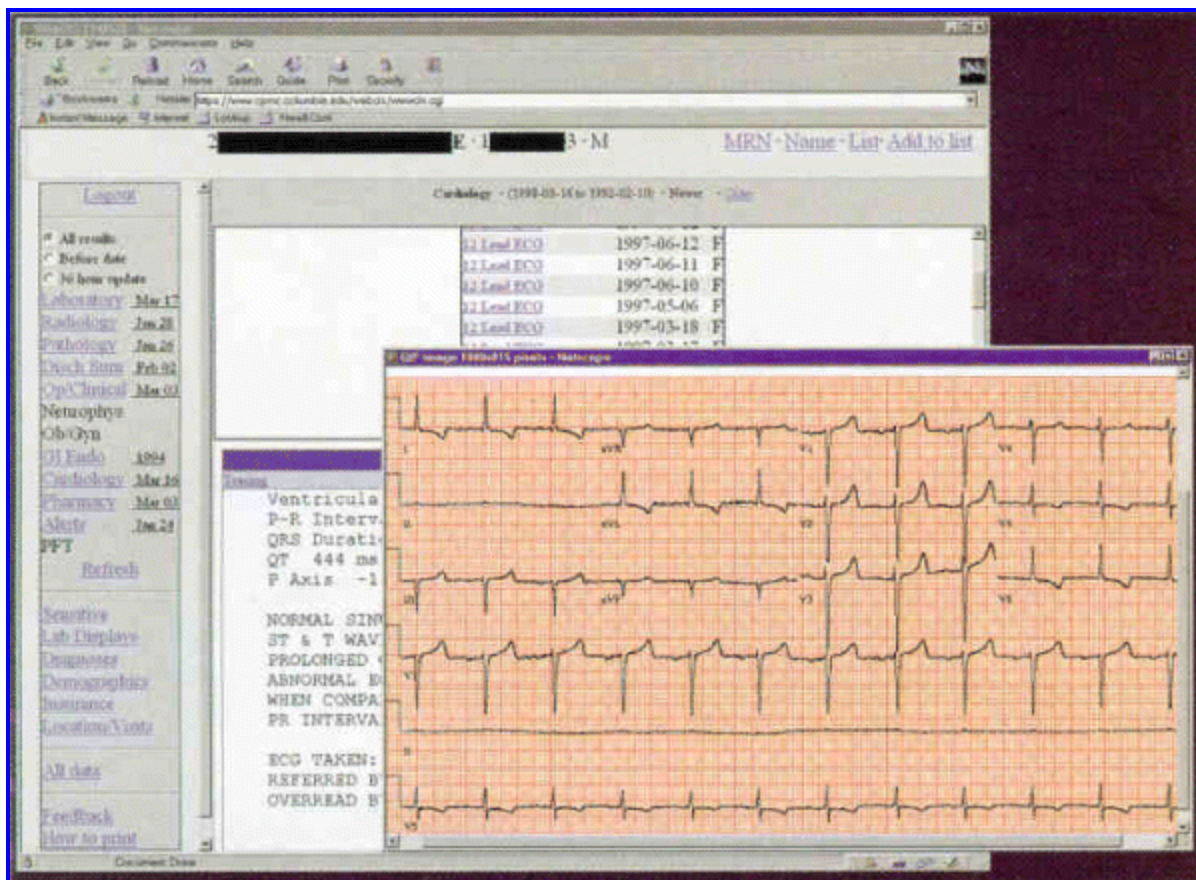


Figure 2.-An electrocardiogram report and the electrocardiogram tracing pulled up on the Columbia Medical Center browser.

For example, via a browser from their home or their vacation retreat, they can check on test results ordered for their clinic patients, and the data are absolutely secure. Authorized physician users must carry a special smart card with a small liquid crystal display (LCD) screen to access patient data over the Internet. The smart card (SecurID, ZONEOFTRUST, Laguna Hills, Calif) generates and displays a new cryptographic access code every 20 to 30 seconds on the LCD screen. The user must type in this access code to access the EMR system. Then they must also enter their hospital identification and secret password as another layer of protection (but only once per session). The system uses the Web secure socket layer standard to encrypt the clinical data as they move from the EMR system to the authorized user. The CIS Web also uses anchors to link from clinical data to medical knowledge bases. A CIS Web user can click on a patient's symptoms, signs, or diagnosis and immediately retrieve related published articles from MEDLINE or potential causes for that problem from Dxplain (Massachusetts General Hospital, Boston), a computerized diagnostic tool. [42]

In general, security requires strong authentication of the user, encryption of all clinical content, individually assigned user identification codes and secret passwords, logging of all accesses, and strong administrative policies with sanctions for violators. These issues are described more fully in other reports. [19,43]

TOWARD A NEW ERA ⁺

We envision a new era in health care computing. The adoption of message standards, such as HL7, and standards for identifying clinical observations, such as Logical Observation, Identifiers

Names and Codes system enable the melding of data about 1 patient from the many existing source systems for the purpose of display and analysis. The adoption of Web technology by vendors of health information systems permits the blending of many program and data sources in one browser screen. This evolution does not require the total rewrite of existing programs. Indeed, it gives legacy programs a new lease on life. Even niche products will be able to be passed into the medical Web browser and then institutions will be able to create a seamless institutional system by linking the systems they have purchased from many vendors.

All of this will happen more quickly if physician members of information systems committees demand HL7 interfaces, the use of standard code systems, and Web technology in their requests for proposals and purchase contracts. One day soon, physicians should be able to access a canopy of clinical information from any computer, freeing them from the time-consuming pursuit of patient data. That clinical canopy will be a scenic, rich, and rewarding place.

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Confidentiality; Hypermedia; Hypertext; Internet; Medical Records Systems, Computerized; Patient Data Privacy

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