Information in practice

Using the technology of the world wide web to manage clinical information

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Practising medicine increasingly requires managing information, particularly in hospital settings. A glance at a typical physician's pile of laboratory results, request forms, reports, and pending discharge summaries is sufficient reminder of this. In the past hard work and good organisation could usually deal with this paper trail, but there is now increasing evidence that important information is lost or misinterpreted even in the best hospitals.[1] In addition, the rapid growth in medical knowledge, particularly the biomedical literature, is further taxing our ability to provide optimum care.[2] However, we are starting to see real clinical benefits from computerisation of clinical data.[3 4]

Early clinical computing systems were plagued by incompatible standards and lack of potential for growth. A few comprehensive systems were built in specific hospitals but have proved difficult to transport to other settings. Many commercial systems have been used, but they rarely offer the ability to connect to competing systems, often making it difficult even to access basic laboratory data on the wards. With the development of the internet and world wide web, however, it is becoming possible to create comprehensive information systems that are easy to learn and use and relatively quick to develop. In this article we focus on examples of hospital information systems, but, as communication security improves, many of these approaches should apply equally well in general practice.[5]

Summary points

- The rapid increase in medical information requires new methods of accessing and organising data
- The technologies of the world wide web are increasingly being used to manage information within organisations
- Web sites can be rapidly set up to display text, images, and even video clips
- Diagnosis programs linked to web sites can be effectively integrated into clinical settings
- Web technologies provide open standards for developing comprehensive medical information systems

The internet, world wide web, and intranets

It should be no surprise that the internet and the world wide web have important potential for clinical medicine. The internet is above all a communication system, and hospitals have made great use of innovative communication systems over the years (such as pagers, internal telephones, air tubes, and fax machines). However, text has stubbornly remained paper based in most hospitals. As a result, problems of legibility and loss of patient notes are daily occurrences.[6]

The internet was developed to link together computers of different makes and operating systems, just the situation in many hospitals. A central design principle of internet based programs is the separation into clients and servers. A server is a program or programs that runs on a computer that stores information and processes requests from users. A client is a computer program that runs on the user's machine and communicates with servers to access or provide data. A typical example of this arrangement is the use of a program like Netscape (a web client or browser) to collect information from a web site (a web server).

The world wide web provides the additional benefit of displaying formatted text and images. Documents are organised with "hyperlinks." These are highlighted areas of text or images on web pages that allow users to jump to other documents at the click of the mouse, providing an intuitive way of accessing information. Finally, programming languages that can run in web pages and on most makes of computer are now available (such as Java[7]). This allows calculations and other processing to be performed in web pages and simplifies the process of exchanging useful programs.

Web technologies are increasingly used on private networks inside organisations. These "intranets" bypass many of the concerns about data security on the web but retain its flexibility and potential for rapid development. Most applications described here are of this sort. These web technologies provide standards and common languages for communication between computers, and their specifications and construction have been published. Therefore, data and programs can be

Benefits of putting documents on a web site

- Publishing is instantaneous, just by saving the file
- Any additions, updates, and corrections are immediately available to all users
- Information from various sources (local, regional, and international) can be linked together to form an organised body of knowledge
- Access to documents can be restricted to one institution, or even to a small subgroup, by means of password protection
- With modern computers, high quality full colour reproduction of images, animation, and sound are possible at minimal cost
- Printouts of forms for clinical data and guidelines or instruction sheets for patients are immediately available anywhere there is a printer

freely shared, avoiding constant duplication of effort and simplifying upgrading.

The *ABC of Medical Computing*[8] and similar books provide a general introduction to the internet and the world wide web.

Basic web sites for clinical data

The world wide web was developed to display research papers and hence is a natural medium for clinical articles, reviews, and guidelines. Text can now be prepared with a conventional word processor—such as Word or WordPerfect—or with an HTML (hypertext mark-up language) editor—such as Microsoft Front Page or Netscape Gold. Images can be scanned into files or created with a drawing program. Many modern computers allow sound files to be recorded with a microphone. More sophisticated programs allow whole lectures to be linked to a web page (such as Real Audio) and video recordings to be converted to a computer format such as Quicktime. Slide making programs now allow slides to be converted to web pages, which can be useful for previewing lectures and other teaching material.

Interactive web sites, forms, and decision support

Static web documents become more powerful tools when users can enter data and receive specific data or advice. HTML forms allow entry of data that is then processed by the server (see fig 1). Programs on the server can allow users to search for names or key words (such as in a hospital physician directory). Patients can be registered in the system with these forms, and tests can be ordered, with the request being sent to the laboratory either by email or as a direct entry in the laboratory database. Finally, patients can be given specific advice by means of diagnostic or decision support programs linked to the web server.[9]

All these interactive functions require some kind of program on the web server or in the web page. While these are usually written by experienced programmers, it has recently become possible to create search programs, send email messages, and even store patient details in a database without real programming skills (such as with FrontPage).

Decision support systems

Decision support is the process of providing relevant information to help with decision making. Textbooks, journal articles, and guidelines are all examples, but it usually means more specific advice such as clinical decision trees, calculators for clinical parameters, or expert systems. All these methods can easily be connected to web pages, which provide a uniquely powerful way of combining this information in an organised and accessible form.

Cardiology support system

A typical example might be a "workstation" to assist management of heart disease. It would include textual material with relevant photographs and diagrams and with links to a Medline web site (such as http://www.healthgate.com) and other sites covering heart disease. Programs to calculate adjustments to drug doses (such as dobutamine) could be written for the web page (with Java) or on the server. Similarly, logistic regression models developed from clinical studies can be easily implemented in a web site—an example of a guide to the probability of myocardial infarction in patients presenting with chest pain[10] is demonstrated on the web site http://lcs.mit.edu/cardiac/chestpain.htm. Programs are also available to display electrocardiograms and radiographic images in web browsers.

The cardiology web pages could be linked to a large diagnostic program such as the Heart Disease Program or DXplain[9] for more complex cases. We have been developing the Heart Disease Program to help with diagnosing haemodynamic dysfunction and heart failure.[11] It is a large program that needs to run on a powerful computer linked to a web server. Doctors can enter the details of a patient using forms implemented as web pages (fig 1). Once the data are entered the form is submitted by clicking a button; the program then checks the initial page and asks for further details of important items, including timing and severity of findings. When data entry is complete the diagnosis is returned in one to two minutes. The program also provides a full explanation of each diagnosis and a description of the likely underlying physiological states of the patient's cardiovascular system (a demonstration is available on http://medg.lcs.mit.edu/projects/hdp/hdp-world.html). We are using this web input system in the New England Medical Center to perform a clinical

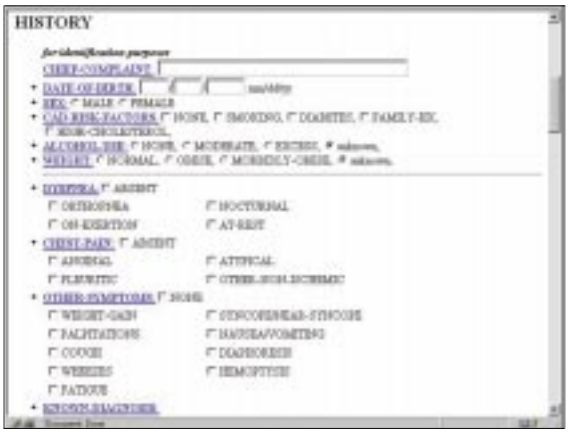

Fig 1 Web form for collecting data for Heart Disease Program

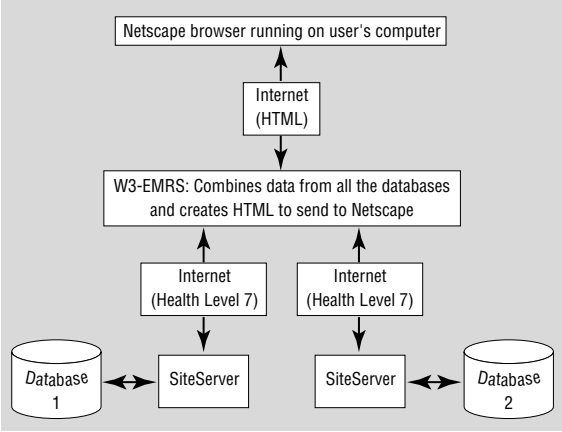

Fig 2 Overall design of W3-EMRS electronic medical records system

trial of the program's potential for giving useful advice to physicians.[12]

To complete the workstation it is necessary to keep records of patients entered into the system. This allows users to refer back to specific patients, and for checks to be made and feedback given on the quality of advice. A link to a standard database can allow collection of the relevant data, but the real benefits are seen by integrating programs into a comprehensive clinical information system. Then information only has to be entered once and cross checks can be made between different types of data such plasma creatinine concentration and drug dosing. The above functions can now be implemented in a few weeks or less (apart from full integration into the hospital system).

Linking to other hospital databases and information sources

W3-EMRS, an electronic medical records system, was developed at the Massachusetts Institute of Technology and the Boston Children's Hospital to provide a common communication system and overcome the problem of connecting multiple systems of varying ages.[13 14] Different databases (such as for patient registration or laboratory tests) typically organise data differently, use different vocabularies, and run on different management systems. Each database is linked to a program, the SiteServer, which converts the data to a common format (or code) for medical information called Health Level 7 (fig 2).[15] The data are then linked together by another program and displayed as web pages. The beauty of this system is that each database needs only one translation program. Just as importantly, the users need only a web browser (such as Netscape), which runs on most modern computers. The hospital can combine information from the old and new systems, which may be in different sites, but users have only to learn the one web display.

The system contains three layers: the database, the programs for translation and formatting of data, and the web browser. This design is an extension of the "client-server" approach described above, which allows each part of the system to be designed and written separately. As long as each component can pass information to the other parts, it does not matter how they are written, or which programming language was used.

W3-EMRS has been rewritten in Java and several other programming languages. The original system is being used daily in the endocrinology clinic of the Boston Children's Hospital. A prototype system is running as a demonstration project connecting databases from three major Boston hospitals into one web display. These demonstrations can be viewed on the web at http://www.emrs.org/. Another version is currently being developed to link together Boston's Beth Israel and Deaconess hospitals. Additional projects are adding displays for real time signals such as electrocardiographic data in intensive care units.[16 17] The system's architecture is currently an "open system" and may therefore be implemented by interested hospitals. Similar systems are being developed in several other centres, particularly the CERC ARTEMIS project in West Virginia[5] and at Columbia Presbyterian Hospital in New York.[18]

Security, confidentiality, and validity of medical data

Confidentiality of data

Patient confidentiality is of great importance, especially with regard to clinical databases and the internet. At present, few systems send data over the internet; almost all systems operate only within the private hospital network (intranet), possibly with telephone connections for doctors at home. Those systems that do have internet connections use a "firewall," a computer that screens all connections to the internet and prevents inappropriate transfer of data.[5] There is a strong drive from commercial internet users to provide secure data transfer for credit card numbers and other personal data, leading to the creation of several secure systems and the use of encryption. These approaches should soon provide adequate security to transmit confidential clinical data, but until then great caution must be exercised.

This year, the United States National Research Council assessed methods for protecting patient confidentiality in electronic medical record systems and recommended adopting several technical and policy approaches.[19] In one test project most of these recommendations have been implemented within the

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W3-EMRS framework (see http://freya.bidmc.harvard.edu/careweb.htm). This includes the use of "smart cards" that contain a computer chip to create constantly changing passwords (recently discussed in the *BMJ*[20]).

Validity of data

A second concern is that articles or programs accessed over the internet may be inaccurate or otherwise untrustworthy. Limiting use of the internet to the sites of well established organisations such as the *BMJ* provides reassurance, but it would be much more useful if all sites of potential interest were screened and certified by competent bodies such as journals or medical schools.

A method for implementing this has been developed by Jim Miller and Paul Resnick at the W3-Consortium.[21] They have created a system to label web pages that can be used to restrict access to certain sites (for example, to limit children's access to unsuitable material). Dr Miller has demonstrated how this system can be used to filter medical web pages depending on various criteria such as relevance, accuracy or reliability of content, and appropriateness for specific audiences.

An additional method for certifying text or computer programs is the use of digital signatures.[19] These mathematical techniques provide a high degree of certainty that a page or program has not been tampered with and can reliably identify the author. Methods of this sort are necessary to ensure that electronic documents can be unequivocally authenticated by doctors.

Conclusions

The different applications described above each have a role in modern medical care, but they cannot realise their full potential unless linked into an integrated whole. Entering clinical data into computers is time consuming, especially for sophisticated diagnostic programs such as the Heart Disease Program or DXplain.[9] However, much of the data (for example, patient details, laboratory tests, and radiology and pharmacy data) is already entered on one or other computer in an average hospital. Linking these computers together creates the opportunity to check different parts of the data against each other.

A few well integrated systems—such as those at the Beth Israel Hospital in Boston and the Regenstrief Hospital in Indiana—now provide some of these functions. For example, doctors receive email reminders if they prescribe a drug to which the patient has an allergy, use an incorrect dose, or do not act on an abnormal investigation (such as a low CD4 cell count in a patient infected with HIV). There is evidence that these reminders can improve patient management and reduce costs.[3 4]

The aim of a hospital information system should therefore be to combine all the available information into one integrated whole. Users can then review the data anywhere in the hospital (or at home), perform analyses, and receive reminders of potential problems. W3-EMRS and similar systems provide a solution to combining information from different sources, which allows the use of a variety of decision support tools. The plan for many hospitals is to move all their data over to one large modern SQL (structured query language) database. Users will then be able to view and add to that data using a variety of client programs such as web browsers. This approach greatly simplifies the job of searching, analysing, and maintaining the data. The W3-EMRS approach should allow many of these benefits straight away and can adjust to a larger central database without users being aware of the change. Meanwhile, hospitals can start constructing web based systems in the knowledge that they can grow by linking in other publicly available or commercial systems, building to the goal of providing comprehensive access to clinical data.

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Netlines

Neuropsychology Central

- Neuropsychology Central (**http://www.premier.net/~cogito/neuropsy.html**) is an award winning site with links to sites covering all aspects of neuropsychology (cognitive, developmental, forensic, geriatric, etc).

Medical education

- If your students are panicking about exams (or, worse still, re-sits), you could try directing them to Birmingham University Medical School's Computer Assisted Assessment site on **http://medweb.bham.ac.uk/http/caa/**. They can try their hand at the short clinical cases and multiple choice questions, which get marked on line.
- Alternatively, pathology students might like to work through David Bowyer's Pathology Lectures at Cambridge University on **http://ittmac1.path.cam.ac.uk/PartOneHomePage.html**.

Hong Kong medicine on line

- With only a few weeks to go before Hong Kong reverts to Chinese rule, now might be the time to surf Hong Kong's medical web sites. The Hong Kong Medical Association, founded in 1920, has a site on **http://www.hkma.com.hk/hkmawell.htm**, complete with press releases, material promoting organ donation in Hong Kong, some educational information for the public (also available in Chinese), continuing medical education material for doctors, and a members only doctors' teahouse.
- The Hong Kong Hospital Authority home page is on **http://www.ha.org.hk/main.htm**, with a patient's charter on **http://www.ha.org.hk/charter/pceng.htm**. You can visit the unofficial web site of Hong Kong's largest hospital on **http://www.iohk.com/UserPages/lcchong/qehhome.htm**.
- More medical sites are listed on **http://www.cuhk.hk/hkwww/n28.html**, and if you want a comprehensive list of Hong Kong's web sites try **http://www.cuhk.hk/hkwww.html**.
- Finally, netsurfing expats who intend to stay on after the handover might want to visit Tianwei Xie's Learning Chinese On-line page on **http://philo.ucdavis.edu/CHINESE/online.htm** or the Chinese-Language-Related Information page on **http://www.webcom.com/~bamboo/chinese/chinese.html**.

Cancer on line

- There are plenty of cancer sites on the web. The Imperial Cancer Research Fund's web site on **http://www.icnet.uk/** has both general and specific information about cancer, including details of laboratory and clinical research sponsored by the fund into all aspects of cancer—causes, prevention, and treatment. You can even investigate employment opportunities or make a donation on line.
- However, the definitive source for cancer information on line is CancerNET, produced by the United States National Cancer Institute, but available in Britain on **http://www.graylab.ac.uk/cancernet.html**. The site contains authoritative information on all aspects of cancer diagnosis, treatment, and prevention. You can even access it in Spanish if you prefer.

Writing a thesis?

- Having trouble writing a paper or a thesis? Then visit the Indispensable Writing Resources page on **http://www.stetson.edu/~hansen/writing.html** for links to almost every writing resource on the web. The major risk is that you spend so long exploring the sites that you never finish the thesis.

Coshing COSHH

- If you have to fill in COSHH assessment forms, you might find the web site of the United States Agency for Toxic Substances and Disease Registry useful on **http://atsdr1.atsdr.cdc.gov:8080/atsdrhome.html**. The site houses ToxFaqs, a set of fact sheets on toxicity profiles of hazardous chemicals, and HazDat, the Hazardous Substance Release/Health Effects Database.
- You can also take a peek at other people's efforts on implementing COSHH with this URL: **http://www-uk.lycos.com/cgi-bin/pursuit?query=coshh&maxhits=200** or check out the official blurb from the Health and Safety Executive on **http://www.open.gov.uk/hse/coshh1.htm**. And if you didn't already know that COSHH stands for the Control of Substances Hazardous to Health Regulations, 1994, you are probably already breaking the regulations.

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web page **http://www.qmw.ac.uk/~rhbm001/mpallen.html**

Netpoints: Patient randomisation on the web

Third party randomisation is the best way to reduce bias in clinical trials. In our multicentre trial, the growth restriction intervention trial (GRIT) in which the intervention is timed delivery, participants require 24 hour entry, and we need to collect considerable data on fetal and maternal condition before randomisation. However, manned telephone or fax services are expensive, and automated telephone dialling is complicated and permits only a small amount of data to be entered. We have therefore recently set up and successfully used an alternative trial entry service on the internet.

Any collaborator with access to the internet and a Java enabled web browser can use it. The publicly available Java software is at **http://java.sun.com**, and the GRIT web site is at **http://epipc05.leeds.ac.uk/grit/grit.htm**. The trial entry program consists of an "applet" that loads from the GRIT server onto the client computer via the internet. The peripheral user sees a data screen and enters the clinical and demographic details. These are validated locally and sent to the GRIT server, which issues a trial number and treatment allocation. The process takes minutes, is cheap, and minimises transcription errors. The internet is used only to transmit the Java applet and for two brief messages, the validated data and the trial allocation. Users require a centre name and password, and, as added security, patients are identified only by their centre code and local hospital number.

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