Application of Technology ■

The Implementation of Telemedicine within a Community Cancer Network

JACK W. LONDON, PHD, DANIEL E. MORTON, MS, DONNA MARINUCCI, ROBERT CATALANO, PHARMD, AND ROBERT L. COMIS, MD

Abstract Telemedicine is being used by physicians at the member hospitals of the Jefferson Cancer Network (JCN) for consultations regarding the diagnosis and management of cancer patients. The technology employed for this telemedicine system was chosen to meet three related specifications: low capital and operating cost, internal maintainability by community hospital data processing staffs, and compatibility with the existing technologic infrastructure. The solution selected is the ubiquitous desktop personal computer and associated software, and Integrated Services Digital Network (ISDN) communications links. The overall performance of this technology has been very satisfactory; ISDN communications has sufficient bandwidth for the transfer of patient data, including text reports, radiographs, and pathology slide images. The presence of the radiologist's interpretation along with the radiographic images allows the presentation of the images on these systems to be acceptable for review purposes. The video frame rates of these systems (12 to 15 frames per second) is adequate, particularly given the "talking heads" nature of the video presentations. Furthermore, the quality of the video image (resolution, size, frame rate) is secondary to the quality of the presentation of the medical information displayed and the capability for mutual annotation of the patient data during the consultation.

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The Jefferson Cancer Network (JCN) is a mutually beneficial association focused on the care of cancer patients; it comprises an academic cancer center, Thomas Jefferson University Hospital's Kimmel Cancer Center (KCC), and seven neighboring community hospitals in the Philadelphia metropolitan area. The goal of this network is to provide the best approach to preventing, diagnosing, and treating cancer for all the patients of the member institutions. The cancer center primarily benefits from this association by gaining access to a larger pool of patients for clinical research studies, while the community hospitals benefit by being able to provide, within their communities, a wider range of treatment for their cancer patients. To be successful, this hospital group must overcome the geographic barrier to the necessary consultation between the community-based physicians and the cancer center oncology specialists regarding the complex, changing aspects of cancer diagnosis and treatment.

Traditionally, information on clinical cancer research trials is transmitted by paper updates. Consultations concerning individual cancer patient management occur by telephone, with occasional physician visits. In 1994, the JCN decided to employ the World Wide Web (WWW) for conveying accurate, updated cancer clinical trials information and telemedicine for physician consultations regarding the diagnosis and treatment of cancer patients.

Background

Cancer Clinical Trials

In 1988, the General Accounting Office reported that many cancer patients did *not* receive treatment considered by the National Cancer Institute to be state-of-the-art. In this study, the fraction of patients treated

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Correspondence and reprints: Jack W. London, PhD, Thomas Jefferson University, 808 BLSB, 233 South 10th Street, Philadelphia, PA 19107. E-mail: J_London@lac.jci.tju.edu

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less than optimally ranged from 20% for those with Hodgkin's disease to 94% of those with colon cancer.[1] Organizational mechanisms such as hospital associations that link physician cancer experts and nonexperts are needed to ensure that patients in all communities have access to the best care.[2]

More than with other diseases, state-of-the-art cancer treatments are related to clinical trials.[3] Cancer clinical trials are research studies initiated to evaluate new treatment approaches that are thought to potentially offer better patient outcomes than existing treatments for that particular disease.[4] However, less than 3% of the estimated 1.17 million newly diagnosed cancer patients participate in clinical trials.[5] It is not surprising that only a small fraction of all cancer patients receive clinical trial treatments, since most cancer patients are originally treated in the community, as opposed to being treated at cancer centers, where enrolling patients on clinical trials is actively promoted.

The lack of access to clinical trials in the community not only may deprive current cancer patients of the best treatment available, but it also compromises the treatment of future cancer patients by slowing the progress of the cancer research, which depends on these trials to measure the effectiveness of investigational treatments. These scientifically rigorous studies often require previously untreated patients. Because most cancer patients originally receive treatment in the community, not at cancer centers, patients at cancer centers are frequently ineligible for enrollment in trials because they were previously treated at their local community hospital. It is therefore beneficial to the patient and to the medical research that cancer patients are offered clinical trial treatment when appropriate under the guidance of their community physician, at their local hospital.

Six physician-related barriers to the accrual of patients on clinical trials have been cited.[5] Three of these obstacles—clinical trial complexity, physician compensation, and unreimbursed clinical procedures—need to be addressed through improved study design and changes in research funding and medical treatment reimbursement. However, computer technology may contribute to overcoming the other three cited obstacles: lack of clinical trials awareness or access, physician treatment biases, and physician fear of patient loss.

The first of the barriers that technology may help to overcome is the lack of awareness of available cancer clinical trials. There is much detailed information on cancer clinical trials, with changes occurring almost daily. Maintaining up-to-date paper documentation on cancer clinical trials is a labor-intensive task, usually only properly carried out at cancer centers, which have sufficient dedicated support staff. Traditionally, affiliates are sent voluminous mailings to be read and filed. Resolution of specific questions can only be obtained by two similarly time-consuming actions: retrieving the appropriate filed paper document, or placing a telephone call to the academic center's clinical trials support office. Advances in information technology may reduce the burden of quickly obtaining information of available clinical trials for a given disease.

As for physician biases and fear of patient loss, technology may also provide improved physician–physician communication, which could ameliorate the negative perceptions of clinical trials participation. Specifically, physicians not primarily engaged in clinical cancer research are sometimes biased against clinical trial therapy, considering it to be not as good as standard therapy. Additionally, referring physicians often fear loss of control over the treatment of their patients who are placed on clinical trials. Establishing more personal relationships between the academic and community physicians allows for a clearer understanding of the benefits of clinical trials to cancer patients and lessens concerns over patient loss. The best way to maintain good working relationships is by having the physicians meet at one of the hospitals. However, current technology may provide alternatives for this travel that are less time consuming.

There is more need for consultations between academic and community physicians than communicating a better understanding of the nature of cancer clinical trials and creating good relationships. It is important to keep in mind that cancer clinical trials are scientific studies; they have rigorous eligibility rules as to which patients can be treated in the study to ensure that the study's results are based on a patient population with consistent, defined characteristics. These eligibility rules include stipulations on the patient's medical history, diagnosis (including extent of disease), and prior treatment. The precise evaluation of these eligibility factors and determination of optimal treatment is often best accomplished by cancer specialists who, on a daily basis, exclusively treat patients having a particular disease (e.g., breast cancer, lung cancer, colorectal cancer).

Two years ago, a project was initiated to promote enrollment in clinical trials of patients in the community by utilizing currently available, low-cost technology to provide community physicians with cancer clinical trials information and an efficient means for consultations between them and expert cancer specialists regarding the diagnosis and treatment of cancer patients in their community. Specifically, the KCC created and

maintains WWW pages with continually updated information on cancer clinical trials, both institutional (i.e., KCC) and cooperative group (e.g., National Cancer Institute, Eastern Cooperative Oncology Group, Radiation Therapy Oncology Group). Physicians in the community who are associated with member institutions of the JCN access this information when presented with a cancer patient to see whether a clinical trial is a treatment option. Should clinical trial treatment be a possibility for a patient, the JCN physician arranges for a videoconference with a cancer specialist at KCC to discuss the specific patient's diagnosis and treatment. The personal computer (PC) is the platform for these one-to-one video consultations. Basic Rate Interface ISDN provides a 128-Kbps communications link. Thus, the WWW is the technologic tool being used to overcome the obstacle of lack of awareness of clinical studies, while videoconferencing is being used to facilitate the dialogue between cancer specialists and referring physicians regarding the nature of clinical trials and their use with patients in the community.

Related Telemedicine Projects

An oncology-related telemedicine application was part of the European ''Telemed'' project. Oncology staff at the University of London and its other European collaborators utilized videoconferencing with cancer outpatients, providing them with information and emotional support.[6] The ability to see the patients was thought to be of great value in assessing their emotional states.

The University of Kansas Medical Center provided oncology video consultations to its rural outreach clinic in Hays, Kansas.[7] On four occasions in 1993, when severe weather interrupted travel to Hays, a Medical Center oncologist used videoconferencing to examine patients who were at the rural clinic. An oncology nurse at the rural clinic assisted with the examinations. The preliminary findings of this study suggested that telemedicine could be a viable alternative to some on-site consultations.

Georgetown University Medical Center (GUMC) is currently assessing three PC-based telemedicine applications[8]: urology clinical consultations, pharmacology telementoring for residents and medical students, and pediatric trauma care triage. The urology consultation application is similar to our project in that it involves consultations between specialists and subspecialists to arrive at clinical decisions for patient treatment. A subspecialist who has urinary stone disease management expertise at GUMC advises general urologists at a West Virginia hospital on the best treatment option for a patient. While our video consultations have been entirely physician-to-physician, this GUMC project also includes subspecialist interaction with the patient. Technically, this project also utilizes Pentium PC platforms and ISDN communications links (336 Kbps rather than our 128 Kbps). The goal of this GUMC study is to determine the suitability of their system for remote surgical stone disease consultation services, including the benefits obtained from the subspecialist–patient interactions.

System Design

Design Constraints

Our system design was constrained by the following concerns: low capital and operating costs; maintainable by in-house staff at each hospital; and compatibility with existing technologic infrastructure.

Consistent with the health care environment of the past several years, a prime constraint on any telemedicine consultation system to be employed by the JCN was that it be cost effective. While a videoconference offers functionality not available by a traditional telephone consult, the price that the participants were willing to pay for these added features was limited. Discussions among the JCN members concluded that the individual videoconference workstation cost should not exceed $5,000, and total capital costs per hospital should not be greater than $10,000. Likewise, operating costs should be kept to less than $100 per month.

Another constraint was that the telemedicine systems be maintainable by the in-house data processing staffs at all the hospitals involved. Complex systems that would require continual support from the KCC computer staff were not desirable; KCC did not have sufficient personnel to service seven other sites, and each JCN member preferred to have control over all computer systems within his or her hospital.

Also, since the need for consultations was immediate, any technology used must be presently available and reasonably proven. Technology that would require costly enhancements to the existing infrastructure, such as extensive internal cable installation, was to be avoided.

Design Solution

Our system comprises the following elements:

- Ubiquitous PC/Windows platform
- Integrated Services Digital Network for video and data transmission

- World Wide Web access to clinical trials information
- Intel Corporation's *ProShare* videoconferencing product

The PC platform with Microsoft Corporation's Windows operating system (either version 3.1 or "95") fulfilled of our design specifications to a greater degree than workstation alternatives employing Unix or Apple Corporation's Mac operating systems. Personal computer platforms capable of supporting videoconferencing hardware and software can be obtained for approximately $2,500. While Macs cost about the same, suitable UNIX workstations have prices of from two to four times that of a PC. Just as important as their relative low cost is the familiarity with the PC common to JCN community hospital computer support staffs. Many PCs were already in use at the member hospitals, and in-house technical resources already existed for training and maintenance. This widespread familiarity with PCs does not exist at these hospitals for the Mac and UNIX platforms.

Basic Rate Interface Integrated Services Digital Network (ISDN), a mid-bandwidth communications technology that utilizes existing digitally switched public telephone networks,[9] best met our system requirements. Because ISDN does not require fiber optic cable, no expensive infrastructure modifications were required at the community hospitals; the existing copper wire telephone cables were sufficient. However, ISDN does require that the telephone central offices involved have digital rather than analog switches. Fortunately, the local telephone operating company (Bell Atlantic) has upgraded enough central offices in the Philadelphia area to offer ISDN wherever needed in this region. Also, ISDN offers flexible connectivity, being "switchable" via dialing another site's ISDN phone number, as opposed to prearranged "point-to-point" dedicated lines. Finally, ISDN also offers low installation and operating costs (Table 1). Basic Rate Interface 128 Kbps (two bonded 64Kbps channels) ISDN exhibited sufficient bandwidth for the data and video transmission needs of this application. The patient data "meeting" files, being several megabytes in size, require only a few minutes for transmission. The limited action of the video (one physician talking to another) is adequately displayed at the 12- to 15-frame-per-second rates obtainable with ISDN and the hardware and software video compression/decompression capabilities of the PC.

The World Wide Web addressed the need for an efficient means of communicating continually changing information. Every week, it is common for at least one cancer clinical trial to "open" or "close." Modifications to the treatment plan of at least one ongoing clinical trial likewise will almost surely occur each week. Updates specifying these changes must be mailed or faxed in order to maintain accurate on-site documentation at any institution involved in these clinical investigations. However, obtaining a copy of the latest protocol specifications is often not convenient for a physician who is presented with a cancer patient and who is considering possible treatment options. Having the latest information available from desktop computers at hospital locations and physician offices is a very efficient solution to this problem. Using the World Wide Web as the vehicle, as opposed to developing special software with other tools, has the advantage of platform independence. Web browsers are available for almost all operating systems. This is important at academic medical centers, such as Thomas Jefferson University Hospital, which, unlike their community associated institutions, have physicians with UNIX and Mac platforms as well as PCs. Information maintenance is correspondingly simplified, since a single HyperText Markup Language (HTML) document can be viewed by all users, regardless of their desktop platform's operating system.

The "Clinical Trials" link of the Kimmel Cancer Center WWW page (*http://www.jci.tju.edu*) provides protocol information (e.g., schema, eligibility criteria, principal investigator, and coordinator contacts) keyed to the cancer site and the extent of the disease (e.g., "stage IV breast cancer"). For institutional and some cooperative group studies, the complete protocol text is available, along with abstracts and consent forms. There are also links to a description of the clinical trial process, general protocol monitoring information, and a synopsis of recently closed or opened studies, revisions, and suspensions. The KCC Clinical Trials Support (CTS) Office provides editorial supervision for the clinical trials WWW link, and, with the exception of protocol details for cooperative group studies, creates the content. When the link was first created in 1994, CTS was already creating and maintaining the information using word processing. While initially the word-processing text was manually con-

Table 1 ■

Approximate Capital and Operating Costs for Videoconferencing Systems Employed by the Jefferson Cancer Network

Personal computer	$2,500
Videoconferencing hardware and software (ProShare)	1,500
ISDN installation	150
Scanner (10-bit, 3.0 optical density range) and transparency adapter	$3,000
Monthly ISDN line charges	$40 + 4 cents/min

verted to HTML files, this process is now almost entirely achieved using PC conversion tools (specifically, Internet Assistant for Microsoft Word). No additional personnel have been involved in preparing this information for the WWW, and the amount of effort spent is decreasing as better Web publication tools become available. The cooperative group information had always been obtained as text files. A C language program was written in 1994 that converted these rigidly formatted files to HTML.

Intel's ProShare product is one of several videoconferencing hardware/software packages available for the PC and ISDN. This product was selected because it is reasonably priced, provides features such as a whiteboard and a software developer's toolkit, and complies with the H.320 videoconferencing standard. This last attribute allows ProShare users to engage in videoconferences with other vendor systems that are also H.320 compliant.

System Utilization

When presented with a cancer patient, the physicians at the JCN community hospitals can obtain updated information on available cancer clinical trials by accessing the KCC Web page. This is not patient-specific information. If a consultation with a cancer specialist concerning a particular patient is desired, the physician telephones the Clinical Trials Support office at Jefferson with a request to have a videoconference with an appropriate colleague. The community physician then assembles the relevant patient data for the consultation: text reports (history and physicals, radiology and pathology interpretations, clinical laboratory values), radiographic films, and pathology slides (or color photographs). The information from these paper, film, and glass slide materials must be transferred to a PC disk file. This is typically accomplished by scanning the documents, films, and slide photographs with a high-quality (10-bit, 3.0 optical density range) scanner with a transparency adapter. Pathology glass slide images can be imported from a video camera mounted on a microscope. The image quality of the scanned radiographs and pathology slides is sufficient for review purposes, especially since the radiologist's or pathologist's dictated interpretations are also available. The acceptability of the quality of the images displayed on the PC is consistent with the experience of others.[10] Should any of the data be already available in machine-readable form, this scanning step could be replaced by copying a computer file. The PC disk file having all of the patient data for the videoconference is referred to as the "meeting" or "notebook" file. This file is displayed by the ProShare software in a PC "whiteboard" window, which may be annotated using the PC's mouse.

Once the meeting file is completed, it is electronically transferred from the community hospital to the desktop PC of the cancer specialist at the KCC. The specialist's office PC has ProShare software that enables the meeting file to be reviewed when convenient prior to the actual videoconference. The specialist may make annotations to the file contents.

At the scheduled time, using the ProShare software, one participant dials the ISDN number of the other participant, and the videoconference takes place. The material in the meeting file is displayed concurrently on the whiteboard windows of both PCs, and simultaneous annotations may be made by either side (different colors are used to distinguish the source of the annotations). In addition to the whiteboard window, two video windows display each participant, their images being captured by a small camera mounted on the PC's monitor (Figure 1). Any video signal can be channeled to this window instead of the PC camera output. For example, a microscope with a video camera mounted on it has been used to transmit magnified images of pathology slides to the video window. These video window images can be pasted to the whiteboard window and subsequently saved in the meeting file.

Experiences to Date

The World Wide Web has been an excellent means of communicating information on cancer treatment trials. It is frequently used at the JCN hospitals. (On average, there are 11.1 requests per day for clinical trials information.) Training people to use the WWW is becoming less and less of an issue as individuals learn to use it in other areas of their personal and professional lives. As mentioned previously, to minimize the maintenance of the clinical trials Web pages, software has been obtained (e.g., Microsoft Internet Assistant) or written to automatically convert the text files that previously were printed and mailed to physicians to HTML files. Use has also been made of "helper" applications such as Microsoft's Word and Adobe's Acrobat Reader to directly display documents without conversion to HTML.

At this time, there are four videoconferencing workstations on the Jefferson campus, and five other workstations have been installed at three of the JCN hospitals. Nine clinical consultations have taken place over the past year. These consultations average about 30 minutes in length. Discussions have involved a variety of topics, including whether a patient had a re-

Figure 1 Captured PC screen displaying ProShare whiteboard with annotated fluoroscopic image and video windows showing remote and local participants.

currence or a new primary, whether only palliative treatment should be considered, procedures for bone marrow transplant, and unusual cell pathology. Not only has there been a communication of state-of-the-art cancer treatment, but a collegial dialogue has been established that has definitely been enhanced by the ability of the participants to see one another. These video interactions seem to be more effective than simple telephone calls in establishing a relationship between the academic and community physicians. It is hoped that this reduces the anxiety of the referring physicians over loss of control should the patient be involved in a clinical trial. The ability to utilize the whiteboard during the consultations helps explain the rationale behind clinical trial treatments under discussion and, it is hoped, lessens any bias against the clinical trial treatment. The overall sense is that a videoconference is a more effective substitute for an actual physician visit than a simple telephone call is. Overall, clinical trial patient accrual has increased from 4 patients in the year prior to utilization of the WWW and videoconferencing to 14 patients in the first full year after installation of the initial systems. While no formal study was carried out to determine the factors contributing to this increase in clinical trials involvement, participants in this project have stated that these technologic tools have lessened the effort required to put patients on study and have helped to further a collaborative attitude among the physicians.

Technically, the ISDN–PC-based videoconferencing has also been very satisfactory for our clinical consultations. We have found that ISDN has sufficient bandwidth for the required meeting file data transfers, these files being between 5 and 10 megabytes in size. The ProShare video compression/decompression and ISDN result in 12 to 15 video frames per second, which has been adequate for the "talking heads" nature of the video component of the telemedicine sessions. Furthermore, the ability to simultaneously view and annotate the medical data on the whiteboard is of greater importance to the participants than television-quality video frame rates.

The basic ProShare system's audio capability is similar to that of a speakerphone: only one person's voice is heard at any one time. Background noise and speaker feedback can cause poor audio quality. Noise cancellation hardware can be added to each system, which would produce the more natural audio characteristics typical of a telephone call.

The community physicians requesting consultations have also learned that restraint is worthwhile when selecting data for the meeting files. While the procedure itself is quite simple, time is required of someone on their staff to scan in the patient's reports, films, and slides. It is a poor use of time to scan an entire 50-image CT study instead of selecting one or two important slice images for the file. The radiologist's report (or the radiologist) can be relied on to select the

appropriate slices, if it is not obvious. This greater attention to the information included in the meeting file is helpful to the consultant physician, since more focused data are being passed along. About 30 to 45 minutes is needed for scanning the materials of a meeting file. We have also learned that it is very worthwhile to allow the consultant to review the meeting file prior to the videoconference. Less time is wasted during the actual consultation, and the consultant has an opportunity to check reference sources.

Conclusions

For our project, we have found that the World Wide Web is an efficient means for communicating updated information on cancer clinical trials to community physicians. Similarly, telemedicine consultations have been very useful, with physician participants unanimously concurring that they are more effective than traditional telephone consultations. However, attention must be given to the human engineering aspects of carrying out these remote medical conferences for them to be a truly efficient alternative to the simple telephone consultation. Work is currently in progress to enhance the whiteboard software to provide basic image manipulation (e.g., zoom, pan) and to facilitate the ad hoc addition of patient data during the conference. From a technical perspective, the PC platform with ISDN has been demonstrated to be a reasonably priced platform for these medical video consultations. Most important, these telemedicine consultations have contributed to the increase in the number of patients enrolled in clinical trials from the Jefferson Cancer Network hospitals.

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Editorial Notice

The Institute of Medicine Committee on Evaluating Clinical Applications of Telemedicine has released a report entitled "Telemedicine: A Guide to Assessing Telecommunications in Health Care." A summary of the report is on-line at http://www.nap.edu/nap/readingroom. The complete volume is available for sale from National Academy Press, 2101 Constitution Avenue, NW, Box 285, Washington, D.C. 20055. The report will be reviewed in the March 1997 issue of the Journal.