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Telemedicine Expanding the Scope of Health Care Information

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Abstract The definition of health information is growing to include multimedia audio, video, and high-resolution still images. This article describes the telemedicine program at East Carolina University School of Medicine, including the telemedicine applications presently in use and the virtual reality applications currently under development. Included are the major design criteria that shape the telemedicine network, some of the lessons learned in developing the network, and a discussion of the future of telemedicine, including efforts to incorporate telemedicine within a fully integrated health information system.

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The digital revolution is rapidly converting patient medical records, hospital billing records, physician procedure codes, pharmacy records, and other financial, administrative, and clinical data into electronic information. Computer networks make this information readily accessible to many health care system participants (e.g., hospitals, physicians' group practices, private billing services, pharmacy benefit managers, ambulance services, and so on). The common goal of these rapidly expanding health information networks is "online, real time communication—with less reliance on phone, fax, mail, indecipherable handwriting and files crammed with triplicated forms."[1] From a paper-and-pencil world to one of digital information, this model of health care informatics has essentially retrofitted technology to accommodate the current paradigm of care: i.e., it puts traditional medical information where it needs to be in a more timely and efficient manner. While this obviously offers tremendous advantages over the old paper-and-pencil system, the digital revolution holds another piece of the health care information puzzle that could alter the current model of health care. New digitizing and data compression technologies are making telemedicine—the transmission of audio, video, and high-resolution still images of patients—a reality.[2]

In this article, we describe how the East Carolina University (ECU) School of Medicine telemedicine program uses information technologies to provide a variety of health care services to people in North Carolina. We briefly describe the telemedicine program at the ECU School of Medicine, including the telemedicine applications presently in use and the virtual reality applications currently under development. In this description, we include the major design criteria that shape our telemedicine network. We de-

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Table 1 ■

Clinical Consultations by Specialty, August 8, 1992 –September 3, 1996

Specialty	Consults
Dermatology	553
Gastroenterology	97
Neurology	93
Adult cardiology	47
Rheumatology	27
Allergy, asthma, & immunology	33
Endocrinology	23
Pediatric cardiology	23
Pulmonary	22
Orthopedics	12
Hematology/oncology	14
Infectious disease	11
Adult psychiatry	9
Vascular surgery	8
Radiology	6
Child psychiatry	5
Emergency medicine	5
Nephrology	4
Internal medicine	3
Surgery	3
Ear, nose & throat	2
Ophthalmology	2
Thoracic surgery	2
Rehab medicine	2
Urology	1
Pediatric gastroenterology	1
Obstetrics	1
Geriatric psychiatry	1
Reconstructive/plastic surgery	1
Total Consultations	1,011

scribe some of the lessons learned in developing our network, and we discuss the future of telemedicine, including our efforts to incorporate telemedicine in a fully integrated health information system.

Status of Telemedicine at the East Carolina University School of Medicine

East Carolina University School of Medicine serves the very rural area of eastern North Carolina, where there are serious shortages of health care providers. Telemedicine is helping to overcome this shortage by making specialty medical consultations available to people in rural communities. Between August 1992 and September 1996, ECU physicians conducted more than 1,000 clinical consultations via telemedicine. These consultations occurred in 29 different specialties (Table 1), with a majority in dermatology (55%). A typical distant consultation involved a nurse at the "spoke site" (rural hospital, rural clinic, or prison clinic) presenting the patient to the specialist physician at the "hub site" (ECU School of Medicine in Greenville, North Carolina). The physician would interact with the patient much like he or she would in a face-to-face clinic visit.

The ECU telemedicine network is a scalable, hybrid communications network that comprises T1, asynchronous transfer mode (ATM), plain old telephone service (POTS), microwave, and SW56 transmission modes. A variety of compression engines have been tested, deployed, and integrated into a multichannel bridge that interconnects all of these technologies. This multichannel bridge allows cross-platform communication. For example, our ATM-based telemedicine sites routinely take part in continuing medical education teleconferences that are primarily T1-based sites. Telemedicine at ECU is not a "one-size-fits-all" model. Rather, it is a scalable system designed to conform to the functional and financial constraints of the hub (ECU School of Medicine) and the spoke sites (four rural hospitals, two rural clinics, one maximum security prison, and one naval hospital).

A primary component of telemedicine at ECU is an optimized physician workspace in which specialty physicians at ECU conduct consultations with patients at the spoke sites. The ECU physicians sit in custom-designed, 6- by 12-feet, sound-proofed booths and have a range of telediagnostic tools available (stethoscope, otoscope, ophthalmoscope, dermatology camera). Figure 1 illustrates the basic system.

Another component of the telemedicine system at ECU is an application that connects a small, rural hospital's emergency department to a tertiary care center's emergency department. Teleradiology services are included in this application so that the tertiary care center can receive high-resolution images of a patient's radiologic studies. This application uses North Carolina's statewide network for high-speed video, audio, and data communications over ATM/SONET, a switched broadband network. This network includes all four medical schools in North Carolina, and ECU is one of the hub sites. This network has been designed to protect patient privacy by using dedicated 27 Mbps circuits for each telemedicine link. The links provide full support for all telemedicine tools and include far-end camera controls and full-motion, 30-frames-per-second video.

The newest component of telemedicine at ECU, a still-image transfer system that uses standard telephone lines, illustrates the scalability of the network. Compared with the emergency medicine application described above, which uses the highest bandwidth and the most expensive technology available, this application uses standard telephone service and equipment with a total cost of less than $10,000. Using a video telephone, a primary care physician on the Outer Banks of North Carolina can transmit dermatologic or orthopedic images to specialty physicians at the ECU School of Medicine. The video phone includes an image storage system, so multiple patient cases can be bulk transmitted in a store-and-forward manner. Accessories for the system include a dermatology camera and a document camera.

Two other components of telemedicine at ECU are distance learning and administrative teleconferencing. Since 1991, over 3,000 educational programs, conferences, and meetings have been conducted over the telemedicine system at the ECU School of Medicine. These have included weekly transmission of family medicine grand rounds to physicians at the rural sites on the Rural Eastern Carolina Health Network (REACH-TV), administrative teleconferences, and nursing courses broadcast to hospitals and community colleges in rural areas of eastern North Carolina.

Along with the application currently in use, the telemedicine program at ECU is also involved in research to develop the next generation of telemedicine application and tools. The technologic research at ECU includes things as diverse as the DOCking station, which explores the optimum physician interface for next-generation telemedicine systems; hands-free, voice-operated telediagnostic tools; and virtual reality (VR) simulations for medical training. Two VR tools are currently in development: a binaural digital stethoscope to provide spatialized heart and lung sounds, and a stereo dermatology system that provides three-dimensional displays of skin lesions. Our telemedicine network is growing and evolving as we learn more about the potentials of this technology. However, certain design criteria are shaping the growth.

Design Criteria for the ECU Telemedicine Infrastructure

The goal of our telemedicine network, and for any comprehensive health information network, is to support and improve medical decision making. In order to achieve this goal, a central design criterion for our network is to make accessible all pertinent clinical information and diagnostic tools to the physician or other provider. This means that the infrastructure should seamlessly integrate electronic patient records, integrated practice management systems, access to medical literature, and audio and video tools for distant consultations. While our current system primarily supports distant consultation using audio and video tools (e.g., stethoscope, dermatology camera, interactive video conferencing), we are working toward a fully integrated model. For example, the physician specialist has access to the World Wide Web (WWW) and the MEDLINE database from a personal computer located in a telemedicine booth. The next major step is to provide electronic medical records to the consulting physician. Currently, the patient's medical record is faxed from the spoke sites to the physician at the hub site (ECU). We are working on a system that will present the patient's medical record on a personal computer in the telemedicine booth where the specialist physician is located. The spoke site's computers are connected to the computer in the telemedicine booth via a wide area network (WAN) using the same T1 connection that provides audio and video. Although presenting a single patient's medical record does not constitute an electronic medical record system (EMRS) in its broadest sense, it is a step in the right direction.

Another important criterion for a fully integrated health information network is that the technology be transparent to the user. In other words, the hardware and software interfaces must be friendly and easy to use. For example, in our network, the physician at ECU can switch from one rural site to another with the touch of a button. In our regularly scheduled dermatology, cardiology, allergy, and rehabilitation clinics, the ECU specialist may see a patient at Central Prison in Raleigh, then switch to a rural hospital almost 200 miles from Raleigh. This is all accomplished without the physician leaving the telemedicine suite.

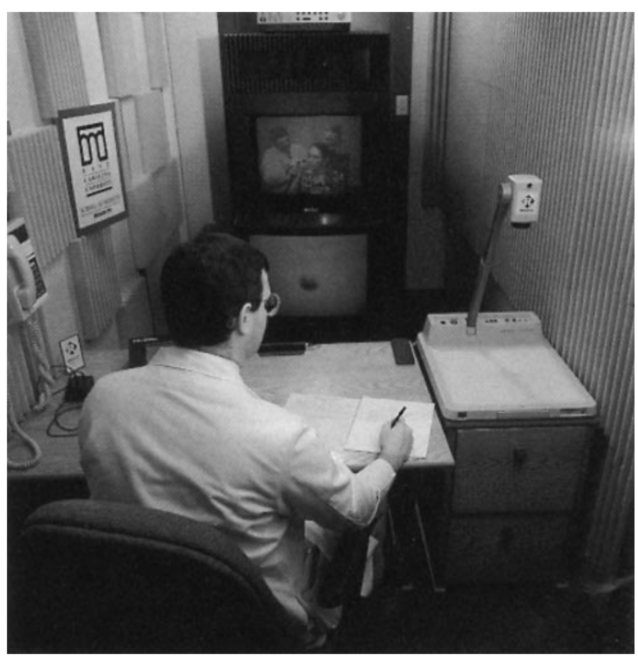

Figure 1 The physician workspace at the ECU School of Medicine. (Photo by Richard K. Davis.)

The next design criterion for our program is that the network must support production telemedicine. In other words, the system must efficiently support scheduled routine consultations, urgent consultations, distance learning, and continuing medical education events. Our multipoint and point-to-point network allows for multiple events to occur simultaneously. For example, while a dermatologist examines a patient at one spoke site, a cardiologist may be performing an examination at another site. At the same time, physicians in rural communities may be participating in a continuing medical education event such as grand rounds via the telemedicine network. Further, our network interconnects a variety of telecommunications services, including T1, microwave, ATM, SW56, and POTS. This contrasts with most telemedicine programs, which use only one telecommunications service, typically T1 or integrated services digital network (ISDN).[3]

Finally, important criteria regarding the physical setup of the telemedicine equipment shaped and continue to shape our telemedicine program. There are two guiding principles. First, the telemedicine equipment must have minimal impact on the current physical plant and yet still be an optimized space for on-line consultations. Second, the space must be quiet and private, with minimal distraction. To meet these important design criteria, we built a custom-designed suite of four 6- by 12-feet, sound-proofed booths in which the physician has access to a full-range of diagnostic tools and can conduct examinations with few distractions.

Lessons Learned

Building a health information infrastructure that includes components of telemedicine requires much more than hardware and software. There is a clear need for a high level of teamwork among all network participants (physicians, engineers, nurses, technicians, etc.).[4,5] In a new field such as this, where all participants may not share the same terminology or understanding of the technology, good interpersonal communication is especially important. Due to the newness of this technology, it is also important to consider the need for "techno-social integration." In other words, it is not enough to put the equipment in place and say, "Here it is; use it." Telemedicine is a new way of communicating, and the socio-cultural component cannot be overlooked. To address this issue, we conduct frequent demonstrations and "test drives" with physicians, nurses, administrators, and the community to introduce this new way of communicating and transmitting medical information. By introducing telemedicine technologies to a broad base of health care system participants, we hope the technology will gradually be accepted as a common component of health care in rural areas. However, we do not expect every patient, physician, nurse, or administrator to be enamored with this new technology. As others have also found, it is important to use a phased approach in developing a telemedicine infrastructure.[6]

Another important lesson regards staffing. Staffing needs in establishing a telemedicine network were greater than we anticipated. We found that implementing a multipoint infrastructure requires designated staff at each site. For the daily operation of our network, we employ three engineers and two program coordinators at the hub site (ECU School of Medicine) and part-time nurse coordinators at each spoke site. Until this technology is as ubiquitous and reliable as standard telephone service, there will be a need for troubleshooting and equipment adjustment. Equally important to the overall success of the network are the medical director, technical director, physicians and nurses at both the hub and spoke sites, and the administrative support staff.

We have also learned the importance of scheduling in telemedicine. Because we have multiple sites and limited resources, a very organized and systematic approach to scheduling telemedicine activities is imperative. Therefore, we implemented an on-line scheduling system in which the rural sites can electronically request specialty consults. The on-line system tracks the availability of the telemedicine equipment at both the hub and spoke sites and does not allow a resource be scheduled if it is already scheduled. Because the physician booths in the telemedicine suite and videoconferencing rooms at ECU can be connected to various sites, it would be very easy to cross-book resources without an on-line scheduling system.

Finally, we have learned that the technical requirements for this kind of network are also relatively new to local telephone companies. Therefore, we designed and built our own alarm system to inform our engineering staff when the T1 and ATM lines go down. While phone companies have good error detection in place for standard phone service, they are not as dependable for detecting problems in high-bandwidth transmission of low-frequency signals.

Next Steps: Telemedicine Meets the Internet

We believe that multimedia applications are an important part of the future of health information. Along with traditional paper-and-pencil information, the digital revolution has converted audio, video, and high-resolution still images into readily transmissible data. The power of these new technologies is that a wide spectrum of data can be made accessible to physicians and other health care providers regardless of the proximity of the patient. At ECU, we have demonstrated the feasibility of distant medical consultation. The next step is to incorporate distant consultation with other forms of health information to give physicians full access to all necessary information in treating patients. Until very recently, a model of healthcare information that incorporated *all* forms of data, including, audio, video, and high-resolution still-images, was almost unimaginable. However, we feel the Internet may provide the backbone to make this new model of health care informatics a reality.

The necessity of computer-based patient records has become an accepted reality and much work has been done to create electronic medical record systems.[7] However, communicating among the wide variety of institution-specific electronic medical record systems is still very problematic. Ziegler compares the current state of health information networks with the American railroad system in the early nineteenth century.[1] With each railroad system maintaining its own track, there was no uniformity in rail service. In 1863, Congress established standard rail widths, which eventually led to the standardization of rail service. Currently, health information and telemedicine networks are much like the early railroad systems—they do not share common operating systems and standards. The WWW has the potential to provide a common interface to current health information systems, and the Internet will eventually have the bandwidth to transmit most of the health information (financial, administrative, clinical, audio, video, and still image data) described above.

The feasibility of incorporating multimedia in a comprehensive, Web-based network is rapidly becoming realistic. Kohane et al. have already demonstrated a prototype of a National Electronic Medical System via the WWW.[8] Further, Internet security issues are being resolved by using firewalls and passwords with time limitations. Although much more work must be done on store-and-forward image transfer via the WWW, the capability to transmit medium- to high-resolution clinical images via the Internet has been demonstrated.[9] Further, the Internet currently provides a wealth of clinical reference information.[10] However, to increase the usefulness of this aspect of the Internet, custom filters need to be built that facilitate easy and rapid access to specific health care information. The ECU telemedicine program is enlisting the help of librarians and Web experts to develop these Internet filters and support tools.

Conclusion

We believe the future of telemedicine is extremely promising. On the physician's desktop, in small, rural clinics, in large, inner-city clinics, in the patient's home, or wherever medical information is needed, the technologies to connect patient with provider are rapidly becoming a reality. At the ECU School of Medicine, our goal is to integrate these technologies into a comprehensive network of care. We have primarily used telecommunications technology for distant consultation and distant medical education activities. However, we believe that telemedicine must become fully integrated with traditional medical information systems to be more effective. By incorporating a Web-based electronic medical record system and other Internet-based applications in our telemedicine network, we hope to realize the potential of the digital revolution in health care.

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