Teledermatology: one application of telemedicine*†

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Telemedicine can be defined as the use of telecommunications technologies to provide medical information and services. This field has recently begun a period of explosive growth. Oregon's teledermatology program within the National Library of Medicine's high-performance computing and communications initiative is designed to generate much-needed basic and clinical research information about one specific telemedicine application. The background of this program is discussed, and the research objectives are described.

INTRODUCTION

Telemedicine can be broadly defined as the use of telecommunications technologies to provide medical information and services. This field has recently begun a period of explosive growth [1]. Although fewer than ten telemedicine programs existed in the United States in 1990, at least thirty-five states have begun telemedicine programs as of early 1994. The growth of clinical telemedicine is already creating a demand for information about the safety, effectiveness, and clinical utility of these technologies. The field is so new, however, that relatively little high-quality information currently exists. A database search in June 1994 on the CD-Plus current MEDLINE file with the subject heading "TELEMEDICINE" yielded only sixty citations.

The telemedicine portion of the National Library of Medicine's (NLM) high-performance computing and communications (HPCC) initiative is designed to generate much-needed basic and clinical research information about various telemedicine applications. The Oregon HPCC project expects to demonstrate how teledermatology can enhance the provision of dermatologic care to rural areas of the United States.

OVERVIEW OF TELEMEDICINE

Telemedicine is not a homogeneous entity. Rather, it is a diverse collection of technologies and clinical applications. The defining aspect of telemedicine is the use of electronic signals to move medical information from point A to point B. Telemedicine systems can therefore be characterized by the type of information sent (radiographs, clinical findings, etc.), and the means used to transmit it. Many areas of medical practice have potential telemedicine applications. Image transfer is an integral part of radiology and pathology. Specialized tests such as electroencephalograms and electrocardiograms can be captured and remotely displayed. Even interactive examinations, such as psychiatric interviews, are possible. Telemedicine can therefore be useful in any situation in which physical barriers prevent the ready transfer of information between patients and health care providers, and the immediate availability of information is key to proper medical management.

There are nearly as many ways to relay telemedi-

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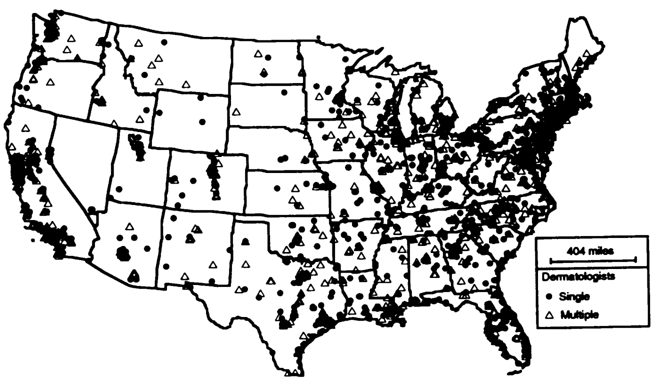
cine data as there are applications. Although telemedicine is frequently described in terms of two-way interactive televideo (IATV), disparate medical problems may have quite different information and transmission requirements. Ordinary telephones are cheap, ubiquitous, and perfect for many uses, including quick consultations and some patient management. Fax machines are routinely used to send electrocardiograms and medical records. Transmitted still images are an excellent medium for viewing skin conditions, radiographs, pathology images, and fundoscopic findings. More complex applications, such as neurological examinations and remotely assisted surgery, require at least one- or two-way full-motion video. Choosing and using the most appropriate communications technologies for each medical application is important, because equipment and communication costs are directly proportional to the amount of information to be transmitted. The carrying capacity needed to transmit a given amount of information, or "bandwidth," still serves as a practical limit to the size, cost, and capability of today's telemedicine systems. An uncompressed, full-motion, two-way interactive video requires nearly 1,300 times more bandwidth than a conventional telephone call!

After decades of pilot and demonstration projects, telemedicine moved from relative obscurity to a period of rapid growth in the early 1990s. Like many recent changes in health care, the primary stimulus for change has largely come from outside the medical profession. In the case of telemedicine, the most important driving factors are arguably based on the politics and economics of mandated access to competitive managed health services and the electronic "information highway." Telemedicine is seen as a tool that can help manage the medical and financial risk of patient care in rural and other underserved areas. Providers with telemedicine capabilities are hoping to become more competitive in winning health care contracts, to reduce the health risk of caring for patients in rural areas, and to provide relatively low-cost specialty services to areas where full-time staffing is generally impractical or uneconomical.

THE NEED FOR TELEDERMATOLOGY IN RURAL AREAS

Skin diseases are a serious and persistent problem in the United States and around the world. Approximately eighty million U.S. residents have at least one clinically significant skin condition [2]. Of those affected, one third consider their condition to be a substantial social or physical handicap. Skin cancers are the most common malignancies in the United States, and their incidence is continuing to rise around the world [3-5]. The direct and indirect costs of this illness amount to many billions of dollars annually. An

Figure 1
Distribution of dermatologists within the continental United States, 1991–1992*



* Source: The American Academy of Dermatology.

estimated 2% of total national health expenditures are directly related to diseases of the skin and connective tissues [6]. Unfortunately, proper diagnosis and treatment of skin conditions are very difficult tasks, especially in remote areas. The lack of available dermatologic expertise in rural areas makes them especially susceptible to skin-related death and disability. As shown in Figure 1, large areas of the United States are many miles from a source of dermatologic care. For example, there are only two dermatologists in the entire eastern two thirds of Oregon [7]. In fact, for many rural residents, the nearest dermatologist is literally hundreds of miles away. The resulting effects on health care are troublesome for rural physicians and patients alike. Rural and small-town patients with skin diseases have few health care options and may not receive adequate treatment without long and expensive journeys to the nearest metropolitan center. Well-trained primary care providers are sometimes unable to provide adequate dermatologic care and have no source of assistance for difficult or emergency care or continuing education to improve their diagnostic skills.

The Oregon HPCC teledermatology project is designed to bridge this health care gap and improve the delivery of dermatologic care by innovative use of high-speed computers, wide-area computer networks, and full-color digital image storage for both archival and educational purposes. The most efficient and practical ways of improving dermatology services are by making the clinical expertise of metropolitan dermatologists available to rural providers and patients where and when it is needed and by improving the diagnostic abilities of primary care physicians. Those can be achieved by using dermatologic digital imaging as both a medium for communication and a method of education. When primary care physicians are faced with unusual or complicated skin problems, a compact, moderately high-resolution color camera will be used to create a digital image of the affected area at nearly any desired magnification. These images are then transmitted via wide-area network (WAN) to a consulting dermatologist at Oregon Health Sciences University (OHSU) for review and discussion with the primary care physician. The system is store-and-forward rather than interactive, so there is minimal disruption of the normal clinic routine at either end. Speed of reply can be tailored to the urgency of the situation. Consultations between the referring and consulting providers may be conducted immediately with the patient present or at a later time.

THE OREGON HPCC TELEDERMATOLOGY RESEARCH PROGRAM

The safety and efficacy of telemedicine are a function of its ability to transmit medically important data. The data transmitted must be complete and accurate enough to make correct diagnoses. Measuring a system's ability to capture and transmit clinically relevant data is the most basic form of "technology evaluation." Is the resolution high enough to detect subtle abnormalities? Is the rendition of color accurate? Is the information transmitted complete in itself, or is additional data (such as history or lab values) necessary to make the proper diagnosis? The utility of a system relates to the effect it has on the overall provision of medical care in rural areas. Does the provision of care materially improve after the system is installed? Are the resulting treatments less expensive or more effective when the system is used? Measuring all of these factors is important. Even the safest and most effective system will be of limited value if it does not have a measurable impact on medical access or the quality of care. The teledermatology program at OHSU incorporates research in all of these areas.

Basic research

Although digital imaging is increasingly being used in dermatology, very little is known about dermatologists' ability to accurately diagnose skin conditions using electronic images [8]. The basic research component of this project is designed to verify this ability to make accurate diagnoses based upon digital images, and define the minimum technical specifications needed to ensure that diagnostically important information is captured. The final result will be an optimal, low-cost, store-and-forward (as opposed to real-time) teledermatology system that will be subjected to field testing in the clinical phase of the project. This will be done in a series of steps.

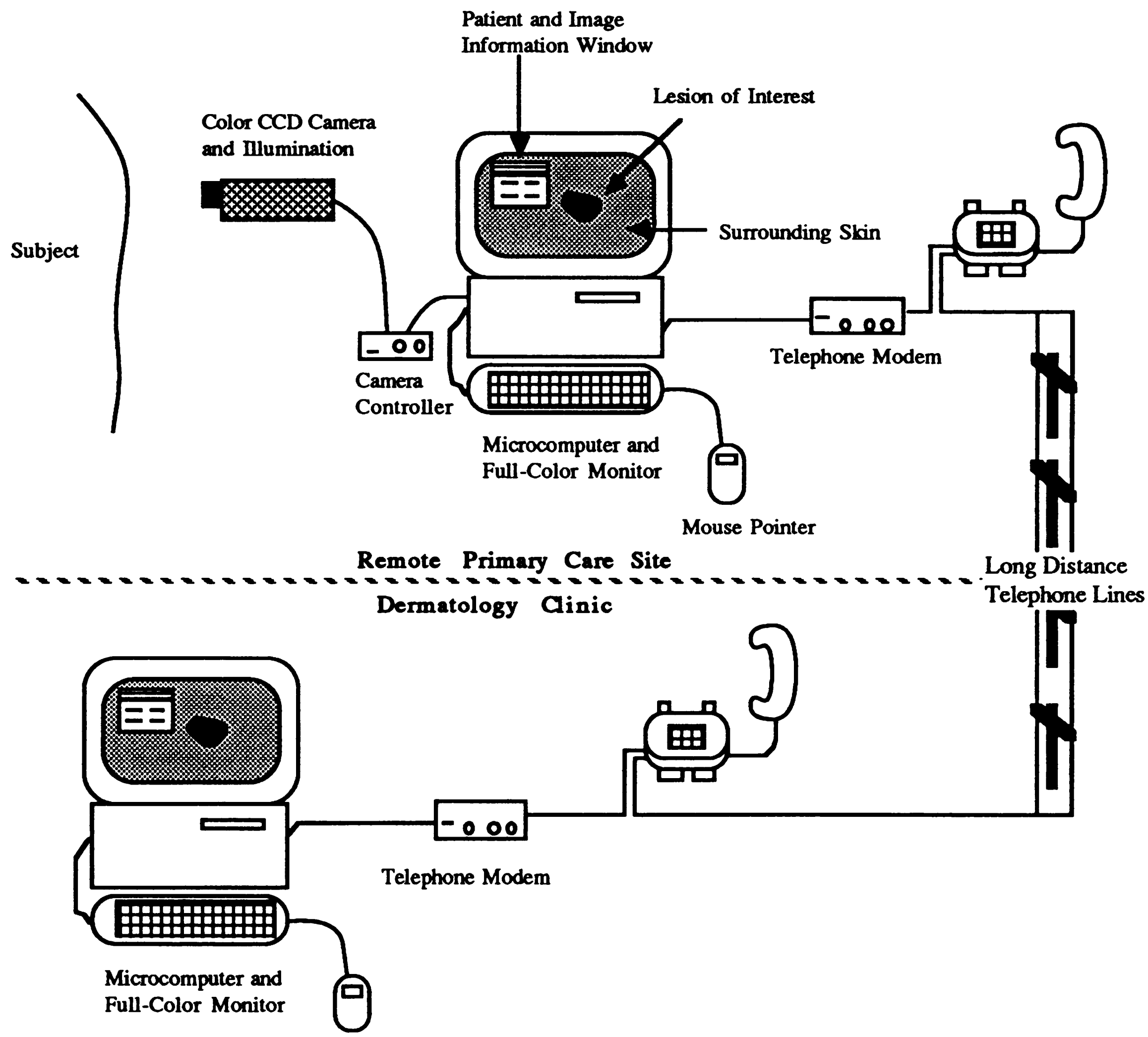
Step 1. Prospectively obtain at least 1,500 high-quality photographs of clinically important skin conditions for which the diagnosis has been or can be definitely established. The quality of any method of digital imaging can be compared against a photographic standard for its ability to relay diagnostically important information. Photographs in the collection will then be arranged into a number of distinct "logical competitor sets" of morphologically similar conditions [9]. This library will serve as the basis for subsequent image experiments.

Step 2. Using clinical photographs with proven diagnoses as a "gold standard" for dermatologic imaging, determine the minimum digital image resolutions needed to convey critical diagnostic information with a high degree of reliability. This will include an analysis of both spatial and color resolution requirements. Receiver Operating Characteristic (ROC) testing will be used. The basis of ROC analysis is relatively simple. Recognition of a given morphology or disease in an image is a result of visually analyzing the image for diagnostic clues. These clues (or signals) are either present or absent and allow an observer to say that the condition in question is either present or absent. Although variations in observer sensitivities tend to bias conventional "accuracy" computations, ROC curves will document diagnostic accuracy at any given level of sensitivity [10].

Step 3. Assess the informational, computational, and transmission trade-offs of the most promising color image compression schemes. The issue of whether any degree of informational loss due to compression is acceptable has been extensively debated, and the answer is still unclear. Although it has been repeatedly asserted that any loss of information is unacceptable in medical applications, there is little or no experimental or clinical evidence that this is the case. It is likely that skin images of some conditions may be compressed more than others without loss of important information. An attempt will be made to establish the relative advantages and disadvantages of various image compression schemes as they specifically relate to dermatologic imaging and image transmission.

Step 4. Once minimum acceptable resolutions are determined by ROC analysis, gauge the acceptability of standard, nonstandard, and emerging image acquisition and storage technologies. These may include a variety of image formats, such as VHS and S-VHS video television formats, eight-bit (256 color), twelve-bit (4,096 color), and twenty-four-bit (16.7 million

Figure 2
A typical store-and-forward teledermatology system



color) digital imaging, high-definition television (HDTV), and, if possible, advanced digital television (ADTV), for use in clinical teledermatology, dermatology education, and imaging research applications.

Step 5. Examine efficient, economical, and user-friendly communication techniques for use in teledermatology imaging, utilizing commercially available hardware for WANs, commercially available software, and, where needed, custom software specifically developed for this project. The major guidelines for this project include efficiency, cost-effectiveness, use of commercially available hardware and software, and system integration.

Step 6. Using the data collected, assemble a prototype teledermatology imaging and transmission system that has been optimized to be maximally informative, is easy to use, and can be assembled at a relatively low cost. A diagram of a typical store-and-forward equipment configuration is shown in Figure 2. As shown, the system will consist primarily of common, readily available components and technologies. Once assembled, teledermatology imaging and transmission systems will be installed in three primary care clinics serving rural, dermatologically underserved areas of Oregon. The sites chosen represent a cross-section of the rural areas found throughout the state, and they are widely disbursed geographically.

Clinical research

The utility of the teledermatology system developed in the basic research phase of the project will then be evaluated in a two-year clinical trial. The purpose of this trial is to establish whether this technology will improve the process of health care delivery by increasing information flow and reducing isolation; improve the provision of dermatologic care; and increase the primary care provider's knowledge of dermatology. As in the basic research phase, the clinical evaluation will proceed along several fronts for the duration of the project.

Step 1. Objectively test both dermatologists and two groups of primary care providers in rural areas for their ability to recognize clinically important skin cancers by use of color transparencies or digital images. One important goal of this project is to increase overall ability of primary care physicians to recognize skin cancers and other important conditions. Success will be measured by pre- and post-intervention testing of diagnostic ability.

Step 2. Test and compare the baseline dermatologic knowledge of clinical dermatologists and two test groups of primary care physicians. This will be done by use of multiple-choice written examinations that are designed to test knowledge of the prevention, diagnosis, and management of skin cancers and other important skin conditions. Pre- and post-testing will be performed on primary care providers participating in the project and nonparticipating control providers.

Step 3. Provide teledermatology consultation services to these primary care physicians for a period of two years, collecting data on use patterns, information flow, and alteration of treatment plans. Together, the Oregon rural consortium sites and their associated clinics are the primary medical care providers for more than 47,000 people in Oregon, California, and Nevada, and handle nearly 135,000 outpatient visits per year. Approximately 5%–10% of these contacts (between 6,500 and 13,000 visits per year) are for primary or secondary dermatologic complaints. The experience of these primary care physicians and the available literature both suggest that approximately one third of these cases (3,372 visits per year = sixty-five cases per week) will represent diagnostic or therapeutic difficulties for which consultation would be valuable, and approximately one fourth of these cases, or fifteen to twenty cases per week, will represent skin cancers [11].

Step 4. Measure any improvement in the provision of dermatology services at each site that is the result of installing the teledermatology system. The project's success can be gauged not only by the extent to which raw knowledge of skin diseases is improved at the rural sites but also by the degree to which three desired missions are accomplished: providing services and improving the provision of dermatology care in rural areas, improving continuing dermatology education for rural physicians, and reducing the sense of isolation currently felt by consortium primary care providers. Progress will be tracked in all three of these areas by gathering accurate and (where possible) quantifiable data before, during, and after the demonstration period. Data collected on images, diagnoses, and treatment plans will be entered into a computer database shared among sites as part of the regular process of image capture, transmission, and consultation. This strategy greatly increases our chances of obtaining the results needed to measure the benefits of the program and, in turn, increases the probability of successfully transferring these techniques to other rural areas.

CONCLUSION

Telemedicine research is of increasing importance to both providers and consumers of medical information and services. Remarkably little is known about the safety, efficacy, and utility of telecommunication technologies in remote medical diagnosis and therapy. The Oregon HPCC teledermatology project is an attempt to definitively establish the technical and performance specifications for a telemedicine application for one specific area of medicine. The study design emphasizes low-cost solutions that can be easily maintained and operated even after the study period ends. The Health Care Financing Administration is actively considering reimbursement for telemedicine consultations. Payment for services would make future use of the system quite likely.

While long-term projects of this type are extremely valuable, many of the most important questions about telemedicine are difficult to answer if research is restricted to a relatively small number of remote research sites. We anticipate that many future studies will require collaborative efforts linking many remote sites at multiple institutions. Efforts are already underway to establish an infrastructure for supporting cooperative telemedicine research [12].

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