Chapter 8

Executive Summary

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INTRODUCTION

IN AUGUST 2001, more than 200 participants, from North and South America, Africa, Europe, and Asia, took part in an International Symposium on the State-of-the-Art in Telemedicine/Telehealth in Ann Arbor, Michigan. The University of Michigan Health System and World Health Organization cosponsored the gathering with additional support from a number of other entities.[a] The goals of the symposium were to: (1) assess the state-of-the-art in telemedicine/telehealth (hereafter referred to as telemedicine) and (2) develop a set of recommendations for research and policy to advance the field at the regional, national, and international levels. After a brief discussion of the role of telemedicine in health care, this report provides a summary of the assessments and recommendations produced by the symposium on the following topics: clinical applications, public health, medical education, organizational models, technology and diffusion.

The symposium adopted a broad definition of telemedicine to incorporate the remote delivery of health services and health information via information technology, and telemedicine systems to consist of integrated networks offering such services.

TELEMEDICINE AND HEALTH CARE

In 1981 and again in 1994, the World Health Assembly identified the need for equity of access to essential health care services as a desideratum in national and international health policies. Accordingly, available health resources should be equitably distributed so that no one would be denied access to essential health care. In *Healthy People 2010*, the U.S. Department of Health and Human Services identified several action areas, each containing concise goal statements and specific objectives, all aimed at improving health.

The promise of telemedicine lies in its potential to enhance accessibility to care for remote, isolated, and confined populations by reducing the need for travel to specialty centers, and by reducing appointment waiting times. Simultaneously, telemedicine technology can contain medical care cost inflation by effective substitutions and possible reductions in the intensity of care, and by enabling more patients to receive appropriate care in their home communities. The ready availability of specialty care, information, and resources via telemedicine can also improve the distribution of quality by according remote providers ready access to specialist colleagues at tertiary care centers and up-to-date information, and con-

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tinuing education. Finally, the equitable distribution of telemedicine can bridge the medical care "divide" between countries and promote the globalization of health care, thereby contributing positively to improving access to health care for people everywhere and the global goal of "health for all."

Despite its remarkable promise, definitive research necessary to substantiate the role of telemedicine is still considered incomplete. This situation derives from a number of problems, including: (1) short-term funding for projects without plans for long-term sustainability; (2) lack of mature telemedicine programs and associated comprehensive, scientific evaluations; (3) limited acceptance by practitioners and administrators; and, in the United States particularly, (4) state-based protectionism and inconsistent federal policies and financing regulations.

CLINICAL APPLICATIONS OF TELEMEDICINE

Whereas telemedicine has been applied in practically all areas of clinical medicine, the vast majority of applications are represented in the following fields: radiology, pathology, psychiatry, dermatology, cardiology, ophthalmology, surgery, pediatrics, and emergency medicine. This group of clinical applications varies by "maturity," defined on the basis of the quantity and quality of related research, development of standards and protocols, and acceptance by the profession. The order of their presentation here is based largely on these criteria. Subsequently, each clinical application is assessed in terms of published research pertaining to performance attributes such as technical feasibility; diagnostic accuracy, sensitivity and specificity; clinical outcome; and, cost effectiveness.

Teleradiology and telepathology are the most mature specialties due, in large part, to: (1) The fact that these specialties rely heavily on imaging rather than direct patient contact; (2) explicit standards for quality assurance have been established in these areas, and they are accepted by the professions; (3) there is a wealth of national and international scientific evidence demonstrating their clinical effectiveness and potential cost effectiveness. In addition, these services are reimbursable under U.S. government

rules, all of which consequently led to greater professional acceptance and diffusion.

Improvement in teleradiology and telepathology can be made in terms of developing new and user-friendlier equipment. In telepathology specifically, there is a need to develop additional protocols, methodologies, and technology for remote image-field assessment, and to improve the quality of static-image transfer.

Telepsychiatry, teledermatology, telecardiology, and teleophthalmology

Despite the large amount of research and development in each of these specialties, there has not been a commensurate degree of acceptance by the respective professions. This may be caused, in part, to a perception of limited evidence and definitive cost-benefit evaluations, which are often precluded by the constrained funding for research projects.

Telepsychiatry is among the most commonly used applications involving real-time consultations. Research has consistently demonstrated a high degree of concordance in diagnostic reliability between telepsychiatric and in-person consults. Moreover, some studies reported some cost savings in telepsychiatry as compared to in-person care.

Because of the inherent nature of this practice, telepsychiatric consultations require real-time synchronous links with higher bandwidth. Psychiatrists have to be able to observe emotional and behavioral manifestations of clients for diagnostic and treatment purposes. The higher costs associated with the technological requirements for effective telepsychiatry and the limited scope and duration of many projects precluded definitive conclusions regarding its cost-effectiveness.

Teledermatology relies heavily on visual imagery and high-quality images have assisted in the development of this specialty. Research in this field has demonstrated a high level, although not perfect, trend of diagnostic concordance between teledermatology and in-person consultation. In several studies, diagnoses were not significantly different between teledermatology and conventional dermatology, especially when performed by experienced clinicians. Problems identified in this application pertained to increased length of synchronous

clinical examinations due to the time necessary for capturing transmissible images and difficulty in evaluating dark-skinned individuals.

The critical importance of timely diagnosis, and the high prevalence of morbidity and mortality related to heart disease make telecardiology especially appropriate. A substantial body of national and international literature points to successful transmission of echocardiograms and cineaortography (angiograms). Remote sphygmomanometry (blood pressure reading) is prompted by the potential to install home monitoring devices for the control of hypertension and reduction in cardiovascular morbidity and mortality. Several studies reported small rates of misdiagnosis, on the order of 5% or less, but more timely diagnosis, considerable savings derived form reductions in patient travel, and prompt transfer of patients requiring surgery. In at least one instance, enhanced image display resulted in a more effective blood flow analysis and lesion identification when compared to conventional cardiac care.

Teleophthalmology seems well suited because optical and imaging devices provide the basis for ophthalmic evaluations, and ophthalmologists tend to rely on diagnostic images in assessing, diagnosing, and treating eye disease. Several studies have demonstrated the clinical feasibility and effectiveness of teleophthalmology. Generally, agreement between diagnosis by means of teleophthalmology and conventional diagnosis has been high. Considerable efforts in Europe and the United States have focused on detecting diabetic retinopathy in adults and children.

Telesurgery, telepediatrics, and emergency medicine

This last group of specialties is classified as emerging in that efforts in each are relatively recent; pertinent research is limited, as is professional acceptance.

Interest in telesurgery is probably spurred by the success of laparoscopic and arthoscopic surgical procedures, miniaturization, and robotic technology. Telesurgery subsumes both telementoring and actual remote surgery. The former involves surgical specialists directing remote providers in surgical procedures, while the latter involves the actual performance of surgery by a surgeon remote from the site of the operation. Despite obvious interest in telesurgery, definitive research remains scarce. Studies have been largely descriptive and somewhat anecdotal. Questions of patient safety, provider liability, and cost of robotic equipment/instruments are currently limiting the definitive investigation and proliferation of telesurgery.

Interest in telepediatrics, as in other specialties, derives largely from a geographic imbalance in the distribution of qualified providers. Telepediatrics, to date, has focused on care for chronically ill children and those with special health care needs. As with telesurgery, the majority of the literature is largely descriptive and emphasizes patient/family/provider attitudes and perceptions. Nevertheless, in a randomized clinical trial, Internet videoconferencing led to substantial cost reductions related to shortened hospital stays for very low birthweight infants. Telepediatric care has been demonstrated to be both feasible and acceptable to parents of children who are poor, uninsured and/or live in remote areas where these issues were explored.

As recently as 1994, emergency telemedicine was recognized for its potential to contain emergency medical costs and improve patient management in trauma care. Telemedicine has been used successfully in several areas of emergency medicine including "off-hours" interpretation of radiographs and computed tomography (CT) scans, remote mentoring and consultative services for onsite trauma centers, and follow-up care for trauma patients returned to their communities after initial stabilization and management in tertiary care centers. In addition, in-transit (prehospital) emergency medical services comprise an essential component of emergency telemedicine. Despite the considerable potential embodied in the emergency telemedicine concept, its diffusion has been slow.

Among problems identified is the need for timely coordination of equipment and personnel at both remote and consulting sites at unpredictable times and of unknown duration. Technology requirements for remote assessment of various types of trauma are considerable, as are reliable transmission modes.

Scientific research in clinical emergency telemedicine is especially lacking. However, in the only randomized clinical study, no significant differences were observed between experimental and control groups in terms of return

visits, need for additional care, physician-patient interaction and overall patient satisfaction.

Rare diseases. While not included in the list of clinical applications considered here, mention should be made of using of telemedicine to provide services for patients with rare diseases, defined generally in the United States as diseases afflicting 200,000 people or less. For many people suffering from diseases such as cystic fibrosis, sickle cell anemia, and Addison's disease, treatment is often complex and requires specialist care. Often, access to such specialists is problematic. Telemedicine could assist in medical diagnosis, treatment, and maintenance programs, thereby coordinating the delivery of care as well as reducing the need for travel.

Homecare. Finally, mention is made here of "telehome care," which refers to the provision of care electronically in the home. It is spurred by the aging of the population, reduced length of hospital stays, and increased outpatient procedures. Telemedicine can provide new opportunities for more comprehensive and monitored health care in the home environment, which includes remote monitoring of blood pressure, electrocardiogram (ECG), glucose, forced vital capacity, and other vital data. The potential for telemedicine to contribute to cost containment and cost savings is considerable.

Recommendations

Clinical applications hold considerable promise for improving access and quality, as well as containing cost containment across the spectrum of clinical applications. Teleradiology and telepathology are already well established, mature applications that have demonstrated their value and are being widely accepted into the mainstream of medical care. It is in the other clinical specialty areas that research and action agendas must be engaged in order to provide the necessary scientific evidence for a reasoned, merit-based deployment of telemedicine. These recommendations are organized by topical areas.

Technology

- Appropriate extant technologies should be adapted/adopted in clinical applications, and they should be continually monitored and updated as new products and services become available.
- Standards and protocols, such as those for teleradiology and telepathology, must be developed by appropriate professional societies and implemented by each clinical specialty.
- A repository of technology research literature should be established in order to ensure the efficient development of specific technologies and synergistic research development.

Human factors

- Research must assess the human-technology interface for each clinical application in an effort to reduce technology-based barriers for providers and patients.
- Research must be conducted in each clinical specialty to determine the extent to which telemedicine technology is appropriate, suitable, and productive in improving patient outcomes.

Research

The following strategies represent some of the most pressing action necessary to facilitate progress:

- Determination of research priorities in clinical applications including clinical effectiveness and safety.
- Support for large-scale, multi-institutional, comprehensive and long-term research utilizing randomized clinical trials, large data sets and/samples.
- Cost sharing, when necessary, among funding agencies for large-scale research among a consortium of research institutions.
- Development of guidelines regarding:
  - Patient safety
  - Provider proficiency, certification
  - Clinical protocols
  - Continuous monitoring for quality assurance
- Integration of clinical applications into medical school curricula.
- Establishment of clinical telemedicine boards within professional societies for the purpose of overseeing research development, pro-

mulgation of research findings, development of appropriate protocols, guidelines, and curricula for medical schools and continuing medical education.

- Development, testing, and implementation of successful organizational (infrastructure) models appropriate to support teleclinical activities within and between provider institutions, and within regional telemedicine networks.

- Efforts must be directed toward enlarging and extending the research base through:
  - Expanding cooperative and coordinated multi-institutional research efforts.
  - Providing funding for long-term broad-based scientific research efforts in order to aggregate the volume of research necessary for rational public policy decisions.
  - Clinical research must proceed from initial "proof of concept" research to that which promulgates evidence-based guidelines for implementation.
  - Research must be conducted that demonstrates the safety and efficacy of clinical applications.
  - Professional societies must be directly involved in development of their respective applications as well as with interrelated developments in other clinical specialties.
  - In addition to sponsored research, funding agencies should support training grants and fellowships in clinical applications.

PUBLIC HEALTH APPLICATIONS

Public health applications of telemedicine range from epidemiologic surveillance through the development of appropriate geographic information systems and deployment of remote sensing technology to health promotion/disease prevention. The development, deployment, and evaluation of these applications must take into account the wide variation in contextual factors, including the socioeconomic, educational and cultural environments where these systems are implemented. The challenge here is to obtain, transform, and transmit knowledge to promote the health and well-being of people at the local, national and international levels.

Epidemiological surveillance is growing rapidly, in part, because of the development of geographic information systems (GIS) and remote sensing technologies. GIS technology provides for the spatial-temporal analysis of disease related information by spatially registering data within a single processing environment. Recent advances in interactive visualization and custom modeling have increased the utility of GIS in disease surveillance. Also, space-based remote imaging and sensing systems are capable of providing high-resolution data for small or large areas. Multispectral imagery produces accurate land cover/land use maps for epidemiologic analysis.

Taken individually and together, GIS and remote sensing/imaging permit the management and convergence of various disease surveillance activities in the public health sector. They provide data on the geospatial and temporal trends in disease incidence and prevalence; risk areas for potential epidemics; and, the corresponding populations at risk. Most importantly, these technologies permit intervention planning and assessment of prevention strategies. Hence, they constitute an important source of information to guide and formulate public health policy and intervention program.

Vector-borne diseases remain a serious threat at the regional, national, and international levels. Therefore, it is important to assess the complex relationships between environmental factors, such as changes in climate, vegetation, hydrography, and land use patterns and the emerging vector-borne infectious diseases. Remote sensing and GIS technologies use aggregate multiple data sets from a variety of sources to assist the development of predictive climatic environmental models. The models, in turn, provide a variety of risk scenarios and remediation measures for rapid and efficient allocation of resources. A number of studies already have demonstrated the potential of these models in specific risk-environments.

Essential to the success of these efforts is development of a decision support management system. Such a system comprises four elements, namely (1) planning (environmental monitoring, modeling, and forecasting); (2) mitigation (resource need forecasts, economic impact models, social stability models, and ac-

tion plans); (3) response (medical attention, vector control, population alert/education), and (4) recovery/preparedness (restoration of environment, elimination of toxic/disease material, educational outreach, inventory of resources).

Health promotion/disease prevention

Information technology can also be used effectively to inform, influence and motivate individuals, groups, and organizations to adopt healthy lifestyles. Interactive health information can be valuable insofar as health literacy and knowledge are required for assuming personal responsibility for health and greater health "self-management." Established interactive health communication (IHC) systems can: (1) provide access to individualized health information on demand; (2) enable informed judgments and health decisions and communication between providers and patients/families; (3) promote adoption of healthy lifestyle; (4) facilitate informed self-management of chronic health problems and supplement existing health resources through remote monitoring; and (5) enhance effective and appropriate utilization of health resources.

The success of IHC systems would ultimately depend on the appropriate utilization, identification of user benefit/cost ratios, and the reduction of barriers to broad acceptance. Enabling factors include: continued expansion in telecommunications capacity (power, speed, options); increasing computer literacy and universal access; promotion of consumer demand for health information and acceptance of shared-decision making with providers; and increased emphasis on prevention. Major barriers to general acceptance and use of IHC systems include: resistance from professional providers; limited reimbursement incentives; lack of individual/group access because of socioeconomic, educational, and cultural factors and lack of sufficient data demonstrating IHC system effectiveness. The potential benefits of IHC systems must be weighed against certain costs or risks. The latter may include inappropriate, inaccurate, or misleading information; delay in necessary treatment; damage to provider-patient relationship; breaches of privacy and confidentiality; misdirection in the development of resources; unintended errors; and, the possible introduction of a multitiered health system.

The research to date precludes definitive conclusions pertaining to cost containment and improved health outcomes sufficient for informed decisions. Evaluative norms, benchmarking, and research that compare IHC systems to traditional arrangements are lacking in this field. Therefore, in large part, the potential opportunities and benefits of IHC systems for health promotion/disease prevention remain as theoretical propositions waiting to be tested.

Promoting international public health

Since 1995, development of global health networks have focused on the goals of interoperability and standardization. At the same time, national and international health agencies have established health policy agendas that focused on disease prevention/health promotion. For the most part, however, international cooperation in this domain has been limited to developed countries, and considerable gaps remain between developed and emerging/reemerging countries. These gaps can be filled only through international collaboration and the advancement of global health networks.

Among developed countries, the United States, Canada, France, Germany, Italy, and other countries of the European Union, have engaged in a number of collaborative projects over the past decade. These projects focused on prevention, early detection, diagnosis and treatment of cancer, cardiovascular disease, emergency services, and so-called "smart (encoded health data) cards."

Recommendations

The recommendations pertaining to development of public health applications can be grouped into five categories: research/evaluation, cost, quality, legal regulatory issues and technology.

Research and evaluation

• Effectiveness and efficiency of epidemiological surveillance and IHC systems must be determined and defined.

- National and international information technology literacy must be addressed.
- Benchline and quantitative measures of progress in promoting health literacy, motivation, and health knowledge levels among the public must be developed and applied.
- Cultural differences in health practices and the potential role of information technology generally and telemedicine particularly must be determined and incorporated into the development of national and international networks.
- Systematic and comprehensive research agenda must be developed and supported.
- An international repository of data on all previous and ongoing telemedicine projects must be developed to promote resource sharing and encourage effective collaborative efforts.
- Suitability of telemedicine applications for specific health/disease sectors must be determined in order to establish the proper proportionate responsibility.

Cost

- Cost modeling must include assessment of the costs associated with storage, archiving, retrieval, and maintenance of digital assets, including consumer owned information.
- Benefit/cost analysis must provide public health policy makers with adequate economic data to allow informed policy and programmatic decisions.

Quality

- Quality must be operationally defined and an enforcement system established.
- Baseline quality indicators and measures must be applied to assess benefits.
- Appropriate educational programs in telemedicine must be introduced into medical school curricula.

Legal/regulatory issues

- Standards, such as those developed by the Interdisciplinary Telehealth Standards Working Group, devised to protect patients and health providers must be established for each telemedicine application.
- "Ownership" of medical records must be defined to provide guidelines and protection for both patient and provider.

Technology

- Development of technology to create secure network systems that provide continuous access, protect confidentiality, and adequate firewalls must be supported.
- Organizational/administrative frameworks and strategies must be developed to support and oversee national and international networks.

MEDICAL EDUCATION

Advanced information technology has the potential to transform medical and health education at the undergraduate, graduate, and professional levels. Some suggest that health education generally, and medical education in particular, is at a "crossroad" in terms of incorporating advanced information technology into the content and context of medical education.

The focus here is on those technologies that provide for the transfer of medical knowledge to remote medical students and professionals, so-called "distance education." Distance medical education has been facilitated by video-conferencing, Internet-based systems, and high bandwidth Internet (Next Generation Internet or Internet2).

At the undergraduate level, science education consists of classroom lecture/laboratory format, whereas clinical education extends to hospitals or ambulatory clinic-based rotations where students actively participate in diagnosis, treatment and follow-up care of patients. Continuing Medical Education (CME) is aimed at keeping physicians abreast of scientific and technical advances, promoting compliance with emerging standards of care, and assuring quality medical care.

Evidence suggests, particularly in CME, that learning is maximized in self-directed situations where physicians actively pursue topics of interest to them in appropriate contexts. Information technology can help create these situations and environments directly through providing (1) self-paced programs; (2) realistic

multimedia simulations; and, (3) custom-designed learning processes that include self-testing with immediate feedback and augmented learning opportunities.

Two-way interactive videoconferencing enables interaction between geographically separated faculty and students. In this setting, faculty and students see and communicate with one another in an environment where images and documents can be viewed and transmitted from place to place. This electronic interactive mode has been used in other contexts as well, such as infection control, radiology, and community health interventions. Indeed, there has been considerable international emphasis on developing international standards for this mode of training and practice of medicine. Several studies have demonstrated an "equivalency" between in-class and remote videoconferencing and telementoring in terms of student performance on standardized examinations, conformity with clinical protocols, as well as the convenience and efficiency of distance education. Significantly, distance CME has been judged to provide a "better" learning experience than that provided in the traditional format.

There is some evidence, however, that "remote" students were not fully "involved in dialogue" with the faculty, and that the success of this modality depended on the presentation of programs by a multidisciplinary team. Ideally, the team would consist of trained competent clinicians who are comfortable with the requisite technology, technology specialists, and distance learning education specialists. The team approach enhances the benefits of videoconferencing by providing remote access to specialists at centralized locations and expanding medical education to larger student populations.

Web-based learning

The advantage of Internet or Web-based medical education lies primarily in the increased access relative to the point-to-point structure of videoconferencing. The ubiquity of the Internet with its vast reservoir of information, potential for multimedia streaming and low cost adds to its appeal for medical educa-tion. Remote access to information sources including lectures, notes, and assignments; interactive self-directed exercises; access to related Internet sites; "chat rooms" that provide for synchronous as well as asynchronous discussion between faculty and students and among students, characterize Internet-based or "virtual" medical education communities, regardless of level. Recent advances in multimedia platforms have been made possible by the Next Generation Internet's expanded bandwidth. This, coupled with compression technology, has contributed to development and delivery of high quality and advanced imagery such as the National Library of Medicine's Visible Human Project. Several studies have demonstrated the equivalency of Web-based learning relative to traditional modalities. Perhaps more important, however, are several studies that demonstrated medical students' preference for Internet-based multimedia over printed materials. It should come as no surprise that students exposed to Internet materials performed much better than those using printed materials, although the length of exposure to the Internet materials was necessarily greater.

Generally, impediments to adoption of new educational technologies can be classified into three types: learner issues, instructor issues, and overall effectiveness. It is necessary to understand learners' familiarity with the requisite technology. Appropriate training in the use of this technology can facilitate the adoption of Web-based education. The technology must also be user-friendly, high quality, reliable, and effective. Many, if not all, of the same issues can be related to instructors using information technology. They must be experienced in and comfortable with the technology. This, in turn, will improve the likelihood of student acceptance of the modality.

Recommendations

Evaluation is paramount. To date, the "proof-of-concept" has been demonstrated, but there is a paucity of scientifically rigorous outcome studies. Evaluation is hampered primarily by the lack of adequate and reliable measurement tools, limited funding for systematic research and the dearth of research specialists in this

area. As with most evaluation strategies, research into videoconferencing and Web-based education technologies suffer from inherent limitations and generality stemming from variability in the level of applied technology.

Advanced information technology has the potential to enhance, facilitate, expand, and improve distance medical education in all areas and at all stages. Hence, it can provide unique opportunities for the improvement of medical education at the regional, national, and international scales. Several challenges lay ahead, including skills and preferences of instructors and students, curriculum design, technological configurations, cultural context, social and regulatory constraints. These challenges can be met only in conjunction with development and support for ongoing, systematic, comprehensive scientific evaluation programs to demonstrate the efficiency and effectiveness of the information technology in medical education.

ORGANIZATIONAL MODELS AND REGIONAL NETWORKS

Organizational models and regional networks constitute some of the essential building blocks in the development of telemedicine systems. Hence, it is of some import to determine the key attributes of these networks and the requirements for their success.

To date, there are few mature and self-sustaining telemedicine systems to ascertain the requirements for "successful" organizational models and networks. Nevertheless, telemedicine organizational models have been based on one or more of the following variables: geography, target or service population, and/or specific disease or medical specialty. In addition, telemedicine networks can operate either as open or closed systems.

Geographically based models provide medical and health services to people residing in a defined geographic area. Population-based models target the health care needs of a defined population, which receives health services on the basis of some type of entitlement, such as membership in the armed services, residents of institutions, or membership in health care

plans. These populations may be geographically discontinuous or located in a specific target area that helps define them, such as medically underserved areas. Specialty or disease-based models bring together clinical, research, and educational expertise to assist people with certain illnesses. Finally, some networks operate as open systems permitting global access to their services, and some operate as closed system limiting access to them.

Observers have identified some of the basic requirements for successful telemedicine networks, regardless of type. These include:

- A clearly articulated mission, with specified program objectives.
- Ongoing, systematic evaluation of processes and outcomes for quality assurance.
- Identification of service providers and specification of services to be provided to meet needs of targeted area and/or population.
- Development and deployment of technology appropriate to meet the needs of the program.
- Built-in organization/technology flexibility to adopt new technologies when available and appropriate.

As information technology continues to evolve, sound organizational models and their attributes must be identified, described and presented to potential telemedicine network developers, institutions incorporating telemedicine, and public policy makers.

At both the national and international levels, concern is being directed toward the geographic imbalance in access to quality health care among national regions and between countries, respectively. In both theory and practice, the creation of regional medical care systems is aimed at coordinating and integrating health resources and facilities within areas to promote both efficiency and equity. Efficiency is achieved by maximizing the locational efficiency of resources. Equity is achieving by giving people greater access to health resources. The appropriate development of telemedicine may achieve both efficiency and equity by obviating the need to relocate existing facilities, establishing new facilities at minimal cost, and creating flexible virtual regions

that rise above traditional geographic constraints.

The European Union and G7/8 countries are cooperating in developing several regional telemedicine test beds, but the most comprehensive efforts toward developing (international) regional hierarchical telemedicine networks can be found in Europe. Moreover, both developed and lesser-developed countries, including medically underserved areas of sub-Saharan Africa and Asia have organized such networks. At the same time, variations in information technology infrastructure, the culture of health, illness, and medical care, and language have hampered further development of these international networks.

Attempts to develop regional telemedicine networks have encountered other problems in applying the regionalization concept, including organizational control and national policy. "Virtual colonialism" may emerge as an issue if more developed countries try to control lesser-developed ones. Global regionalization in this case must acknowledge and accommodate the indigenous medical values and systems.

Recommendations

The ultimate success of regional telemedicine networks depends on making progress toward a nested hierarchy of regional programs that lead to national and ultimately international regionalized telemedicine networks. In order to make this progress, the following are recommended:

- National and international organizations should develop guidelines, regulations, licensing procedures as well as security and privacy protection for patients and providers, especially in emerging networks.
- Regional national and international networks should develop mechanisms for ensuring cooperation and coordination among extant and future telemedicine programs.
- Efforts must be made to increase equity and efficiency in the distribution of infrastructures in various countries with the aim of overcoming the "digital divide" within and between countries.
- International collaboration must be based on the principles of cultural diversity as well as variations in socioeconomic factors, and medical systems.
- Support must be provided for long-term development of large scale "test beds" to ascertain the true attributes of successful/unsuccessful regionalization models.
- Standards, protocols, and guidelines that are mutually acceptable to all members of proposed regional telemedicine networks must be developed.

TECHNOLOGY

Technology constitutes an essential feature of telemedicine, and it has been a driving force behind its development and evolution. Indeed, the ultimate success of telemedicine may depend on how well the various sectors of the health and medical care systems capitalize on and tie into the ever-expanding capabilities of advanced information technology. Among the many facets of technology and its development, technical design, technical applications, interoperability are critically important.

Technical design

Over the past 5 decades, information technology has changed considerably, and has been introducing a vast array of technical capabilities at an accelerating pace. Of particular relevance is the current multitude of high-speed service offerings applicable in the design of telemedicine systems. The Asynchronous Transfer Mode (ATM) is one of the new high-speed offerings available in today's telecommunications market. ATM systems are preferable when high data rate transfers are required. When coupled with the Synchronous Optical Network (SONET) configurations, ATM systems offer high-quality and low-delay conditions. Currently, fiberoptic systems are being designed to support data transmission rates as high as 40 gigabytes per second (Gbps) suitable for advanced telemedicine medical systems.

Currently, wireless systems are expanding at a fast pace, and their use in everyday communication has already surpassed wired systems. Wireless system can be classified as first or second generation. These network designs offer

services for analog voice as well as digital services up to 38 kbps. The next generation of wireless systems incorporates broadband, multimedia mobile operations with digital services ranging from 144 kbps across all environments and from 384 kbps pedestrian outdoors up to 2 Mbps indoors. Because the next generation digital cellular network will have faster and larger transmission capabilities, more complex medical services can be delivered reliably and without degradation of quality.

Technical applications

The range and complexity of telecommunications technology requirements vary with specific medical/health applications. As the next generation digital cellular network will have faster and larger transmission capabilities, more complex medical services can be delivered reliably and without degradation of quality.

With the exception of digital devices ranging from blood pressure monitors through compressed and full-motion video, the majority of vital sign medical devices require relatively low data-transmission rates. Capabilities currently offered by these systems, including first and second-generation wireless and basic telephone connections, would support the transfer of information provided error free or as "error detecting and correcting" processes.

Interoperability

Most of the early engineering work supporting telemedicine consisted of integrating "off-the shelf" components to specific clinical applications. Currently, several firms now provide customized telemedicine components. While efficient for the specific setting and purpose, systems comprising these components can be costly and inflexible. Adding, modifying or otherwise restructuring custom designed systems can be costly and time consuming. Moreover, most of these designs are configured as a single vendor system, and communication between vendors may be problematic. There is an increasing need to develop interoperable systems. The term "interoperability" refers the compatibility and ease of communicating between individual telemedicine systems and between nodes in a single telemedicine network. There are three levels of interoperability to be considered: (1) interaction between stations; (2) interaction between devices connected to a station's platform with that platform; and (3) interaction between components that constitute the platform with one another.

Interoperability in a complete system implies the integration and standardization of four kinds of devices available at each station, namely, those involving:

- User interface
- Medical process
- Patient record
- Communications

Recommendations

Any action agenda pertaining to telemedicine technology is based on the premise of closer cooperation between the information technology and health/medical care sectors. This cooperation is critical to the development of telemedicine systems to deliver health and medical care more fully, effectively, and efficiently, regardless of the type or scale of application being considered.

- Efforts should be directed toward developing fully interoperable telemedicine stations that interact with and make use of one another's devices. Essential to this development is merger of policies and regulations and the development and promulgation of industry standards.
- The development of "middleware" is essential. Middleware engineering links the work of software and network engineers.
- Research into the human (patient/ provider)–machine interface must be a high priority. There is a need for better displays that are more natural and for better and less invasive sensors.
- Development of "intelligent" medical robots may be critical to the future of some telemedicine sectors. Research should be directed toward the development of these robots, which could decrease medical errors and enhance the quality of care.
- Security systems must be built into every telemedicine network.

- Technology transfer, exchange and cooperative development must be a high priority. The ultimate goal is to guarantee end-to-end connectivity. It is essential that technology transfer between "resource rich" and "resource poor" become a high priority.

DIFFUSION

The ultimate measure of the success of telemedicine, whether it be in clinical or public health applications, or medical education, is the extent to which it is integrated into the mainstream, or its diffusion. The assessment of telemedicine diffusion is complicated by its many forms and the inclusiveness of the field. One obvious conclusion drawn from previous sections in this report is that various applications of telemedicine have developed or diffused at different rates. Overall, the exceptional promise of telemedicine has yet to be matched by a corresponding level diffusion.

Adoption/diffusion process

The adoption process is at the base of observed rates of all innovation diffusion, variously defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" or the change in geographic/functional distribution of a phenomenon over time. The adoption process related to telemedicine involves a series of stages including awareness, interest, evaluation, trial, and finally adoption or rejection. For most innovations including telemedicine, it is not sufficient that the innovation simply match the value of the technology in place. Generally, the innovation must overcome inertia of the current technology/ practice by being demonstrably superior. Also, in the case of telemedicine, there are a number of different actors in the adoption process, including providers, administrators, institutions, funding agencies, and the public.

The overall diffusion process can vary considerably between these groups. In each group, we may find gatekeepers, innovators, early acceptors, late acceptors, and laggards. This too, leads to differential rates of diffusion, as does the recency of the innovation. The current generation of telemedicine is barely one decade old. Finally, external environmental factors can limit or facilitate the diffusion of telemedicine. For example, the presence or lack of appropriate communication technology infrastructure, the ability to implement information received, and the social, economic, and cultural milieu related to health and illness behavior can significantly alter the rate of diffusion. All this must be considered against a backdrop of the consistent evolution of the technology of telemedicine and improved affordability over short periods.

Growth and diffusion of telemedicine

Apart from the notable exception of teleradiology and, to a much lesser extent, telepathology, the overall diffusion of telemedicine is below expectation. Whereas aggregate statistics reveal a consistently positive trend in the number of providers, programs, and consultations, growth is unevenly distributed across various applications and regions. Several states in the United States have developed comprehensive state-wide systems, while other states have few, small and geographically restricted efforts. In 1999, an estimated 4000 physicians in the United States participated in telemedicine (out of an active nonfederal physician supply of almost 700,000). However, in a recent sample survey, the American Medical Association reported that more than 9 of 10 physicians use computers in their practices, and a majority of them use the Internet for medical research, legal and regulatory updates, and e-mail communication. Nevertheless, the average number of teleconsultations per telemedicine site was less than 40. Among a sample of 132 programs, only 15 reported more than a 1000 teleconsultations per year.

A cursory assessment of the diffusion of telemedicine in other countries also illustrates wide variability in terms of scale, driving forces, opportunities, and geographic landscape. In Australia, for example, with a widely dispersed population, a developed economy and a history of providing health care for remote populations, telemedicine is relatively widespread. Emphasis placed on telemedicine in university medical departments has helped propel the diffusion.

Malaysia also has a dispersed population, with West Malaysia located on the southern portion of the Malay Peninsula and East Malaysia on the northern one third of the island of Borneo. The nation is separated by water for a distance of 640 km. Here, a concerted government-sponsored effort is underway to incorporate and rely heavily on telemedicine to bring health care to its population.

The situation in South Africa is one in which there is a paucity of traditional health services in many parts of the country, especially rural areas. Telemedicine is viewed as a way of spreading health and medical care equitably and efficiently to these areas. However, this cannot be accomplished without significant investment in an information infrastructure and training of health professionals to serve in the remote areas.

Thus, the situation facing telemedicine diffusion varies substantially country by country and region by region. The diffusion of telemedicine depends on addressing and adapting to the special needs of each country, and overcoming the obstacles faced in each environment.

The complexity of assessing the telemedicine diffusion as presented above is matched by the number of influences on the diffusion process, and includes: the structure of decision-making; role of opinion leaders; availability of significant research data; improvement in efficiency; impact on quality of service; cost of technology; organizational/social structure; risk or uncertainty; consistency with social/cultural norms; compatibility with in situ care; organizational change required; and learning curve of providers and patients.

Enhancing the diffusion of telemedicine

Regardless of context, early identification and substantive demonstration of the potential benefits of telemedicine and significant cost/benefit ratios will enhance the acceptance and diffusion of telemedicine by various actors in the adoption process. A suitable framework, including necessary technological and educational infrastructure must be established for the introduction and utilization of telemedicine. Telemedicine must be integrated into the local/regional health sector and adapt to the social and cultural health and medical milieu.

Consideration of and prospects for the diffusion of telemedicine must be based, therefore, on the following clearly articulated set of criteria:

- Demonstrable need
- Explicit statement and demonstration of anticipated benefits
- Understanding of distributive impact of telemedicine
- Detailed methodology for implementation
- Sound methodology for evaluation
- Service delivery policy and protocols

Recommendations

It has been stated, "When technological innovations are not accepted or implemented properly, generally the failure may be traced to a poor fit between the nature of the innovation and the vested interests, resources and expectation of its major gatekeepers." Nonetheless, the proponents of telemedicine must provide convincing evidence of the benefits of telemedicine vis-à-vis traditional medical and health care modalities. This can only be done on the basis of scientifically sound experimentation and evaluation. Concern over a target or a desirable rate of diffusion may be misdirected. In many ways, this generation of telemedicine is in its infancy. And, it may be argued that because of a lack of data from long-term, large-scale projects and test beds that demonstrate the effectiveness of each telemedicine application, the relatively slow pace of diffusion is not only to be expected, but fitting. The highest priority should be given to funding appropriate, long-term large-scale telemedicine projects by national and international agencies. Positive results from these types of undertakings will expedite the rate of diffusion.

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