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Telemedicine in the U.S.A. with Focus on Clinical Applications and Issues

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Telemedicine usually refers to the use of information-based technologies, such as, computer and communications systems, to provide healthcare across geographic distances. Although telemedicine has the potential to improve healthcare, the number of clinical applications is still small and constrained by custom, regulatory, reimbursement and technical issues. In this review paper, a short historical review of telemedicine is provided, followed by an overview of clinical telemedicine applications, including cardiology, dermatology, emergency medicine and trauma care, homecare, pathology, psychiatry, radiology and surgery. Current telemedicine issues in clinics and technological problems to be decided, improved, and challenged, are reviewed. This is followed by conclusions.

Key Words: Telemedicine, clinical application, telemedicine issue, monograph

INTRODUCTION

Telemedicine usually refers to the use of information-based technologies, such as computer and communications systems, to provide healthcare across geographical distances. Telemedicine is defined by the Telemedicine Information Exchange (TIE) in 1997, as the "use of electronic signals to transfer medical data (photographs, x-ray images, audio, patient records, videoconferences, etc.) from one site to another, via the Internet, Intranets, PCs, satellites, or videoconferencing telephone equipment, in order to improve access to health care".[1] As such, the use of advanced information technologies enable telemedicine to exchange health information and provide healthcare services across geographical, time, social and cultural barriers. The practice of medicine through telecommunication, which is wellknown as telemedicine today, began actively in the early 1960's when the National Aeronautics and Space Administration (NASA) first put men into space. Since the 1960's, there have been numerous attempts to advance information-based technology to augment healthcare delivery. There is no doubt that telemedicine is emerging as an important new facet of healthcare. Moreover, telemedicine is becoming increasingly possible, due to the confluence of ongoing technical advances in such areas as, telecommunication, imaging, multimedia, computing power, robotics and information systems. However, in spite of the rapid dissemination of technology with a great potential for improving healthcare, its simplicity, the apparent logic of the concept and forty years of experience, the number of clinical telemedicine applications practiced today is still small and restricted, rather than widely deployed. This is the result of numerous barriers, which need to be broken through clinically, financially and technically. Reviewed in this paper, is the state of the art in telemedicine for clinical applications and issues, with focus on the U.S.A (thus, international potentials are not explored in this paper). Telemedicine supports different levels of activity, such as, medical consultation, diagnosis, medical and patient education and surgical planning, as well as administrative conferencing. This review is not intended to be comprehensive, but to give an overview of the field, with focus on clinical applications and current issues. The paper is organized

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as follows. The next section gives a brief historical review of telemedicine, which is followed by an overview of clinical applications where telemedicine has been applied. The clinical applications are then explored; they include cardiology, dermatology, emergency medicine and trauma care, homecare, pathology, psychiatry, radiology, surgery, and etc. We review current medical and technical issues that must be settled, improved, and challenged, followed by conclusions.

A BRIEF HISTORY OF TELEMEDICINE

The application of new technology to healthcare has been a continuing process for centuries. Telemedicine was first used for psychiatry in 1959. The College of Medicine, University of Nebraska, successfully accomplished the first documented use of visual telecommunication in psychiatric care in 1959.[2-4] In April 1968, Massachusetts General Hospital (MGH) established a microwave video link between the hospital and Boston's Logan Airport. This was intended to provide immediate access to a physician without requiring one to be permanently assigned to the airport. Examinations conducted included cardiology, dermatology and radiology. The study of this service concluded that telemedicine does provide improved access to medical care and established that telemedicine was very useful in avoiding medical delays due to patient/physician travel.[5,6] In December 1968, the INTERACT program by Dartmouth Medical College and the University of Vermont, started providing medical and educational services to 10 sites in rural Vermont and New Hampshire. This program represented one of the first to establish a network for supporting rural clinics using telemedicine. The program provided access to medical specialists for consultation and education. At its conclusion, the program demonstrated an improvement in access to medical care and education in the rural areas of Vermont and New Hampshire. It was restarted in 1995 as VTMEDNET, a text based statewide system.[7,8] Like many programs of its time, the program ended in 1985 after the grants ceased. In 1971, 26 sites in Alaska were chosen by the National Library of Medicine's Lister Hill National Center for Biomedical Communication, to see if reliable communication would improve village healthcare (later it was called Alaska ATS-6 Satellite Biomedical Demonstration). The primary purpose of this undertaking was to investigate the use of satellite video consultation to improve the quality of rural healthcare in Alaska. It was determined that if the satellite system was workable, it could be used effectively by health aids at its various locations, and could be used for practically any medical problems except emergency care.[9,10] The joint Canadian/U.S. Hermes satellite provided Canadians with an opportunity to use satellite technology for distance education and medical care in 1977. The Telemedicine Centre at the Memorial University of Newfoundland has been a model for the judicious and low-cost use of telemedicine technology. These studies showed that for many applications, there is no need for higher-end, higher-cost videoconferencing equipment.[11]

Higher bandwidth, more technically advanced systems, were implemented in the early 1960s when the National Aeronautics and Space Administration (NASA) first put men into space. One pioneer telemedicine program by NASA was Space Technology Applied to Rural Papago Advanced Health Care (STARPAHC from 1972-1975) which was designed to deliver healthcare to the Papago Indian Reservation in Arizona. A van with a variety of medical instruments, including an electrocardiograph and x-ray machine, was staffed by two Indian paramedics. The van was linked to specialists at the Public Health Service Hospital by a bilateral microwave transmission.[12-14] During 1974, NASA conducted a study with SCI Systems of Houston to determine the minimal television system requirements for accurate telediagnosis. A high-quality videotape was made of an actual medical examination, conducted by a nurse who was supervised by a physician watching on closed-circuit television. Interestingly, the results for this application included: 1) statistical significance between the means of the standard monochrome system, 2) no significant difference in the overall diagnostic results as the pictorial information was altered, 3) no significant difference in remote treatment designations of TV system type that would cause detriment to patients.[15-17]

During 1989, NASA was active in developing and studying telemedicine systems. NASA conducted the first international telemedicine program, Space Bridge to Armenia/Ufa, after a powerful earthquake struck the Soviet Republic of Armenia in December 1988. Telemedicine consultations were conducted under the guidance of the US/USSR Joint Working Group on Space Biology, using video, audio and facsimile between a medical center in Yerevan, Armenia and four medical centers in the United States.[18,19] In 1993, the University of Washington joined Lewis Research Center and the Jet Propulsion Laboratory on a teleradiology project that uses an Advanced Communications Technology Satellite. In 1994, NASA collaborated with the University of Pittsburgh, WHO (World Health organization), PAHO (Pan American Health Organization), USAID (US Agency for International Development) and the World Bank, to organize Global Health Network, which provides telepreventive medicine. In 1995, Ames Research Center, Trident Inc. and Cedars Sinai Medical Center in Los Angeles, collaborated on a telemedicine demonstration project.[14,20]

Other federal agencies having responsibility for large populations have been heavily involved in using telemedicine in the delivery of healthcare. Among these are the US Department of Defense (DOD) and Veterans Affairs (VA). The DOD has made some of the largest investments in the world on telemedicine research and development, primarily aimed at bringing medical care to the soldier on the front lines of battle (The Army's Telemedicine and Advanced Technology Research Center (TATRC)).[21] The VA has numerous investments in telemedicine through its nationwide network of hospitals and health facilities.[22] In a recent symposium, Bashshur pointed out the increasing long-term federal support for telemedicine, unlike the short-term fundings which were found in the first generation. While there are no reliable estimates for total U.S. investment in telemedicine, the American Telemedicine Association estimated federal (both military and civilian) expenditures on telemedicine in 1999 at about $240 million. This estimate does not include Medicare expenditures on teleradiology or patient monitoring. The total federal expenditures in the United States over the past 5 years may well exceed $1 billion.[23]

Since the 1970's, as part of their mandate to provide expert care to surrounding communities, medical institutions have used telemedicine applications to provide specialized medical care to patients in geographically isolated, rural areas.[8,24-27] Some examples include: 1) The WWAMI program (named after the participating states, Washington, Wyoming, Alaska, Montana, and Idaho) by the University of Washington[28] begun in the 1970s, in response to a shortage of primary care doctors in rural areas. Today the program is well-established and provides community-based medical education from those five states. 2) National Laboratory for the Study of Rural Telemedicine by the University of Iowa.[29] According to the 1999 Iowa Telehealth Survey,[30] there were 124 telehealth facilities in Iowa, composed of 92 hospitals (26 teleradiology only), 3 medical clinics, 5 VAs, 7 residential facilities, 9 prisons, 2 health agencies, 3 nursing homes, 2 medical education centers and 1 AEA. 3) The Telemedicine Resource Center (TRC) at the University of Michigan Health System.[31] The TRC serves to support, facilitate and enhance the University of Michigan Health System's broad mission of improving health and well being, by setting, meeting and integrating high standards for leadership in patient care, education, research and community service. 4) PEACESAT by the University of Hawaii[32,33] has worked with doctors and communications personnel from the Tripler Army Medical Center, to experiment with telemedicine applications in Pacific island countries by facilitating the use of telecommunications and information technologies in the Pacific Island Region. 5) The University of Arizona[121] has an extensive network of clinics within a number of different Native American Indian tribes throughout the state. In this diverse group of institutions, telemedicine is an accepted and established part of everyday practice.

CLINICAL APPLICATIONS OF TELEMEDICINE

Overview

Telemedicine involves the transmission of information. The information may include medical images, live bi-directional audio and video, patient medical records, output data from medical devices (including vital signals) and sound files. The simplest consultation between experts, by telephone, dates from the turn of the century. Telemedicine in the modern era may include live, bi-directional audio and video interaction between patients and medical professionals, sending patient monitoring data from the home to a clinic or transmitting a patient medical data file from a primary care provider to a specialist. Telemedicine uses a variety of transmission modes, including ISDN (Integrated Services Digital Network), T1, ATM (Asynchronous Transfer Mode), DSL (Digital Subscriber Line), satellite, microwave, wireless, wireline, Internet, Intranet etc. The transmission mode depends on the need, available technical and financial resources and the need for telemedicine to be applied in real time. Services such as specialist-assisted surgery or psychiatric consultations usually require a live video: interactive video system (IVS). However, real-time transfer of information is not always required. The use of store-and-forward (SF) technology has proven cost-effective in cases such as radiology and pathology.

Early clinical applications using telemedicine in rural healthcare proved to have great beneficial effects on patient survival and recovery, but its use was not expanded because of expensive equipment and short-term funding.[7,34-36] The use of Telemedicine technology has increased and the cost of equipment has decreased in the past ten years, resulting in an increase in the number of telemedicine programs and an increase in the scope of those programs. During the past decade, the vision of telemedicine has changed radically. With the cost and size of the equipment reducing and improving technical quality increasing, telemedicine has become much more feasible to use in rural healthcare. The success of the Internet, and powerful and inexpensive technology, has enabled the development of global hospital infrastructures. The electronic patient record, commonly used in many hospitals today, is easily accessible through the Internet with appropriate security safeguards.[37-42]

Telemedicine became one piece of a much wider movement aimed at building a nationwide telecommunication infrastructure. It is now on the verge of having the technical capability to project telemedicine applications on a nationwide basis. What remains is the work of building partnerships and clinically meaningful networks, to take advantage of telemedicine technology.[12]

There is also a huge technical barrier to nationwide deployment of telemedicine: the lack of a single, universal, secure, electronic medical record, which needs to be developed. Healthcare partnerships are forming, from urban physicians to rural clinics and hospitals, schools and homecare agencies to tertiary care medical centers. These partnerships are becoming crucial to improved access and quality of care in healthcare systems. Successful telemedicine programs are moving towards a sustainable clinical efficacy, with the technology incorporating distance learning and continuing medical education (CME) across a common infrastructure.[43-45] The partners are linked by a range of technologies and a commitment to improve the health of the citizens of a region. Because there is a significant shortage of healthcare professionals throughout rural areas, this is clearly an important need and service. One type and size of telemedicine system does not fit all situations. The location and service of the telemedicine program determines the infrastructure strategy for implementation. For example, rural sites often need real-time video systems but other sites may not. The type of clinical applications and the volume of consultations will determine the characteristics and costs of the appropriate telemedicine systems.

The first survey on telemedicine programs was in 1993. In 1996, about 80 active telemedicine programs were listed in 38 states and Washington, D.C.: eight use only store-and-forward technology, while 72 use bi-directional interactive audio-video technology. Allen and Grigsby showed the dramatically increasing growth rate of telemedicine in the United States during the period from 1993-1997.[41] There were only 10 active programs in the US in 1993, but the number of programs has doubled yearly since then, while the number of teleconsultations has tripled since 1995. Grigsby et al. summarized a positive trend of growth in the numbers of programs and providers from 1994 to

1999 based on data from the Association of Telemedicine Service Providers (ATSP) annual survey of telemedicine.[46] The number of programs identified in 1994 was 24, while the number in 1999 was 179, increased by a factor of seven. In addition, the number of teleconsultations increased from 2110 in 1994 to 74828 in 1999.[46,47-51] IN 2001 the number of programs also increased, but the number of teleconsultations did not.[116] In 2002, there was a slight decrease in the number of telemedicine programs as reported recently on the TIE website.[118] This reduction corresponded to expectation, due to the huge budget cut of the fiscal year 2002, especially OAT, as Brown already pointed out[118] : the number of program identified in 2001 was 206, while the number in 2002 was 150, an increase by a factor of six compared to that of 1994, but a decrease by 27% compared to that of 2001. The following table shows the numbers of telemedicine programs and teleconsultations identified by annual reports by Telemedicine Today, ATSP and TIE.[38,40,41,47,50,51,116,117]

In addition, the following aspects were analyzed, based on the available master data tables of each annual telemedicine survey report (1995 through 2002):

- Transmission type and speed
- Equipment
- Uses in clinical applications
- Barriers (to?)

Despite changes in equipment and bandwidth cost, there have not been significant changes in transmission methodology. There are no large, diverse changes in the trends of the transmissions types, transmission speed and the top three system types, even with the cost and size of the equipment reducing and improvements in technical quality rising. ISDN is the first ranked transmission type (ISDN, T1, Telephone in order) and 384 kbps is the most commonly used transmission speed. Interactive video system (IVS) is the first ranked system type (IVS, SF, IVS with SI (still image) in order). However, it should be mentioned here, that increasing use of the Internet strongly affects the changing trend of system types and equipment, where the combined system type with IVS with SI, is growing rapidly and is expected to become a major type. The rollabout is ranked first in 2002, the first time since the initial telemedicine annual survey in 1993 (rollabout, desktop, roombased, in order) and will be the most commonly used equipment, especially with M (mobile)-telemedicine which is optimized for a laptop.

It is interesting to note that the most used top three services in clinical applications, based on the number of teleconsultations conducted annually, are mental, cardiology and dermatology excepting ER. These ranked in the top three in 1996 and ophthalmology ranked in the top three in 1997 and 1998 (this is because of the well-known teleophthalmology consultations at the University of Texas Health Sciences Center in San Antonio).[41] The clinical applications will be explored further in the following subsection.

It is also worthwhile to note, that while one of the main barriers to telemedicine, was high communication charges, now that lower charges are decreasing the total cost, the next barrier still relates to reimbursement. Apparent since the first telemedicine annual survey in 1993 is the difficulty in getting a reimbursement. This implies that the issue of reimbursement should be solved, or at least defined clearly, for the rapid dissemination of telemedicine. These issues will be explored in the following section. Note that all the data summarized in the above tables were not compared uniformly within the same time

Table 1. Growth in Number of Programs and Teleconsultations over Time

	1993	1994	1995	1996	1997	1998	1999	2001	2002
Number of Programs	10	24	49	86	132	157	179	206	150
Number of Teleconsultations	1750	2110	6138	21732	41740	52223	74828	40492	79212

1) The numbers for 1993 - 2001 based on the Table 2.1 of 2001 ATSP Report on U.S. Telemedicine Activity (for more details, see Dahlin MP, Watcher G, Engle WM, Henderson J. 2001 Report on U.S. Telemedicine Activity: Association of Telehealth Service Providers, 2001.)
2) The numbers for 2002 based on the recent Telemedicine Information Exchange update.

Table 2. The Most Used Clinical Applications Based on the Teleconsultations over Time

Most used clinical applications	1995	1996	1997	1998	1999	2001
1	Psychiatry	Mental	Mental	Mental	Mental	Mental
2	Dermatology	ER	Cardiology	Ophthalmology	Dermatology	Cardiology
3	Cardiovascular	Dermatology	Ophthalmology	Cardiology	Cardiology	Dermatology

1) The ratio for 1995 based on the master table of program-specific information of the third Annual Program.[40]
2) The ratios for 1996 based on the 4th Annual Program.[38]
3) The ratios for 1997-2001 based on the master table of program-specific information of the each ATSP Report on U.S. Telemedicine Activity.[41,50,51,116]

sequence, as the analyses were based on specific information from the available master tables data of each annual report. Thus, the analyses presented here are not meant to be comprehensive, but instead helpful in getting some insight into how the focus of the programs changes.

Krupinski et al.[52] categorized clinical applications in telemedicine into three groups, by level of maturity based on several factors. They include 1) the quantity and quality of research pertaining to the application, the degree to which the application has been accepted by the profession; 2) the development of standards and protocols for the application and technical feasibility; 3) diagnostic accuracy, sensitivity, specificity, clinical outcome and cost effectiveness. Mature groups include pathology and radiology, while maturing groups include cardiology, dermatology, ophthalmology and psychiatry. Emerging groups include emergency medicine, pediatrics, rare diseases and surgery (for details, see Krupinski et al.[52]).

Clinical applications

A number of specific clinical applications have been discussed in the order of cardiology, dermatology, emergency medicine and trauma care, homecare, pathology, psychiatry, radiology and surgery. Detailed clinical applications to be mentioned herein can be found in the following literature (this is not intended to be a comprehensive list for all clinical applications of telemedicine): cardiology,[53] correctional care,[44,45,54,55] dermatology,[56,57] emergency medicine and trauma care,[58-61] homecare,[44,45,62-65] nursing,[66,67] pathology,[68-71] patient monitoring,[44,45,53,72,73] psychiatry,[55,74-76] radiology,[44,45,77-82] telementoring,[83-87] telesurgery.[88-91,120]

Cardiology

This is an intensive and life saving telemedicine application that has flourished in recent years. Improvements in integrating the tools of the cardiologist, such as, echocardiograms, ultrasonography machines and electronic stethoscopes, with telemedicine systems, can be anticipated to improve diagnostic utility of the application in the future.

Correctional care

Prison-based populations in the US receive guaranteed healthcare coverage. However, due to the cost of transporting prisoners to a medical clinic, the remote location of many correctional care facilities and the potential danger to civilian populations as a result of the prisoner transport, telemedicine is a large and growing application in correctional care. It should be noted that telemedicine for prisons is essentially a government (usually state) funded subsidy, as is Indian Health telemedicine. It therefore does not have to make a financially cost-benefit justification for sustainability.

Dermatology

Teledermatology has gravitated to the use of still images during interactive video examinations, which proven to be very effective. A standard video camera view of the skin is not sufficient for diagnosis. Thus, the use of specialty dermatoscopes or examination cameras is being incorporated as part of conducting a telemedicine consultation.

Emergency medicine and trauma care

Emergency or trauma telemedicine emerged in 1996 as one of the fastest growing applications of this technology. Rosenfeld noticed that at least 35,000 intensivists are needed to cover the Intensive Central Unit (ICU) patients in the US, 24 hours a day, seven days a week, but only about 5500 are available in active practice now.[62] Telemedicine has been used as a way of providing coverage to many remote emergency departments during off-peak times. This allows for the distribution of scarce personnel resources during times of need.

Homecare

With the aging of the population, in-home medical care via telemedicine technology, has probably one of the greatest potentials for rapid growth nationwide. The shortage of physicians specializing in homecare can be mitigated by use of a telemedicine system.

Pathology

The use of visual collaboration between pathologists has been a leading telemedicine application for the past ten years. By simply connecting a video camera to the microscope, two or more pathologists can collaborate on a difficult case, using store-and-forward (mostly) and real-time live images. Several studies have demonstrated that the use of telemedicine between pathologists significantly reduced the need for onsite subspecialty pathologists in remote areas.

Patient monitoring

Remote patient monitors, which replace Holter-based monitoring systems used within hospitals, allow the patient to remain at home and deliver the monitoring data to the health professional by telemedicine. The largest use is in cardiac monitoring. Fetal and pulmonary monitoring are also widely deployed and supported by major insurance plans.

Psychiatry

Telemedicine has experienced wide acceptance by the mental health community.

Due to the interactive nature of video-conferencing, mental health professionals can converse with a patient located in a remote town, village, prison, or long- term care facility, while maintaining full observation of their behavior. These interactions provide access to mental health services in places that typically cannot retain these specialists due to isolation, low patient volume, or economic constraints.

Radiology

In use for 30 years, teleradiology involves the transmission of medical images, such as x-rays or MRI scans, to a radiologist for interpretation. This is one of the first uses of telemedicine to receive full reimbursement under US Medicare and its application in the U.S. is the most widely deployed and established telemedicine.

Surgery

There are several benefits achieved by applying video-conferencing to surgery, specifically pre-operative, intra-operative and post-operatively. First, it can be used as a means to screen surgical candidates, without having them travel to the surgical center. In addition, surgical nurses can utilize the same technology to prepare the patient for the procedure, by linking with them prior to surgery. The second benefit is obtained during surgery. Telemedicine can be used to connect with a colleague or mentor during an operation (telementoring) or to demonstrate the procedure to medical and surgical students without having them crowd around the operating table (tele-education). Telementoring applications for surgery in the operating room can allow surgeons at distant sites to collaborate and learn new operating techniques. The third benefit is obtained during post-operative follow-up. Telemedicine has been successfully used by surgeons to monitor the process of healing and recovery after surgery. It is worth mentioning finally, the first use of true remote tele-surgery on a routine basis, from Hamilton, Ontario Canada to North Bar, Ontario (300 miles away), for advanced laparoscopic procedures, this is beyond the scope of this paper.

Advanced information technology is being applied to clinical problems in area such as tele-endoscopy, surgical follow-ups, surgical telementoring, distance learning and even telesurgery.

One remarkable progression, is the fast dissemination of robotically-assisted technology through telemedicine. Two companies have recently developed telesurgery robotic systems for minimally invasive surgery, which can be controlled at a distance (da Vinci by Intuitive Surgical Inc.[92] and ZEUS by Computer Motion Inc[83]). In addition, with a robotic telecollaboration system for telementoring (SOCRATES by Computer Motion Inc[83]), those roboticallyassisted technologies are becoming a paradigm shift in clinical applications of telemedicine for remote telesurgery. The initial clinical applications of the systems have been in cardiac surgery, although other applications are beginning to appear as well.

Other applications

There are numerous other less frequently utilized or "niche" clinical applications (programs) conducted through telemedicine, which can be found in the literature (summaries of these can be found in Viegas and Dunn,[93] and Field[94]). In addition, there are many clinical applications (programs) implemented through telemedicine, which are not explored in this paper. The number has been increasing exponentially, even though some key clinical and technical issues have not been settled yet. It is obvious that the diffusion of telemedicine will be much accelerated if those barriers are broken through. These issues are explored in the following section.

CURRENT TELEMEDICINE ISSUES

Issues in clinical deployment

The major obstacles facing the use and deployment of telemedicine today, are not in the development of technology, but rather in changing restrictive laws, regulations and the attitudes of many involved in the traditional delivery of medicine.[95] Among these, some issues to be settled are given in this section.

Patient consent

Informed consent with respect to the performance of telemedicine by his/her physician must be obtained: patients must consent to the use of telemedicine after being advised of risks, benefits and limitations.

Liability and responsibility

One of the major barriers preventing widespread use of telemedicine, physician liability, could be significantly lowered by the following:

- Liability of the performing physician and hospital for any patient injuries sustained at the local site, as a result of malfunction of the telemedicine and/or telecommunication equipment and for any acts or omissions of the local physician, in addition to the normal liability of the local physician and hospital for such injuries.
- Liability of the manufacturer and/or vendor of telemedicine equipment for a malfunction: product liability for equipment deficiencies affecting diagnosis and treatment.
- Liability for inappropriate use of technology.
- Liability for other non-physician, healthcare provider involvement in consultation and treatment.
- Liability of the federal government in connection with a demonstration program.

Licensure, litigation and legislative mandates

Licensure statute varies in each state and some states have even adopted rules that strictly define telemedicine activities.[44,45,96] A strategic investment policy in both public and private sectors, is necessary for the effective diffusion of telemedicine. The US General Accounting Office (GAO) called for a federal telemedicine strategy to enable effective investment in telemedicine in 1997.[97] A growing number of states require telemedicine licensure in addition to state licensure for those areas served by telemedicine. It will be necessary to overcome these traditional regulations which mandates that the practice of medicine is within the purview of individual states. Those mentioned herein might be used until telemedicine licensure has nationwide acceptance.

- Licensure by endorsement: government boards grant licenses to providers licensed elsewhere.
- Legal authority for the physician to perform

telemedicine in a remote area.

- Mutual recognition: authorities mutually agree to accept policies and procedures of home state licensure, mutually and legally.
- Consultation exceptions allowing a physician not licensed in a particular state to practice there at the request of, or in consultation with, a referring physician.

Nationwide reimbursement approval

Telemedicine services in the U.S.A. may be divided into primary and premium services.[44,98] Primary services have widely been accepted by patients and medical professionals, covering distribution of general medical information through the Internet. On the other hand, only teleconsultation and remote diagnosis in radiology (teleradiology) have been accepted by healthcare insurance companies in some states, for reimbursement as interactive premium services: real-time consultation, where the physician and the patient talk with each other. This is very important, because the most significant reimbursement issue has been with the insurance companies insisting on 'face-to-face' between the doctor and patient, meaning that the physician must physically be with the patient. Other premium services such as remote image processing, remote image fusion, remote three-dimensional surgical or radiation therapy planning, or even remote data archiving, do not yet play a significant role.[41] As of October 2002, the Centers for Medicare and Medicaid will reimburse for interactive consultations, but not store-and-forward technology. Many private insurers still do not reimburse for telemedicine consultations.[99]

The following are also required for the reimbursement of telemedicine services.

- The scope of malpractice insurance coverage must include both the involved hospitals and physicians.
- Payment standardisation for remote and local hospitals: payment for the procedures must be precisely defined when performed at a remote hospital versus payment for the services provided by the local hospital and physician.

Confidentiality and security for patient information and records

Telemedicine is an information-based technology, and thus the electronic patient record must be protected from public exposures. The Healthcare Information Portability and Protection Act (HIPPA) has delineated obligations and responsibilities of all healthcare entities (physicians, other healthcare providers, hospitals, etc) to protect the confidentiality and security of patient information and records on behalf of the patient. These responsibilities include:

- Federal and State laws
- Medicare requirements for participation.
- Special laws protecting specific, highly sensitive information, such as substance abuse, HIV status, etc.
- The risk of disclosure of information due to electronic transfer, access by multiple users, hackers and mistakes.
- A secure method for data integrity and validation

Validation and objective assessment of telemedicine

The only way to ensure the development of an effective body of knowledge on the impact of telemedicine, to demonstrate its benefits, to ensure that there are no adverse effects and to ensure that risks can be adequately controlled and managed, is the development of an objective validation and evaluation program. To the present time, there has been little definitive standards for exact assessment of a telemedicine system, even though much effort has been devoted to standards.[100] Previous efforts showed the difficulty in assessing the impact on the quality of medical practices, including quality of care and and use as a training tool.[101-103] The following two considerations may help to standardize an objective evaluation program.

- A generalizable formula for cost savings calculation- a cost/efficiency ratio (this is usually referred to as a 'cost-benefit ratio'); cost effectiveness reflecting setup, services, and maintenance; cost analysis for consultations [104-107]
- Objective Patient's Satisfaction Survey form,

completed after being treated (teleservices versus in-person services).[108]

There is research showing that most patient satisfaction studies to date find that patients on the whole are satisfied with long distance care.[99]

Medical protocol development

Any clinical application using telemedicine is encouraged to develop protocols for systematic, compatible and long-term usage. They include:

- Protocol for data-based (web-based) self-diagnosis and emergency treatment: Developing and evolving standards of care in telemedicine
- Protocol for patients or physician or providers: a standardized protocol for physicians and other healthcare providers to enter information into patient records[109,110]
- Protocol for organization and management of telemedicine services: administrative, clinical and technical protocol development[111]

The Department of Health and Human Services (HHS), recently announced two new steps in building a national electronic health care system, to allow patients and their doctors to access their complete medical records anytime and anywhere they are needed. These efforts are, makeing records available without charge throughout the U.S. and the Institute of Medicine being commisioned to design a standardized model of an electronic health record.[119]

Issues in technical deployment

Telemedicince is based on the relationship of human-human (physician-patient) and/or human-machine interaction through information-based technology, thus the technology remains the most critical component in a telemedicine initiative. This may include issues relating to telecommunications, video and audio display for ergonomics, video and audio technology, communication/network, as well as aspects of implementation and performance.[112] Representative issues to be researched and improved are categorized into the following:

Telecommunication selection

Telecommunications support has varied from basic telephone service to broadband Internet, incorporating online diagnostics, remote patient monitoring and today's virtual touch computer interfaces, referred to as haptics.

The first, but most difficult step that telemedicine program planners face is to decide on the telecommunication type (that is, transmission modes) from among various options, including ISDN, T1, ATM, DSL, satellite, microwave, wireless, wireline, Internet, and Intranet among others.[113] The choice is closely related to the program's needs, availabilities, the costs of communication and the shifting of rapidly changing technology.

Video and audio display

Telemedicine performance is based on bi-directional video and audio information exchange and is highly affected by human ergonomics. Thus, the improvements achieved on video and audio display might be a critical key to successful clinical practice through telemedicine. They include:

For video display,

- High resolution for dynamic/static variable
- Stereopsis avoidance: a factor contributing to depth perception and 3-D visualization
- Adaptable video communication delay
- Sickness reduction by long-time use of eyeglasses or head-mounted display
- Standardized specifications of video compression and communication

For audio display,

- Spatial and qualitative presentation of audio input
- Standardized specifications of audio compression and communication for the sound contained in a video conference.

Communication/networking

For successful clinical practice using telemedicine, it is important to guarantee the fast and stable connection between a remote and local area (referred to as 'quality of service). The following areas should be a high priority for research:

- Signal quality improvement

- Latency reduction for signal processing, including compression schemes
- High bandwidth requirements
- Traffic prioritisation
- Guaranteeing security of the transmission network (encryption)
- Network architecture optimization (scalability, reliability, redundancy)
- Appropriate integration with hospital information systems (electronic patient records, billing, scheduling)
- Increasing reliability of connections (ease and reliability of access)
- Interface standards; transmission protocols for next generation communication or internet (NGC/NGI), Internet2

Image

Image technology has advanced rapidly as computing power has increased.

Achieving an improvement in the quality of imaging will contribute to the rapid deployment of telemedicine:

- Imaging: sensory amplification (augmented reality), synthetic data, image properties and distribution,[114] image overlays (overlay of digital anatomic and physiologic data)
- Image quality: color reliability, movement artifacts and avoidance of deterioration of image quality

Implementation of information management systems to control telemedicine networks.

For more efficient and cost-effective use of telemedicine systems, it is desirable that any telemedicine system to be deployed, supports the compatibility of available resources:

- Readiness for follow-up and traceability of exchanges.
- Compatible (combined) use of store-and-forward technology with real-time technology.
- Dynamic overlay feasibility of digital imaging data with a high update rate

Productivity

Statistical methods for objective performance assessment, including risk, time and cost, should be formulated to support the productivity of the telemedicine.

Interoperability

While telemedicine applications perform well in terms of their intended functions, adding new features can be costly and time consuming. Moreover, the "closed" design and proprietary constraints of the current systems mean that the telemedicine stations from one vendor may not be able to communicate with those produced by another vendor. To improve or support the interoperability (compatibility) between different telemedicine systems (even within the same systems), considerations of the following might be helpful:

- Open system (design) for general purposes rather than closed system (design) for a special purpose
- Introduction of Middleware concept: the most pressing need is for middleware (the area between software and network engineering), in both hardware and software. Middleware will be the glue that renders incompatible standards interoperable, and it has feasibility in the short term.[115]

CONCLUSIONS

People living in rural and remote areas throughout the world struggle to access quality, specialty, medical care in a timely manner. Telemedicine allows many elements of medical practice to be effected when the patient and healthcare provider are geographically separated. This separation could be across town, across a region or even across the world. Health providers in a growing number of medical specialties use telemedicine, including cardiology, dermatology, emergency medicine and trauma care, homecare, pathology, psychiatry, radiology and surgery. The next logical step is the use of the Internet as an information vehicle for the delivery of medical care. In fact, this is happening already and currently is becoming a major factor in the delivery of healthcare. Numerous companies have quietly invested in Internet based healthcare delivery services and healthcare systems, in an effort to emerge as a major player in providing consultations, diagnoses, treatment and delivery of prescription medications, through this information vehicle. This opens the potential for virtual-reality (or augmented-reality) based healthcare, which has been recognized as the virtual online medical system (or virtual online hospital). These services will primarily be in general medical treatment at first, but will eventually include specialty care services as well as training. This has created a challenge in regulating the safe delivery of healthcare on a national level, with international bodies established medical systems also. Significant obstacles still remain, such as, legal and regulatory barriers and acceptance of the use of telemedicine by traditional medical establishments. These barriers are starting to come down and there is a growing body of research data that indicates how telemedicine can improve patient outcomes and reduce healthcare costs. Telemedicine is in a transition that is indicative of an industry that is maturing. Even though the growth in the number of telemedicine programs has been slowed by the budget reduction at governmental level, the government, including federal and state levels, has still played an important role in telemedicine's development with support by funds and legislation. The industry is still healthy as a whole, but for the programs to be more robust and self-sustaining, other funding sources such as teleconsultation fees should be provided in a natural way. This has complete relevance to the reimbursement issue. The long-term prospect for telemedicine is very good and all indications point to this being a huge market. Telemedicine will become a ubiquitous tool, accessed anytime, anywhere, with any able device and any able network, to improve healthcare and quality of life. Because telemedicine will be viewed as a tool to enhance patient healthcare, all care provided using telemedicine will be fully reimbursable. The question is not "WHEN", but "NOW" and we are in "NOW".

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