Telerehabilitation: Expanding Access to Rehabilitation Expertise

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Encouraged Paper

The potential of modern telecommunications and computing technologies as tools in the delivery and evaluation of assistive technology (AT) has been discussed and has been termed telerehabilitation. The problems of providing AT in rural areas parallels the delivery of health care to rural areas where the proportion of people with chronic illnesses is higher and the means to pay for them is reduced. Large distances mean long travel times, increasing costs associated with any service delivery, and consuming valuable time skilled professionals could be using to provide services elsewhere. The technology available for practicing telerehabilitation is significant and expanding at a rapid rate. Currently, plain old telephone systems (POTS) and broad-band videoconferencing equipment, Internet and World Wide Web, and embedded processor systems are most widely available. These technologies continue to evolve as well as emerging technologies such as wearable sensors that will have telerehabilitation applications. Issues of payment, safety, liability, and licensure need to be resolved, as legislation lags the development of new technologies.

Keywords—Internet, rehabilitation, smart-technology, videoconferencing.

I. INTRODUCTION

Telemedicine, or medicine at a distance, has been in existence for years. First documented in 1959, an interactive video was used to deliver mental health services in Nebraska [1]. Subsequent projects were conducted in the late 1960s by Dr. Kenneth Bird to establish a link between Massachusetts General Hospital and a walk-in clinic at Boston’s Logan International Airport. In addition, there have been telemedicine experiments and services involving teleradiology, telepathology, and teledermatology [2]. Only one program, located at Memorial University in Newfoundland, has succeeded as a self-sustained telemedicine program since 1975 [3]. In the late 1980s, the need for high quality health care at an affordable cost emerged and emphasis was placed on using new and developing technologies to increase telemedicine capabilities.

Many different medical disciplines have tested the feasibility and success of telemedicine in their practices. Within dermatology, studies have been completed evaluating the comparability between in-person dermatologic exams and videoconferencing exams. Results have shown that teleconsultation and in-person interviews are comparable 80% of the time [4], [5]. The progress in dermatology provides important background for pressure ulcer treatment; a problem that plagues many people with disabilities. Research has also been completed examining the feasibility of orthopedic teleconsultations in rural areas. Videoconferencing equipment was used to transmit radiographs. Results indicated that no adverse events occurred to those patients seen via teleconsultations and the patients were satisfied with the care they received from their physician [6]. Although problems can arise with the technology of telemedicine, in general, telemedicine research has shown that patients continue to be receptive to the idea of telemedicine.

A. Telerehabilitation as it is Currently Defined

Telerehabilitation can be defined as the application of telecommunication, remote sensing and operation technologies, and computing technologies to assist with the provision of the delivery of medical rehabilitation services at a distance. There are likely a wide variety of medical rehabilitation services that can be augmented, enhanced, or replaced by telerehabilitation. Areas where there are a shortage of rehabilitation professionals or where specialists...
are unavailable are driving the demand to develop telerehabilitation. The provision of assistive technology services (including home and work-site assessment), wound care (an extension of the work being done in dermatology), and home health care for people with disabilities are expanding through the use of telerehabilitation. Telerehabilitation is currently in a nascent stage of development with most programs being either at the pilot or research phase. It is possible to apply the same technology learned in other telemedicine disciplines to the field of rehabilitation [9]. Telerehabilitation programs are using videoconferencing, Internet, and data acquisition technologies. Telerehabilitation can be used in educational institutions, rural settings, remote areas, and in situations where it is necessary to provide services outside of a clinical setting (e.g., home visits).

In educational settings, the use of telerehabilitation has been shown to work in multiple settings, for example, physical therapy training [11]. Pressure measurement videoconferencing has been completed between the Center for Assistive Technology, USA, and clinicians at a seminar on Technology for Disabled People in Adelaide, Australia [12]. Clinicians now use the Internet and telecommunication technologies to develop their expertise, collaborate with peers and get information about assistive devices, and community supports for their clients.

The emergence and deployment of Telehealth systems including telerehabilitation does raise additional questions related to policy and impact. While most aspects of telerehabilitation appear positive if services can be delivered efficaciously and cost-effectively, it is important to be aware of some issues in health care. The implementation of telerehabilitation should be done in a manner to insure that there is no disruption to already fragile rural health resources in small communities, and that does not jeopardize people at risk (e.g., people who require home health care or minority populations). The problems of providing health care to people in rural areas are compounded by the high proportion of people with chronic illnesses and the means to pay for the services are reduced [10]. Long distances mean lengthy travel times, increasing costs to both the health care provider and the person receiving the services associated with any service delivery and consuming valuable time, not providing billable services skilled professionals could be using to provide services elsewhere.

B. Demographics Indicate a Growing Need for Technology in Rehabilitation

Many people with disabilities do not currently receive adequate health care, and the situation is only going to get worse unless new service delivery and evaluation methods, such as telerehabilitation are able to increase the capacity of rehabilitation professionals to provide services. [20] Demographic studies indicate progressively increasing numbers of people with disabilities in the U.S. population. The overall estimate for noninstitutionalized persons with a limitation in activity caused by a chronic condition or impairment is 37.7 million (15.0% of the U.S. population), an increase of 14% over a period of ten years [16]–[18]. Using data from the Survey of Income and Program Participation [19], it is estimated that 17.5% of all noninstitutionalized persons age 15 and over have functional limitations. Included in this category are the 7.8% of the noninstitutionalized population who have severe functional limitations [17], [19], [20].

Schoenman determined that approximately 2.6 million individuals with disabilities of working age (about 1% of the U.S. population) were institutionalized in long-term care facilities in 1987 [21]. The population using assistive technology devices has been estimated at 13.1 million persons [17], [18]. A particularly relevant question is, how many of the 37.7 million individuals with 61 million associated disabilities can benefit from “telerehabilitation?” While this question can be answered with only limited accuracy and is subject to a range of conditions and assumptions, the number must indeed be large.

The number of people requiring home health care is growing rapidly, while the funding for these services is declining. For example, the University of Pittsburgh Medical Center Health System, a major academic medical center serving much of Western Pennsylvania, conducted 200,000 home health visits during the year 2000, which represents an expenditure of approximately $25 million. Many health care systems are anxious to discover methods of providing home health care services to more people with fewer resources. Otherwise, the consequences will be a reduction in the availability of services and greater delays before people receive the services that they need. Demographic trends indicate that by the year 2035, 20% of the population will be over 65 years of age and that 55% will have a disability, increasing to 75% for those over 75 years [17]. Dependant elderly people in extended care facilities and others with normal sensation must endure many hours seated in a wheelchair each day. The number of individuals currently using wheelchairs is estimated at 1.4 million. Usage varies according to age. Approximately 150,000 wheelchair users are under 24 years of age. This number increases to 450,000 for those over 74 years. For at least one-third of users, wheelchairs provide the only means for independent mobility. There is reasonable agreement from several sources, as suggested by the above figures, that 75% of wheelchair users are over 50 years old. Approximately 65% retain some degree of ambulation. It can be estimated that about 50% of the total population requires some form of specialized seating and body support, and possibly 60%–70% may use some form of private or public transportation while seated in their wheelchairs. Telecommunications and computing technology may help to alleviate the disparity between the demand for rehabilitation services and the available capacity to provide rehabilitation, both in terms of costs and number of trained professionals. Technology offers the promise of improving the efficiency of rehabilitation professionals, increasing the access to specialists and, perhaps, increasing the quality of care.

II. REMOTE THERAPEUTIC ASSESSMENT AND INTERVENTION

A. Delivery of Rehabilitation Services at a Distance

The Shepherd Center in Atlanta, GA has had a program running for several years that uses plain old telephone system (POTS) based videoconferencing systems enables
them to reach all their patients in need of follow-up rehabilitation services due to the ubiquitous presence of the telephone dial tone [22]. Trepagnier has used video communications for vocational support and similarly has selected POTS-based systems and concludes after focus group studies that there are many advantages in the counselor being able to see the client and vice versa [23]. Dang has remotely evaluated pressure ulcers between Washington, DC and Minnesota [24]. In an ongoing project studying home health care, Finkelstein is using POTS-based video, and remote monitoring using a blood pressure monitor, thermometer, pulse oximeter and spirometer. Focus groups have had an enthusiastic response. Benefits that they perceived were convenience (less travel), and increased access to the clinical care team [25].

Carson et al. developed a multidimensional matrix of evaluation to examine the medical, economic, technical, organizational and social dimensions of telerehabilitation home-based hemodialysis [26]. Major central components of this study address the issues of safety, reliability, acceptability, ergonomics, efficiency, effectiveness, and cost. Initial hospital-based trials in Greece, Italy, and the U.K. with 275 hemodialysis sessions indicate that the evaluation protocol is appropriate for this application and to health care technologies more generally.

In a broad-reaching project involving the remote delivery of rehabilitation services in the areas of seating evaluation, evaluation of home accessibility, setup of computer access systems, and training in the use of augmentative communication devices, Burns et al. detail many of the previously identified issues that continue to be problematic. However, they conclude that telerehabilitation has the potential of being viable in several areas of rehabilitation service delivery [27].

Problems encountered by Oakley et al. [7] in a dermatology telemedicine project included ISDN lines transmission reliability and failure in equipment, making the process of seeing patients at a distance frustrating at times. The investigators went on to say that for a successful telemedicine session, the examination room should be prepared with optimal lighting for videoconferencing needs and a solid-colored background. High speed of data transmission hardware should be utilized and different camera types may be needed depending on the medical discipline involved. For example, cameras that are three-chip (capable of 1:1 close-ups) are much better for close-ups in dermatologic exams [8]. For any discipline of medicine, an interactive video system is helpful to allow for interaction between patient and clinician.

In a report on the realities of development of a mobile rural telemedicine program in Utah, Goddard used store and forward systems in POTS-based videoconferencing [28]. He reports that survey instruments were developed to identify patient satisfaction, provider satisfaction, cost savings, outcomes data, and technical problems. This study showed that cost-effective telemedicine using commercially available POTS-based videoconferencing equipment can be achieved. However, he continues to identify many barriers to successful implementation, including lack of availability of high bandwidth services, skepticism, minimal infrastructure planning and development, legal and policy development, reimbursement and licensure. Brownsell reports on a U.K. based project aimed at reducing the high cost of providing health care for older people [29]. Using a survey of 176 candidates for home-based health care and three different financial models, he concludes that an advanced telerehabilitation system would result in significant savings in a large city in the U.K. and, furthermore, that this would assist older people staying in their homes with greater safety and improved quality of life.

B. Remote Activity Assessment

Outcome data derived from comparing clients’ functional status before and after rehabilitation provide one measure of the success of rehabilitation. However, the desired functional outcome is not the performance of daily living activities in the rehabilitation setting, but rather in the discharge setting [9]. Thus, a more ecologically valid or “true test” of the success of rehabilitation takes into account what happens after clients leave the rehabilitation setting and return to their usual living situation. Unfortunately, once clients are discharged, it becomes difficult to obtain objective performance-based data about their functional status. To do so, clients must either return to the health care setting for testing or a therapist must go to their homes to conduct the evaluation. In either case, clients or professionals are inconvenienced by the need to travel, sometimes great distances, and outcome assessment costs, which are not reimbursable, escalate [119]. Typically, substituting subjective for objective assessment procedures minimizes inconvenience and cost. Clients are interviewed through mailed questionnaires or over the telephone about their functional status [10]. Proxies are used when clients are unable to communicate or are unreliable informants. Generally, proxies are family members, friends, or health care personnel who are familiar with the client. Thus, to date, outcome research has relied primarily on questionnaire or interview-type instruments and procedures, such as the Medical Outcomes Survey (MOS-36), the Functional Status Questionnaire, or a self-report version of the Functional Independence Measure [13]–[15]. Strong correlations have been shown between results obtained through in person assessments and telephone interviews for several measurement tools, including the Activities of Daily Living Scale [13] and the Functional Independence Measure [14], [15].

Despite the convenience and cost-effectiveness, reliance on self-reports and proxy-reports of functional status is problematic. Methodological research indicates that outcomes vary depending on the source of the information, with clients generally being more optimistic about their functional status than proxies. Magaziner [30], Rubenstein [31], and Sager [32] ascertained that estimates of concordance of client self-reports and proxy-reports with performance-based measures range from a low of 63% to a high of 94% depending on the specific daily living task. When objective data gathered at discharge is combined with subjective data obtained at follow-up, differences in functional status may be attributed as much to the use
of different data-gathering methods as to true changes in functional status or environmental factors. Obtaining an accurate outcome measure of functional status depends upon the ability to administer the same assessment procedures in both the rehabilitation and the home setting.

Telerehabilitation provides a solution to this dilemma, and it has the potential for doing so at a reasonable cost. The telecommunications technology presently available allows us to send a nonprofessional (henceforth called a delegate) into the homes of clients upon discharge. The delegate records the client’s performance of activities of daily living and transmits visual and auditory images in real-time to a remote site for interpretation by a rehabilitation professional [33]. A simple delegate setup is presented in Fig. 1. The use of a pair or POTS video camera systems with televisions at each end allow visual communication between the expert and delegate. A separate telephone line for voice communication allows higher bandwidth for the visual image. The combination of voice and image are important for conveying accurate and reliable information between the expert and delegate. Thus, performance-based data obtained in the rehabilitation setting at discharge can be compared to performance-based data obtained in clients’ homes at follow-up and errors in outcome determination due to methodological differences can be avoided. By using interactive video, the professional can guide and monitor his or her delegate through the assessment process so that needed information is obtained. In addition, during the assessment the rehabilitation professional can make clients and delegates aware of general safety precautions as well as those that are unique to a particular home (e.g., the presence of uneven stair rises).

Telerehabilitation does not end once the performance-based assessment is completed. If the assessment identifies performance discrepancies between the rehabilitation and the home settings, the professional can devise an intervention plan to reduce them [34]. As appropriate, clients may implement these plans by themselves through “home programs,” or referrals may be made to local home health agencies. Once a functional telerehabilitation system is in place, applications could be extended to other uses, such as: 1) periodic monitoring of progress; 2) presurgical assessment in the home in the case of elective procedures; and 3) interactive assessment-intervention of tasks not commonly done in medical rehabilitation, such as community way finding or shopping in the grocery store. Regardless of its use, and prior to its broad usage, the practicality, scientific properties, and cost-effectiveness of its application must be firmly established.

The use of telerehabilitation in speech–language pathology is in the initial stages of development. The American Speech–Language–Hearing Association (ASHA) states that before implementing telehealth applications, the health care community needs to define the problems in the
current delivery system by analyzing the components of a usability evaluation: technical acceptability, operational effectiveness, and clinical appropriateness. According to Peters, “the issue is not whether hardware or software operate correctly, but how using a new technology affects the various subsystems and the system as a whole including the user’s performance” [35]. Suggested applications have included the provision of expert consultants, long-distance therapy, and the supervision of speech–language assistants [36]. While these possibilities offer promise, little information is available on the capabilities and limitations of telerehabilitation models to maximize the use of highly specialized speech–language pathology personnel (e.g., speech–language pathologists practicing in rehabilitation hospital settings) and speech–language pathology supervisors [37].

III. REMOTE HOME AND WORKSITE ASSESSMENT

Rehabilitation is a process involving both functional restoration and environmental modification. In other words, rehabilitation requires the creation of a fit between people and the environments in which they live. Recent advances in technologies to acquire dimensionally accurate, three-dimensional (3-D) models of physical environments have presented an opportunity to enhance our ability to adapt certain physical environments. For example, an opportunity exists for using 3-D models for mobility simulations to make determinations of accessibility in the context of the individuals who must function and interact within the environment [39]. Support of the decision-making process concerning appropriate assistive technology selection and environmental modifications for specific people in particular environments and for accessibility analysis of public spaces relative to population norms are also feasible [42]. The use of this modeling technology in conjunction with advances in telecommunications and the Internet allows for remote use of such accessibility analysis systems via asynchronous or interactive communication links with a central resource [44].

A. Virtualized Reality Telerehabilitation Technology

As an illustration of the potential uses of “virtualized reality” telerehabilitation technology, consider the following scenario. A person returns home following rehabilitation from a spinal cord injury. The accommodating environment of an earlier time may now contain significant barriers. The site would be photographed by the client, family member, or a paraprofessional with a digital camera or camcorder. The images would be transmitted to a central facility where technicians process them to quickly build a virtualized environment. The virtualized environment would then be used in an analysis where architectural features are compared to codes and standards. Features such as doorway widths and passageway clearances would be easily identified and analyzed in a computer model. More complex features, such as under-counter clearance, accessibility problems created by moveable items like furniture, and usability of bathroom elements, likely will require a manual analysis. Such an analysis could be accomplished by a rehabilitation professional using simple plan views of the layout or, if necessary, by immersing themselves in the virtualized environment. Currently, available technology limits this process to a semiautomated procedure [49], but it is far superior to the only alternative—transporting a therapist or rehabilitation engineer to the remote site with tape measure in hand. Proposed changes to the environment can be reanalyzed and visualized as required by either the rehabilitation professional or the client. In some cases, teleconferencing, incorporating data exchange and model rendering, may be desirable for communicating ideas and suggested solutions between the client (and perhaps a community home health care provider) at the remote site and the professional at the central location.

The term “virtualized reality” (VR) was coined and introduced in a paper by Kanade [39]. The traditional virtual reality world typically is constructed using simplistic, artificially created computer-aided design (CAD) models. VR starts with the real-world scene and virtualizes it. For rehabilitation applications, this distinction is significant. One could imagine mobility simulations conducted in artificially contrived virtual environments. Rehabilitation outcomes are likely to be significantly better if clients are evaluated and trained in a virtual world derived from their own physical environments.

The use of VR can improve chances for success and positively influence the interdependency links among professionals, vendors, and end users. With models of their specific environments, clients could try prospective mobility and input devices in virtualized simulations. The simulations will provide the client valuable information on the usability of particular devices in specific environments. If in the course of the simulation problems are detected, alternate mobility devices can be explored or alterations to the environment can be considered.

Again, the problem concerns the “fit” of the person to their environment. In this case, VR is used to improve the fit between persons and their physical environments. VR technology has advanced to a state that allows for the cost-effective implementation of the resulting product [40], [41]. However, as technologies improve and mature, and as time and resources allow, other potential uses of VR should be investigated. For example, using more elaborate sensor systems, virtualized mobility simulations could be staged for people using walkers or other devices, and the simulations can be expanded to include the study of ergonomic features of the environment. It is also feasible to analyze a virtualized environment from the perspective of a person with a visual or perceptual impairment.

Wilson et al. have compiled a review of potential applications for VR in disability and rehabilitation [40]. The main benefits identified are the ability to engage safely in diverse activities free from the limitations imposed by disability, and the ability to learn life skills in a safe environment. Myers et al. commented that VR’s potential for rehabilitation was: 1) adaptation, that is, the ability for people with disabilities
to control their environment through VR adaptive computer input devices and methods; 2) evaluation of dysfunction; and 3) cognitive rehabilitation of persons with hemineglect syndromes and visual perceptual deficits [41]. Scherer discussed the use of VR for simulating residential features for persons being deinstitutionalized and for involving consumers in decisions regarding their residence and assistive technology [42] Latash discusses VR’s potential for motor rehabilitation and cautions that VR’s use for this purpose hinders the process of motor rehabilitation [43]. Jones’ response to Wilson emphasizes the need for rigorous scientific investigation on VR’s effectiveness for training life skills [44]. Ring contends that VR has potential for assisting in neurological rehabilitation for sensory-motor deficits, speech disorders and dysarthria, and cognitive deficits [45]. In a follow-up paper, Wilson noted that one of the limitations of current VR technology is the time-consuming and expensive process necessary for creating (i.e., authoring) virtual environments.

In the area of computer assisted ADA compliance checking, Evan Terry Associates (ETA) performs surveys of existing conditions for barrier removal projects for both Title II and Title III entities. ETA also writes and publishes books on ADA and state access codes and leads training sessions for design professionals on facilities requirements of the ADA. ETA has developed an ADA-compliant CAD drawing package called ADA Design Assistant that automatically and interactively filters the AutoArchitect CAD package for problems with ADA compliance as a drawing is being developed and includes libraries of solutions (http://www.evanterry.com/).

VR telerehabilitation technology requires the integration of existing technologies and techniques to quantify physical environments by digitizing them using a low-cost VR system. The integrated system must quickly and accurately measure and model pertinent objects and other physical constructs in any interior or exterior environment. State-of-the-art computer vision techniques can be used to create a semiautomatic modeling process.

This modeling step is the first critical component leading to a cost-effective implementation of VR telerehabilitation system. Once modeled, the environment can be analyzed for accessibility issues and used in simulation of mobility devices. Widespread and successful implementation of the virtualized environment system depends on its accuracy, cost-effectiveness, and ease-of-use. Someone with minimal training should be able to photograph an environment in less than 15 minutes (depending on size and complexity). Similarly, a technician at a central location should be able to produce a dimensionally accurate, virtualized environment in a comparably short period of time and return or forward it for professional analysis.

Feasibility for the computer vision techniques has been established [46]–[49]. Much of the development effort focused on creating a simple, easy-to-use digitizing system. In the present system, it is accomplished by taking pictures or videos using commercially available camcorders or digital cameras. The operator at the remote site needs only minimal training on the proper techniques for taking pictures of the scene.

Self-calibration of a camera retrieves internal parameters (focal length, aspect ratio, and principal point) that eliminates the need to have a laboratory-calibrated camera and allows for auto focusing and zooming. Recent advances in projective geometry have provided strong theoretical and practical foundation for self-calibration [50]–[53]. Simpler methods like the use of parallel line pairs of known 3-D direction can also be used.

A semiautomatic approach is adopted to capitalize on human knowledge as well as to achieve robustness and simplicity of shape recovery. [54]–[56] The merit of scene reconstruction using constrained camera motion [57] has also been considered in the design of systems. Other methods that use expensive and elaborate sensors are likely not cost-effective and so they are not the preferred technology option in this system.

A semiautomatic system can also make use of existing algorithms for accuracy refinement. For example, extensive research over the past 20 years investigated optical flow estimation. The user’s hand-clicked points can be refined to sub-pixel accuracy by methods such as the Lucas–Kanade algorithm, one of the fastest and most accurate techniques available [59].

B. User Interface Design

3-D modeling languages like the VRML or OpenInventor and texture mapping provide a realistic looking 3-D virtualized environment. These imaging methods have significant advantages over other (e.g., structured light) digitizing methods for reproducing texture information. The texture information is included in the captured data, where as, using the structured light methods, texture information is not included.

The issue concerning which image elements need to be modeled and which can be left as “part of the scenery” is particularly important for the application of the VR system for accessibility analysis. The fewer the objects, the easier it is to form the model. In current practice, a specialist would evaluate an environment using a checklist of items need to be measured or otherwise assessed. The person imaging the environment at the remote site and/or the technician forming the model at the central location would need to be given guidance on which elements to photograph and/or model.

Forming models from a stream of continuous images is an alternate approach to using still images. With a videotape of a room that has been made by moving around with a handheld camcorder, it possible to create a 3-D model of a room. This problem, often called the structure-from-motion problem, has eluded vision researchers for years. Researchers have developed a method, called Factorization, which can give a robust solution to this problem [60]–[62]. Factorization is based on the theorem that the geometrical constraints due to incidence relations among projection rays can be expressed as the degeneracy of a matrix that gathers all the image measurements. The theorem results in an algorithm that factorizes the measurement matrix into
two matrices that represent shape and motion, respectively, based on the robust singular value decomposition (SVD) technique. Three views of model of a portion of kitchen formed using a videotaped sequence are shown in Fig. 2. Video images from different perspective can be combined to create a 3-D virtualized image that can be manipulated to change perspective to determine information that can be used to determine the type and extent of potential home or environmental modifications. Tracking points are used to change the perspective, but also allow measurements of the environment to be paid. These measurements are useful for determining whether environmental modifications are needed to accommodate the assistive technology (e.g., wheelchair) that the client may need to use in their living, work, or school environment.

C. Virtual Use of Assistive Devices

Cooper et al. have developed and tested a system that allows a wheelchair user to control commercially available computer video games through forward and backward motion of the wheels of the chair [63], [64]. An example of the virtual reality training system for wheelchair mobility is presented in Fig. 3. Similar systems have been studied by Caves et al. [65], Flaherty et al. [66], and Chung et al. [67]. Evaluation of such a simulation system to determine the extent to which accessibility problems encountered in the virtual environment reflect experiences in the real environment is somewhat different than answering the typical question concerning the skills learned in simulation and their transference to actual practice. Wilson et al. reviewed the literature on the latter and concluded that, for unimpaired individuals, virtual reality systems “do appear to have significant potential as aids to learning” [68]. Wilson cites flight simulation and combat simulation as examples.

The development of the capability to rapidly, systematically and inexpensively determine the accessibility of a home, public, or, in fact, any built or natural environment would be of valuable in terms of information and as a basis for prospective modification. This visualization also facilitates the inclusion of the client in the decision making team. As this telerehabilitation technology evolves, its integration with a decision support system is possible. With a portable interface and modest computer, multiple configurations of assistive devices can be “tried out” by consumers at remote locations. Using the system and a communication link, a consumer could interact with a professional stationed at a central location during the simulation. In this way, the consumer and the professional may collaborate to make a satisfactory assistive device selection.

IV. SMART DEVICES

A. Remotely Programmable or Monitored Devices

Therapeutic devices have also been designed and used remotely with people with disabilities [69]. Bruderman and Abboud developed a spirometry system that can be monitored from a distance to record lung ventilatory values and for therapy of people with severe asthma [70]. Popescu et al. have tested a system to be used by people in their homes that allows remote monitoring of elbow and knee rehabilitation through force-feedback [71].

There has been increasing use of computer technology in assistive devices. This has led to the investigation of remote monitoring and programming. The Independence 3000 IBOT Transporter (IBOT), is an electronically stabilizing mobility device for people with disabilities (http://www.indeitech.com). The IBOT uses three computers and a number of sensors and actuators to provide a variety of functions [72], [73]. The IBOT is a technologically advanced mobility device designed to overcome many of the limitations of currently available wheelchairs. By incorporating state-of-the-art software and hardware, the IBOT responds to changes in terrain. The IBOT is controlled by a set of central custom computers that help to maintain stability and provide the user with control. The IBOT incorporates a variety of sensors for attitude control (including gyroscopes), speed control, self-diagnosis, and for changing operational functions. The IBOT programming uses a voting process with its redundant computers to determine the actions of the device. The IBOT software also records the operation of the device and maintains a fault log. A pioneering feature of the IBOT is that the device contains an internal modem that allows the device to communicate with the manufacturer or a service representative at a distance. This provides the potential to download fault logs to determine whether periodic maintenance is necessary and to possibly upload software changes. The stair-climbing ability of the IBOT and the PCMCIA interface are shown in Fig. 4.

Invacare Corporation has also developed an electric powered wheelchair controller that allows remote monitoring of its status register (http://www.invacare.com). This system allows service personnel to be better prepared to make repairs and allows tracking of wheelchair maintenance. Respirators are very important for some people with disabilities.
respirators have been designed that allow remote status monitoring and reprogramming for the individual user [74]. The most important variable to follow is the pressure equalization to ensure that the individual receives sufficient air. Prentke-Romich has introduced an augmentative communication device that allows data storage and remote access capabilities to aide in tuning the device for the user (http://www.prentrom.com).

B. Remote Collection of Patient Status

Smart houses have the potential to increase the function and independence of people with disabilities. Smart houses include information technology and telecommunications [75]. The use of remotely monitoring and assisting people with disabilities in the home has important policy implications, such as the need to coordinate health care, social services, and building codes. Smart houses have the potential to reduce the need for dependent care for some people all while using mostly off-the-shelf technologies [76].

Rialle et al. reported on a system in the home that helps to detect falls in the elderly, which could reduce risk of injury [77]. Fisk determined that the structure of the home can have a substantial effect on the usefulness of smart home technologies [78]. Vanderheiden has indicated that advances in digital technologies and telecommunications will allow the extension of remote monitoring outside the home and that this technology may become global [79].

Pressure ulcers are a major problem for individuals who use wheelchairs or spend long periods of time in bed as a result of a long-term illness or disability. Various estimates put the individual cost of pressure sores between $14,000 and $40,000 per incident and the annual cost at $1.3 billion [80]. One of the clinical tools that is becoming more widely used in the management of pressure ulcer risk in SCI individuals is the pressure measurement pad. By analyzing information from the pad, along with other factors, an experienced clinician is able to indicate whether or not there are high pressures that may be causing, or putting an individual at risk of
acquiring, pressure ulcers. There is minimal availability of pressure mats. At this time, approximately 250–300 mats are being used clinically for the prevention of pressure ulcers in North America. A common pressure mapping system output is shown in Fig. 5. This type of output combines numerical information with a “weather map” type of display that facilitates interpretation of the information. Mathewson et al. presented a case study indicating that chronic pressure sore treatment can be improved through remote monitoring [81].

An example of how things are progressing in the sensor technology area is the “computerized shirt” prototypes that are currently being tested (http://www.lifeshirt.com). This
shirt records in real time breathing rate and heart rate. This information is then passed on to an Internet site where “data analyzers” can identify problems and forward the information to a physician. Along similar lines is a prototype demonstrated in 1999 for continuous physiological measurements, which takes the form of a ring worn on the finger. This then transmits data to a local receiver in the home, which, in turn, is transmitted over phone lines to a similar “data analysis center” [82]. A low-cost, store-and-forward or real-time pulmonary function testing system has been developed and tested at a prototype level, which is designed to be used in the home for periodic evaluation of respiratory function [83]. A wrist-mounted activity and pulse recording system has been demonstrated and tested at a prototype level for continuous use [84].

Kawarada et al. developed a prototype smart house component which monitors body weight and excreta weight in the bathroom, and ECG in the bathtub and bed [85]. Barro et al. have developed a wireless technology that is hospital-based enabling physicians to access real time vital signs information in a critical care unit [86]. Finkelstein et al. have developed a system combining POTS-based video conferencing and vital signs monitoring to care for home-based patients with heart failure, chronic obstructive pulmonary disease, and chronic wound healing problems [25]. This system has been well received by the patients since it reduces the need for travel in between home visits by the visiting nurse and relieves the nurse of some of the burden of the travel required to “see” the patient. Rodriguez et al. describe a system to remotely monitor the health status of elderly people and people with disabilities after discharge from a hospital, and also provides an alert for an emergency response team. Several studies have examined the remote monitoring of cardiac rehabilitation [87]–[89]. These studies show that cardiac rehabilitation and patient comfort can be improved through remote monitoring. Telecommunication technologies including cable modems, high-speed phone lines (ADSL), and wireless systems [38] are being developed in response to a perceived huge market. Predictions can be made that bandwidth will increase, video quality will increase and data will be capable of being transmitted in parallel at much higher bandwidth; however, rural areas are likely to be last in line to benefit from these technologies.

V. DECISION SUPPORT SYSTEMS

The Internet has expanded the possibilities for providing resources to patients and clinicians alike. These resources include providing information related to patient education as well as distance learning for experts. The information provided on the web sites can come from a variety of sources, such as expert clinicians and physicians or databases. By using these resources, both consumers and experts are enabled to become better informed in making important decisions, possibly preventing the onset of complications or disease through information [90]. Decision support systems for people with disabilities and rehabilitation professionals lags behind that of other consumer and medical communities. This may be related to the resources available to people with disabilities as well as their limited access to the Internet. Also, rehabilitation programs tend to have less discretionary monies to develop information programs than other areas of medicine.

A. Patient Oriented Web Sites

For those who have access, the Internet is a powerful tool providing a wealth of medical and health-related information. Patient oriented web sites have increasingly appeared...
on the web. Many are designed with general medical information in mind, whereas others are focused on a specific disease or diagnosis. The immediate question is whether or not consumers are really using the Internet to access medical and health-related information. Forstrom and Rigby [91] reported that 20% of the population of Finland use the Internet at least once a week to seek information, with the younger population reporting a focus on using the Internet for medical information and guidance. In the U.S., estimates from 1998 show that 83.7 million individuals are accessing the Internet either at home or work [92] for multiple reasons.

Some patient-based web sites are currently using expert decision support programs that work similarly to diagnostic flowcharts, allowing the consumer to make their own decision as to whether or not urgent medical care is needed [93]. This type of expert system has been tested in the “Diaboto” project, in which a web site was designed containing an interactive questionnaire for assessing the risk of adult onset diabetes [94]. Results indicated that 46% of the web site respondents were found to be at risk for developing the disease and were advised to speak to their physician. Follow-up as to whether the risk actually existed or if the subjects eventually developed diabetes was not presented in the article.

Why are people increasingly turning to the Internet for health information? Eysenbach et al. [90] reported on individuals who e-mailed medical questions to a comprehensive online informational resource on dermatology located on the web. Results provided possible reasons why individuals were turning to the web to answer questions and included lack of trust of physician, anonymity, lack of information provided by physician, need for information for relatives, and frustration from previous sources of information [90]. Interestingly, the same research showed that individuals living in remote or medically underserved areas, or individuals having a physical disability were not obtaining information from the web. This is in contrast to the general feeling that people who live in rural areas are turning to the web for information. The difference in beliefs could possibly be due to the sampling technique used by the study, the population coming from industrialized countries, or the specificity of dermatology. Other research has shown that regardless of education level or computer skills, most could benefit from the knowledge gained from the Internet and if consumers are provided access, it will be used [95], [96]. Within rehabilitation, no published information exists about the numbers of people who are accessing rehab sites to gain information. Some sites, such as http://www.wheelchairnet.org [funded by the Rehabilitation Engineering Research Center (RERC), University of Pittsburgh], do provide answers to persons who e-mail the site with questions. The answers are supplied to the web site by a board of experts (physicians, therapists, rehab engineers) connected to the RERC.

In clinical settings, physicians are using the Internet to aid in patient education. Helwig et al. [95] developed a web page directory to patient education sites on the Internet and made it available to patients during physician office visits. Subjects were monitored for type of information collected, sites visited, amount of time spent using the resource, and the patient’s satisfaction with the addition of Internet access during their doctor visit. Results showed that 94% of the subjects found the Internet helpful, with 77% stating they would change a health behavior because of what they had read on the Internet. The majority stated they were more satisfied with their office visit than in previous visits.

The Internet has also been used successfully in aiding patient self-monitoring. Montani et al. [97] have used a computer-based system connected to the Internet to aid patients in monitoring their diabetes. Traditionally, patients self-monitor the blood level of insulin, the dose of insulin taken, and food intake by written documentation. With Montani’s system, patients use the Teleconsultation Insulin Dependent Diabetes Mellitus (T-IDDM) system to enter relevant information into the computer. The computer in turn sends this information to the treating physician every week, and includes a built in feature allowing for alert messages to be sent in case the patient encounters a problem. The T-IDDM system allows interactive support and teleconsultation for patients and provides the physician with a timely set of data that can be analyzed to determine solutions for avoiding eventual metabolic problems. More effective decisions can be made about the treatment of one’s diabetes with more extensive data. To date, the system has provided evidence that interactive self-monitoring is beneficial to diabetes patients.

B. Quality of Information

Although it is beneficial to provide guidance for risk assessment, few guidelines and regulations exist for monitoring the quality of the information provided to consumers via the Internet. Soot et al. [98] conducted a study examining the quality of online patient-oriented information on vascular surgery that exists on the Internet. Searches about specific vascular procedures were completed on five Internet search engines, and the top 50 hits from each search were analyzed for the quality of the information provided. Analysis included a qualitative examination of information on the 50 web sites as well as a standardized scoring system to quantify the level of information. Results indicated that vascular surgery information is difficult to find, and once found, the majority of the information is of poor quality, with 33% of the information categorized as misleading. Additional studies on pediatrics have yielded similar results; of 41 web sites discussing home management of childhood fever, only four gave complete and accurate information [99]. Similarly, of 60 articles retrieved from 300 sites discussing childhood diarrhea, only 12 conformed to the American Academy of Pediatrics recommendations for the treatment [100]. The quality of information within rehabilitation sites has not been examined, although preliminary research examining accessibility of web sites for the visually impaired has shown 73% of web sites reviewed, focusing on rehabilitation, could pass a Bobby test (http://www.cast.org/bobby/) as well as be read
by a screen reader (Jaws) [121]. The Bobby test is a free service provided to help determine the accessibility of web sites by people with disabilities.

Obtaining medical information from the Internet poses a number of problems, including legal issues for the physician, patient confidentiality, and lack of disclosure of scientific evidence as to the value of a treatment or modality. The question of who is liable, if an individual is injured based on information gained from the Internet has not yet been answered. Is the person or organization posting the medical article on their web site liable or might the physician who presented the results be found liable? For a physician, providing advice over the web can also create problems with licensing and liability [90]. Since physicians are required to obtain state licensing, and the licensing is not consistent across states, providing medical advice on a medium that covers the world is of concern.

The quality of health-related advertising on the Internet also deserves attention. The advertising industry has used the Internet as a medium to market their products. In 1997, the FDA began permitting drug companies and medical device manufacturers to advertise on the Internet. Theoretically, increased advertising could improve the quality of applicable information. But since the quality of advertising is self-regulated, the burden is on the consumer to determine what information is and is not reputable.

Based on research finding the quality of some Internet information to be less than reputable, the thought of consumers making health care choices based on potentially questionable information can pose health risks. Several authors [101], [102] have attempted to create a quality assurance structure that laypersons can follow in order to better assess the quality of web sites and online information. They suggest evaluating the following quality components: authorship—authors and contributors, their affiliations and relevant credentials should be provided; references and sources for all content should be listed clearly and copyright information noted; web site ownership should be fully disclosed; and web site information should state when content was posted and should be updated regularly [102]. Others [103] have provided additional guidance for evaluating the quality of web sites, which include: consider the source; check the date; contact the site directly; be critical; get educated; and do not rely on search engines.

The Internet has the possibility of providing valuable information to those who may not normally be able to access that level of information. Individuals providing health care information to the Internet should uphold the traditional standards that the medical community places on physicians. Patients using the Internet for guidance should be cautioned that medical decisions should be made in consultation with a treating physician. Unfortunately, research indicates that often patients do not tell their physicians that they are using Internet services [91].

At this time, little if any has been written about the quality of information available on rehabilitation. Many web sites have been developed with rehabilitation and disabilities in mind, including “Wheelchair Net” developed by the University of Pittsburgh, Rehabilitation Science and Technology Department (http://www.wheelchairnet.org). The web site has quality information and conforms to the recommendations for judging quality online Internet material; no published documentation exists about the quality of the sites that are linked to the home site of WheelChair Net. Other sites that offer information regarding general information geared toward individuals with disabilities include http://www.cando.com, http://www.rehabnet.com, http://www.halftheplanet.com, http://www.wemedia.com, http://www.disabilitynet.co.uk, and http://www.makoa.org. Most of these sites have information as well as links to other related web sites specializing in rehabilitation and/or disability.

C. Web Sites Directed toward Rehabilitation Professionals

Research has shown that physicians have a need for information on daily basis in order to answer some questions that are posed to them by their patients [104]–[106]. Unfortunately, research has also shown that less than 30% of the patient questions are ever answered [120]. When physicians require additional knowledge, studies indicate that they are most likely use the easiest and most convenient mechanism for finding the answer [105], which often is to ask a colleague [104], [106]. The use of the Internet to obtain answers to questions requires examining online databases, such as MEDLINE. Although research has shown that MEDLINE has been helpful with improving care [107], it can be time consuming and often results in incomplete answers [108].

As with patient web sites, the quality of information available to clinicians has been questioned as well, although not as well researched. McLaughlan et al. [109] compared the quality of information available to orthopedic surgeons via postings on the Internet compared to a professional journal. Findings showed that over half of the Internet listings had at least one referenced journal article and that 77% of the listings were written by senior level physicians. Other studies have shown similar results [110]. Therefore, in contrast to patient-oriented web sites, professionally geared web sites seem to have better quality information, possibly because the clientele reading the information is better educated and less tolerant of poor representation of research or practice.

Other expert/clinician web sites are focused toward increasing or continuing education. Continuing medical education (CME) is required to maintain licensure for physicians and therapists. Peterson et al. [111] examined the usefulness and practicality of providing CME credits over the Internet. Results indicate that usage of the system has increased 2.3-fold over 18 months and that physicians are willing to pay for CME credits and complete the examinations over the Internet. Distance learning has been applied in a variety of settings in medicine including nursing, nurse practitioners and physical therapy [112]–[114]. One example is the University of Kentucky, which in response to a rural health initiative in 1991, developed a distance learning program of physical therapy instruction which combines classroom lectures and discussion via video technology [114]. Initial results showed that there were no differences between the distance learners and the on-site learners.
The Internet also provides a valuable resource for recruitment and monitoring of clinical studies. Many large multicenter clinical trials use the Internet as a source of data collection and management. The Epidemiology Data Center (EDC), located within the Graduate School of Public Health, University of Pittsburgh has developed MATRIX, which is a specialized data entry/management program, enables the use of the Internet for effective data entry and management of clinical research studies (http://www.pitt.edu/~epidept/epihome.html). Although the studies completed at the EDC are not focused on rehabilitation, the techniques for managing large studies are available.

The Kessler Medical Rehabilitation Research and Education Corporation (KMRREC) initiated an Internet project in 1999 targeted to rehabilitation professionals: http://www.RehabTrials.org. The purpose of the site is to increase collaboration and communication between professionals in the rehab community. RehabTrials.org also provides a listing (over 40) of ongoing clinical trials that are being completed across the country at different universities, including Kessler Research, University of Washington, Baylor College, and Pittsburgh VA Healthcare System Center of Excellence. Interested clinicians and patients are able to find out about research studies, and either provide collaborative support or volunteer for the research study. At this time, RehabTrials.org is the only known site that provides such a reference list.

D. Rehabilitation Databases

By definition, a database is the management of any specific collection of information and can extend from a phonebook to a reference manager such as MEDLINE. The marriage between traditional databases and the Internet has facilitated the growth of information that can be used not only by consumers but by professionals as well. Topfer et al. [115] sought to assess the quality, cost and overlap between two biomedical databases that are available through the Internet: MEDLINE and EMBASE. The study concluded that limiting searches to just one database results in the missing of relevant information. In addition, unless there is access to the databases through a public institution, most biomedical databases have minor charges associated with them. For example, EMBASE charges $2.00, PsychInfo (Psychological Abstracts) charges $0.75, and CINAHL (Nursing references) charges $1.50 for each detailed reference. Reference databases that are free to the Internet community include MEDLINE, CancerLIT, and HealthStar (nonclinical aspects) (http://www.healthgate.com). Various agencies also provide personalized search mechanisms of their databases to allow professionals to be alerted to funding opportunities. Two such agencies are http://www.sciencewise.com and Community of Science expertise (http://www.expertise.com).

A primary benefit of web-based databases, especially those storing clinical data is access to the information by all members of the medical treatment team, whether they are located on-site or at a remote facility. For example, in a rehabilitation setting for a spinal cord injured individual, a web-based database would allow review of patient information by the immediate care-giving team (i.e., physical therapists/ occupational therapists), wheelchair seating specialists who may be located at a specialized clinic, and by the researcher working at a university setting. It could allow for tracking of the type of assistive technology that the patient would own and use over time, as well as allowing for better understanding by the policy makers in a hospital to determine what piece of equipment may be more beneficial than others.

At the moment, few published databases exist in the rehab world, with one of the few emphasizing a system of teleconsultation using the Internet in insulin dependent diabetes mellitus (IDDM) [97]. Methods similar to the IDDM experience could be used in settings other than diabetic management. Intensive therapies such as pressure sore management and pressure relief may benefit from similar methodologies.

The Internet is a promising tool that can benefit patients and clinicians alike. An awareness of the issues and an understanding of the work that still needs to be completed is the first step in bringing rehabilitation to the forefront of telerehabilitation as leader in quality information and usefulness of the Internet. The Internet provides many advantages to the consumer and expert. For both, information can be obtained readily, often with little skill required. The cost of providing information is relatively low in comparison to traditional methods such as printing costs of brochures and educational pamphlets. An attractive application of the Internet is the ability to have personalized and interactive sessions. Individuals can interact with others who have similar problems/diagnoses, or with experts from around the world. Within rehabilitation, little research has been completed to determine how the field could benefit from the Internet. To date, no quality guidelines exist for establishing the credibility of rehabilitation information on the web. Therefore, we as the rehab community are relying on each other to self-regulate and provide quality information.

VI. LIMITATIONS AND FUTURE DIRECTIONS

As with all advances in medicine, telerehabilitation faces substantial hurdles. These hurdles include the need for scientific evidence of telerehabilitation’s efficacy, credentialing issues, cost, and reimbursement.

Prior to being fully accepted as a clinical tool, telerehabilitation will have to be shown to be effective and safe. Proving the efficacy of a telerehabilitation is a daunting task. It is necessary to prove that the decisions a clinician makes in person are not different than those made during a telerehabilitation evaluation. Unfortunately, designing a study to prove this is difficult. A single clinician cannot evaluate the same individual twice (once in person and once via telerehabilitation), without the two evaluations influencing each other. Alternatively if two separate clinicians are used, they may not agree on a treatment approach even if they evaluated the same patient in-person. Therefore, it may be difficult to ascertain if differences in clinical approach during a trial of telerehabilitation are due to inherent differences in clinicians or due to
the medium through which the information is obtained, telerehabilitation or in person.

To date a clinical trial proving the efficacy of telerehabilitation has not been completed. We can draw from trials in other areas. The most work has been completed in radiology. In this area, a teleradiology program that used high-resolution monitors was as effective as reading a hard-copy film [116]. Unfortunately, this example does not translate well to clinical service provision in rehabilitation. Clinical research closer to rehabilitation does exist in dermatology. A study by Wirthlin et al. had multiple dermatologists assess wounds and recommended treatment both in-person and remotely through the use of a digital image of the wound [117]. The study found 60% to 95% agreement between in-person and telemedicine evaluations. This was the same level of agreement seen when comparing two clinicians who both viewed the wounds in person. Important factors found to influence the results included level of training and type of wound.

Provided telerehabilitation is proven effective in replacing in-person assessment, the next issue raised is cost. The cost of telecommunications equipment has consistently fallen over the last decade and this can be expected to continue [118]. An early report by the Office of Rural Health Policy found that the cost of telerehabilitation consultations was higher than in-person consultation [119]. This was in part due to the need for billing professionals at both end of the communication link. These costs may be reduced by using providers with less advanced qualifications to conduct the in-person evaluation under the observation and direction of a more extensively trained provider at a remote location. One could envision an occupational therapist (OT) with experience in rehabilitation directing a certified occupational therapy assistant (COTA) who is conducting the in-person evaluation. If this reduced travel time for the OT, it could reduce cost. Data collection and experience will be necessary to determine the optimal combination of providers. Since patients requiring rehabilitation assessment are by no means a uniform population, it may be necessary to identify the ideal configuration of the assessment teams on the basis of impairment or need to be addressed. For instance, evaluation for a seating system may require a therapist skilled in neuromuscular evaluation (manual muscle testing, joint range of motion evaluation, assessment of other motor function) in-person and a team consisting of equipment vendors or technician and clinicians with expertise in seating and positioning at the remote site. On the other hand, evaluation of an amputee may require a therapist or therapy assistant to perform physical evaluation plus a prosthetist or prosthetic technician to make adjustments to a prosthetic device in-person and a physiatrist consulting at the remote site.

Reducing travel time for more highly trained staff such as nurses, therapists and physicians may ultimately reduce costs. Under current reimbursement systems, however, there may be financial disincentives as well. Currently, the services of therapy assistants are not usually reimbursable. In addition, there are limits on what physician and therapist services can be billed on the same day. These reimbursement rules may limit the provision of telerehabilitation services to teams employed by a single facility rather than encouraging cooperation between facilities.

Using the current payment system to understand financing a telerehabilitation program is problematic as it is based on a prospective payment system (for more information, go to http://www.hcfa.org), using diagnoses and number of home visits required. Understanding this limitation, we surveyed a local health care system and found that they received, on average $125 per home visit. Nurses were responsible for the majority of these visits and the associated billing. If the costs permitted under a prospective payment system could be generated using a less expensive health care professional (delegate) in consultation with a home health care nurse, it may be possible to recover actual costs. One could use a number of delegates working with a central expert. At the $125 rate it may be possible to cover the delegates, the expert, and possibly some of the costs associated with the equipment. Despite the potential for improved care for individuals in rural communities, due to greater access to expert providers and decreases in consumer travel expenses, it is obvious that reimbursement issues will need to be addressed before telerehabilitation service will be used in anything but clinical studies.

Another issue to overcome in telerehabilitation is credentialing. This differs across specialties and boundaries. In general, if a telerehabilitation evaluation is occurring across state lines, all parties will need some form of credentialing and licensure for the state in which the patient is seen. For example, physicians are required to be licensed in any state in which they practice. A physician from Ohio cannot practice medicine in Indiana without receiving an Indiana license. Although this does not require a test, there is significant paperwork and a cost associated with each license. In addition, each state has different regulations covering the amount of malpractice insurance a physician must have in order to practice. This situation is not related to a "radio doctor" who provides advice. Radio doctors do not bill and can and do recommend that listeners talk to their personal physician prior to following any medical advice.

The issues related to licensure and billing are not unique to physicians, as most clinicians require a state-specific license to practice. Obviously, this could become an onerous task for a clinician who is involved in providing telerehabilitation consultation in multiple states. It is important to note that some concern is present among the medical community that telemedicine could adversely affect small, local programs [117]. The fear is that individuals would want to have large academically known medical centers involved in their care, thus depleting resources from local hospitals. This concern could make resolving credentialing issues more difficult across state boundaries. Until effective means to handle credentialing are determined, it is likely that telerehabilitation may be restricted to the states in which no licensing issues are present (i.e., telerehabilitation from two locations in the same state).

Lastly, it will take time and experience to get clinicians to learn to effectively use and accept telerehabilitation technology. Clinicians acting as consultants using telere-
habilitation will have to learn to use observation rather than touch and how to effectively communicate with the in-person providers to gather comprehensive and accurate information in an efficient manner. Just as some surgeons have chosen not to master limited incisions and scopes, some rehabilitation clinicians may not choose to provide telerehabilitation services.

Although the hurdles to telerehabilitation becoming a widely accepted clinical tool are many, so are the promises. High quality consultation to underserved areas is greatly needed. Given the promise of the technology and the possibilities of improvement in care, it is likely that each hurdle will be overcome and that this technology will have dramatic effects on how we practice rehabilitation.

REFERENCES


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