Enhancing Quality of Life Through Telerehabilitation

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Telerehabilitation is an emerging method of delivering rehabilitation services that uses technology to serve clients, clinicians, and systems by minimizing the barriers of distance, time, and cost. More specifically, "telerehabilitation can be defined as the application of telecommunication, remote sensing and operation technologies, and computing technologies to assist with the provision of medical rehabilitation services at a distance."[1] Much attention has been paid to the efficacy of telerehabilitation in efforts to decrease time and cost in the delivery of rehabilitation services. Some studies have also compared telerehabilitation services to face-to-face interventions to discover whether these approaches are "as good as" traditional rehabilitation approaches. However, telerehabilitation may in fact provide new opportunities that are more effective by increasing accessibility and creating the least restrictive environment.

Telerehabilitation was first documented in 1959, when interactive video was first used at Nebraska Psychiatric Institute in the delivery of mental health services. Over the past 50 years, technologists and clinicians have investigated the use of bridging the gap between individuals with specialized medical needs living in remote areas and the source of specialty care.[2] Closely related to the emergence and use of telerehabilitation are solutions to problems associated with technological, functional,

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economic, political, and geographic convergence. Technologies that enable telerehabilitation services, such as increased computer power and availability of high-speed data transmission lines, have become more prominent in recent years.[3]

Winters provides a comprehensive review of the conceptual models of telerehabilitation.[4] He explains that telerehabilitation falls under a broader category of services that use telecommunication to provide health information and care across distance, termed telehealth. Telehealth is broken into 3 subcategories: telemedicine, telehealthcare, and e-health/education. Telerehabilitation is classified into the category of telehealthcare along with telehomecare, telenursing, and telecoaching. Not clearly defined, these terms are often used interchangeably throughout the research literature. There is an existing need for consensus of the terminology used in this field to allow for a clear description of services. It has been proposed that telerehabilitation warrants a separate and parallel identity alongside telehealthcare and telemedicine.[5]

AN ALTERNATIVE MODEL OF TELEREHABILITATION TO PROMOTE QUALITY OF LIFE

Much of the research literature on telerehabilitation has focused on outcomes measures on decreasing costs, saving travel time, and improving access to specialty services and expert practitioners.[6] The rationale proposed to support the exploration and implementation of telerehabilitation has been essentially based on the use of various technologies to address geographic and economic barriers, and potentially enhance cost effectiveness. An alternative perspective is that the potential benefit of telerehabilitation technologies is that effective rehabilitation services can be implemented in the individual's environment (home, community, workplace, and so forth).

Examples are found in the behavior therapy literature, in which there is substantial evidence that interventions delivered in vivo, or in the patient's natural environment, have been more effective than the same therapy delivered in the clinic. This benefit has been demonstrated with treatment of agoraphobia,[7,8] panic,[9] pain,[10,11] fear of reinjury in patients with back pain,[12] and social phobia.[13,14]

There is also significant impetus to support the value of medical rehabilitation services delivered in the home. Although much of this literature seems to be motivated by providing a rationale for expeditious discharge from the inpatient setting for cost-saving purposes, the research supports that the delivery of some home-based rehabilitation services is at least as effective as the delivery of those services in hospitals, and in some cases adds contextual factors that enhance rehabilitation and outcomes. These findings support the development and implementation of telerehabilitation approaches to facilitate naturalistic rehabilitation treatment in the home.

In a study by Von Koch and colleagues,[15] a comparison between therapy following stroke delivered in the home versus in the clinic revealed that patients treated in the home took greater initiative and were more likely to express goals than patients treated in the hospital. In a similar randomized clinical control study of poststroke patients, Holmqvist and colleagues[16] determined a systematic positive effect for those treated in the home in levels of social activity, activities of daily living, motor capacity, manual dexterity, and walking. Significant differences were also noted in rate of readmission and in patient satisfaction in favor of the home treatment group. Legg and Langhorne[17] completed a systematic review of randomized clinical trials of rehabilitation therapy provided at home, and found that therapy at home resulted in improved ability to undertake personal activities of daily living and reduce risk of deterioration in ability. In-home treatment was found to reduce the incidence of delirium, reduce the duration of rehabilitation, and reduce rehabilitation costs in a frail elderly population.[18]

Telerehabilitation approaches were recommended to facilitate in-home intervention approaches with persons with traumatic brain injury[19] and the elderly.[20]

Attention to contextual factors in rehabilitation is reinforced by the World Health Organization framework that emphasizes an individual's functioning within the context of their environment.[21,22] Recognizing that the social and physical environment can be facilitative (or inhibitory), rehabilitation that can occur with the patient's own home and community has greater relevance to the patient. Ylvisaker[23] states that for individuals with brain injury, cognitive rehabilitation that occurs in the natural setting and within the context of everyday interaction and demand domains is more relevant to the individual. Willer and Corrigan[24] cite that the issue of generalization can be a major obstacle to achieving a successful rehabilitation outcome. What is learned or accomplished in one setting (eg, a clinic) does not necessarily generalize to other settings. Willer and Corrigan[24] assert that the problem of failure of generalizability can be successfully addressed by conducting rehabilitation in the environment in which the skills must be applied.

The literature on supported employment, a demonstrated effective vocational rehabilitation strategy for enabling persons with severe disabilities to achieve competitive employment outcomes, stresses 2 naturalistic features. The model is built on the "place and train" premise, which states that individuals with disabilities should be placed in the real workplace as soon as possible, and that "pretraining" in clinical or simulated environments is less effective. The second feature is that supports and interventions (including cognitive rehabilitation, assistive technology, and adjustment counseling) can be delivered in the natural environment, through a job coach.[25] Job coaching can be delivered by a live job coach, on-site, or through the use of telerehabilitation technologies to monitor and intervene remotely.[26]

In summary, there is considerable evidence to support the value of conducting some aspects of rehabilitation within the natural environment. The literature suggests that such naturalistic treatment increases functional outcomes, addresses problems with generalizability, and enhances patient satisfaction and self-direction. These factors have also been related to quality of life issues. Therefore, telerehabilitation can play a key role in the accessibility and implementation of naturalistic and in vivo treatment.

As of April 2009, 63% of adult Americans reported broadband usage within their homes, up from 55% in May 2008.[27] Given that the availability of Internet access is increasing extensively, and that wireless access is projected to become much more universally available,[28] the potential to integrate treatment and monitoring into the environments where people live and work through in vivo telerehabilitation applications can become a viable option.

TELEREHABILITATION TECHNOLOGIES

Traditional models of telemedicine began with videoconference interactions between a service provider, such as a physician or nurse, directly to a patient at the remote site. In recent years the model has been broadened, and the technologies supporting the remote service provision have diversified dramatically. This section briefly addresses models and then provides an overview of telerehabilitation technologies.

Models for providing telerehabilitation may provide services either synchronously (in real time) or asynchronously, in which data are collected and then later forwarded via email, bluetooth technology, or other electronic format for review by a clinician. Asynchronous applications are therefore often referred to as a "store and forward" approach. The exchange may be directly between provider and patient, but more frequently includes a paraprofessional or facilitating staff person at the remote site who may be tasked simply with technology management, or may play a significant

role in engaging the patient in interview or physical tasks. Telerehabilitation may alternatively follow a consultative model, in which the telerehabilitation provider participates in an assessment with the patient and his or her primary clinician at the remote site. Technology may also be developed in Web-based, robotic, or virtual reality-based formats and used autonomously by patients remotely, with the clinician observing patient responses and modifying the tasks accordingly. Here a variety of commonly used technologies for telerehabilitation are briefly reviewed, including telephones and videophones, video-conferencing, sensors, personal digital assistants (PDAs) and smart phones, virtual reality, and robotics.

Plain old telephone service (POTS) technologies use a real-time, standard analog voice-grade telephone service that remains the basic form of residential and small business service connection to the telephone network in most parts of the world. POTS is available in 97% of United States households.[4] Despite the growing availability of high-speed Internet availability in individuals' homes throughout the United States, the use of the POTS is still the most widely used mechanism for providing home tele-services.[5] This situation may be in part due to the fact that prevalence and acceptance of technologies depend largely on ease of use and keeping implementation costs low.[26] One step further is the *videophone* that is basically a telephone with a video screen, and is capable of full bidirectional video and audio transmissions for communication between people in real time. Videophones can especially be useful to persons who are deaf or who have hearing impairments, and can use them with sign language or for lip reading. *Video-conferencing* differs from the videophone in that it is designed to serve multiple participants through a conference rather than individuals. Video-conferencing is a set of interactive telecommunication technologies that allow 2 or more locations to interact via 2-way video and audio transmissions simultaneously. These interactive systems consist of some version of a video monitor, video camera, speakers, microphone, and a CODEC. The CODEC (stands for COder-DECoder) uses hardware or software to simultaneously code and decode (compress and decompress) digital video and audio information, and sends it to another CODEC where the same process is also being done.[29]

Real-time access may also be provided through *wireless technologies* that transfer information over a distance without the use of electrical conductors or ''wires.'' The distances involved may be short (a few meters as in television remote control) or long (thousands of miles for radio communications). When the context is clear, this term is often shortened to ''wireless.'' Technology that is able to be provided wirelessly allows increased freedom to be used within various environments and unrestricted movement.

PDAs and cell phones are some of the most common and widely used wireless devices. PDAs are handheld computers, also known as palmtop computers or handheld mobile computing. Newer PDAs also have both color screens and audio capabilities, enabling them to be used as mobile phones (smart phones), web browsers, or portable media players. Many of today's PDAs or smart phones can access the Internet, intranets, or extranets wirelessly. Wireless, interactive, Web-based interventions are particularly suited to providing rehabilitation intervention and monitoring in the home and community environments. Gentry has completed studies in the use of PDAs as cognitive supports for persons with traumatic brain injury and multiple sclerosis. Positive outcomes were found with the use of PDAs as an intervention to improve performance of everyday life tasks for both of these populations.[30,31] Technology is quickly converging with the development of smart phones, which combine PDAs with Internet access and cellphone technology as the convention of today.

Likewise, newer technologies include software applications that allow the user to make a voice or video call over the Internet, such as in the popular application called

Skype.[32] However, clinicians must consider the need for security and ensure that all precautions are taken to maintain patient confidentiality in accordance with *Health Insurance Portability and Accountability Act* regulations. Other technologies, including remote desktop control by the therapist (or desktop "push"), are examples of how rehabilitation services, such as job coaching and career development counseling, can be applied remotely.[33]

Many *motion sensors* and technology involving *body monitoring* are now available wirelessly. A motion sensor is a device that contains a physical mechanism or electronic sensor that quantifies motion, which can be integrated with or connected to other devices that alert the user of the presence of a moving object (or person). Some examples of these devices include accelerometers for determining position in space and rate of movement, physiologic monitoring sensors that can track or check blood pressure or body temperature, electrocardiogram for heart rate, contactless sensors fatigue electromyogram for monitoring muscle activity, or electroencephalogram for monitoring brain electrical activity.[34]

A newer technology that is being used with increasing frequency is *Virtual Reality* (VR). VR technology allows a user to interact with a 3-dimensional computer-simulated environment, whether that environment is a simulation of the real world or an imaginary world. VR systems provide sensory feedback to the user and whereas most systems use visual feedback, some simulations include additional sensory information, such as sound through speakers or headphones. Although VR is not geared toward the natural environment, it approximates or recreates it. For example, the popular game called The Sims encourages players to make choices while fully engaged in an interactive environment. This characteristic has helped the game successfully attract casual gamers.[35] The Sims does not have the person engage in their natural environment to practice social skills, but creates a quasi-realistic setting to safely practice skills, with consequences but without long-term detrimental effects.

Other advanced systems called haptic systems now include tactile information, known as force feedback in applications. *Haptic technology* interfaces with the user through the sense of touch by applying forces, vibrations, or motions to the user. The user can "believe" objects in the virtual environment, and with practice can become skilled at subconsciously using an object as if it were an extension of their own body (ie, a pen for writing).[4] Rehabilitation robotics is a growing area in which haptic technology is being used to aid and augment the traditional therapy intended for patients with motor disabilities to improve motor performance, shorten the rehabilitation time, and provide objective parameters for patient evaluation.[36]

TELEREHABILITATION APPROACHES TO ENHANCE QUALITY OF LIFE

Rehabilitation services often comprise a scope of services, beginning with assessment, moving on to intervention, and then assure patient success and outcome via follow-up services. telerehabilitation strategies and applications provide additional venues to allow for provision of rehabilitation services at a distance where persons live, work, and play. Not only has home and community-based rehabilitation been found to be preferred by persons with disabilities,[37] provision of services within the naturalistic and least restrictive settings has also been found to be more effective in several ways, as noted earlier. In particular, skills are more likely to generalize if taught in the environment(s) in which they will eventually be used in the person's daily life. Although it is not possible to provide a description of every possible clinical application of telerehabilitation in an article of this brevity, reviews of several venues for telerehabilitation focused on home and community-based rehabilitation efforts are included to exemplify

the variety of clinical applications and the magnitude of potential to improve quality of life.

Remote assessment of rehabilitation needs has been described for neuropsychological status,[38] apraxia,[39] motor speech disorders,[40] wheeled mobility and seating,[5] and gait,[41] among numerous other applications. A particularly time-consuming assessment critical to everyday function has been the evaluation of a patient's home environment for accessibility and potential home modification. As part of the University of Pittsburgh's Rehabilitation Engineering Research Center on Telerehabilitation, a protocol with supporting software has been developed to allow accessibility assessment of a home without the need for on-site assessment via data (photos), which can then be sent electronically back to the University. The software can produce a detailed 3-dimensional visual layout of the home with adequate specificity to render architectural drawing, and to make recommendations to the patient and family about potential interventions without the professional making a time-consuming trip to distant locations.[42]

Intervention in the home or work environment has been provided remotely for numerous needs, including cognitive rehabilitation using the Internet,[43] constraint-induced movement therapy using a computer and sensors to guide the patient through exercises,[44] and speech pathology for children with autism.[45] In recent years, there has been a trend toward self-management programs as a long-term intervention tool for individuals with chronic medical conditions. Although these programs were initially presented in face-toface, usually group-based formats, they have now moved to Internet-based modalities.[46] Whereas the original interventions were focused on a few medical conditions such as asthma and diabetes, they have now expanded to a wider variety of chronic conditions such as epilepsy,[47] and have incorporated a variety of self-assessment tools, education, goal-setting, and discussion board modalities to support increased self-management. These Internet-based interventions can be conducted without requiring the patient to travel to a central site, allowing them to learn and be provided feedback on daily functions specific to their progress, and also engage with others, with the relatively simple technology of a computer and the Internet.

Another area for intervention and monitoring in rehabilitation is falls. Falls are one of the most commonly occurring problems within the aging population, often resulting in prolonged periods of or permanent disability, and typically require rehabilitation interventions. In a recent study conducted by the University of California at Los Angeles (UCLA), ''falls were responsible for 70% of accidental deaths in persons age 75 or older.''[48] Several new devices have recently been created to reduce the incidence of falls, or at least decrease the severity of injury and impact on the individual. The SmartCane was developed by researchers at UCLA to prevent falls. Equipped with contact pressure sensors in its handle and base, this device can predict risk for falling and communicate this information wirelessly to the individual, caregivers, or medical providers. This information reveals whether the person is using the cane properly. If improper use of the SmartCane is identified, the person can then receive additional training in the proper use of the device. The lightweight SmartShoe similarly is able to determine fall risk by analyzing walking behavior patterns. Also, training can take place to improve safety and proper ambulation with use of a mobility device such as a walker.[48]

The need for ongoing case management, follow-up, or monitoring in the home environment has also found varied support in telerehabilitation, ranging from videophone support of families caring for individuals in a minimally conscious state[49] to monitoring of the number of steps taken in patients with Parkinson disease at home via a wearable sensor.[50] A more complex and well-developed system of case management and monitoring in rehabilitation was developed for veterans with polytrauma.[51] In this

project, the Low Activities of Daily Living Monitoring System (LAMP) used therapists as care coordinators to provide assistive technology (AT), hands-on and remote training on AT, as well as computer and Internet access for daily completion of LAMP questionnaires on functional status, ongoing remote support for self-care, and home modifications.

OBSTACLES AND OPPORTUNITIES

There are multiple challenges and potential barriers to the implementation of telerehabilitation services in everyday clinical practice. Primary among them are concerns held by clinicians, policy issues with reimbursement and licensure, privacy, and confidentiality, and the limited scope of current research on telerehabilitation.

Schopp and colleagues[52] identified several reasons for the decreased satisfaction of clinicians that is relevant to any applications of telerehabilitation. Of note, it is the patient, not the health care provider, who is inconvenienced by the need to travel to an appointment at a distant location to see a specialist, and is therefore most likely to appreciate the opportunities afforded by telerehabilitation. For persons with disabilities or illness, traveling is often very difficult. In addition, most health care providers are accustomed to practicing in an environment over which they have full control, rather than introducing an external environment into clinical service. Many health care providers are also uneasy about use of any technological mediation between them and their clients, and believe that it may hinder therapeutic rapport. Finally, remote service provision is perceived as initially time-consuming for clinicians to learn and to implement.

Policy issues have recently been reviewed in detail, with the finding that there is a paucity of published literature that addresses policy in telerehabilitation; few policy papers have adequate empirical data, and typically only comprise a small part of a larger research article.[53] In terms of licensure issues, licensure restricts the practice of most clinicians to the state in which they are licensed. Telerehabilitation services provided across state lines may jeopardize the clinician's status and render their services as practice without a license. Physicians and other licensed rehabilitation professionals in the federal government are typically allowed to practice anywhere in the country as long as they are legitimately licensed in one state, which has allowed the Veterans Healthcare system and the American military to move quickly to implement telemedicine and telerehabilitation. Policy issues for reimbursement of clinical services are typically led by Medicare, which has implemented funding for telemedicine services (ie, teledermatology, telepathology, telepsychiatry, and so forth) in many states, but has had very limited funding for telerehabilitation.[54]

Due to the electronic nature of data transmission associated with telerehabilitation, there are differing challenges to privacy of clinical service and confidentiality of data and records compared with traditional face-toface services with written or typed documentation. Conducting services in vivo does increase the requirement to explore who might be in the remote environment, and to carefully explain and disclose risks and benefits of telerehabilitation services to prospective patients. Transmission of data electronically affords numerous opportunities for breach of confidentiality, but as with finance and other industries, there are numerous opportunities to enhance security through encryption, networks, and so forth. In addition, many medical systems have migrated to paperless, electronic health records, negotiating many of the challenges to secure electronic communication ahead of time.

The current research literature on telerehabilitation is burgeoning in number of studies, but remains limited to clinical observations and equivalence trials, or is

restricted in generalizability by small sample size. There are few large-scale clinical trials, and research in rehabilitation has traditionally been underfunded.[53] This limited empirical support for specific telerehabilitation practices negatively impacts the ability to convince prospective payers of the viability of telerehabilitation, and suggests that the field would benefit from clinicians and research activity working in tandem to document the appropriate uses of telerehabilitation for improving the quality of life.

RESOURCES

Much of the clinical work and research being done in telerehabilitation is not described in common rehabilitation journals or resources, but a familiarity with professional resources in telemedicine will provide a venue to explore applications that may have direct relevance to rehabilitation. Journals include *Telemedicine and e-health*, *Cyberpsychology and Behavior*, and the *Journal of Telemedicine and Telecare*. Given the emphasis on telemedicine in the military and the Veterans Healthcare system, journals oriented to serving those populations are also more likely to include specific clinical applications or research on telerehabilitation, such as the *Journal of Rehabilitation Research and Development* (JRRD) or *Military Medicine*.

The predominant professional organization in telemedicine is the American Telemedicine Association (ATA) (www.americantelemed.org). The ATA has a Special Interest Group in Telerehabilitation currently finalizing standards for provision of Telerehabilitation services, based in part on the nearly completed standards for Telementalhealth (http://www.americantelemed.org/i4a/pages/index.cfm?pageid=3311). Several professional organizations of rehabilitation therapies have produced position papers on the use of telerehabilitation, including AOTA,[55] ASHA,[56] and APTA.[57] Policy and advocacy issues for telemedicine and telerehabilitation are supported by the Center for Telemedicine and e-Health Law at www.telehealthlawcenter.org/.

SUMMARY

Telerehabilitation is an emerging method of delivering rehabilitation services that uses technology to serve clients, clinicians, and systems by minimizing the barriers of distance, time, and cost. The driving force for telerehabilitation has been as an alternative to face-to-face rehabilitation approaches to reduce costs, increase geographic accessibility, or act as a mechanism to extend limited resources. Most of the literature on telerehabilitation targets these needs, and justifies the use of telerehabilitation by attempts to empirically equate remote services delivered via telerehabilitation to face-to-face services. Another rationale for telerehabilitation is the potential to enhance outcomes beyond what may result from face-to-face interventions by enabling naturalistic, in vivo interventions. There is considerable support for the value of interventions delivered in the natural environment, ranging from addressing efficacy concerns by addressing problems of generalization, to increasing patient participation, including environmental context in rehabilitation, and increasing patient satisfaction. These potential outcomes are consistent with promoting quality of life. Further clinical and research exploration should explore telerehabilitation as a tool for the delivery of rehabilitation services in vivo.

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