Robotics and clinical research: Collaborating to expand the evidence base for rehabilitation

INTRODUCTION

Advances in robotic technology have led to an important crossroad regarding their applications to physical and rehabilitation medicine. One aspect of this crossroad is healthcare providers' and the general public's continuing eagerness to use "robotics" to enhance clinical and patient care. Body-weight support treadmill systems, bionic neurons (BIONs™), KineAssist™, and the Massachusetts Institute of Technology (MIT)-Manus are visible examples of robots that can help improve many patients' function, mobility, and overall quality of life [1–5]. The other aspect of this crossroad is clinicians' and researchers' recognition that systematically implementing these promising technologies in treatment and rehabilitation regimens requires a greater scientific base of evidence [6–7]. The biomedical, rehabilitation, biomedical engineering, and behavioral sciences continuously add to our understanding of how robotics can be used in rehabilitation. Yet several questions regarding design, man-machine interface, biological/physiological mechanisms, and treatment parameters still remain. Furthermore, more rigorous clinical trials are particularly needed for providing definitive scientific evidence for clinical guidelines [8].

Recent efforts sponsored by the Department of Veterans Affairs (VA) Office of Research and Development (ORD) are helping to fill these gaps. The Veterans Health Administration (VHA), as the largest integrated healthcare system in the United States, funds a major intramural research program specifically intended to improve veterans' health and healthcare. ORD-sponsored activities range from preclinical research to multisite clinical trials to studies for determining how to best implement research findings. These activities are overseen by four research services: the Biomedical Laboratory Research and Development (R&D) Service, the Clinical Science R&D Service, the Health Services R&D Service, and the Rehabilitation R&D Service. Although certain types of research may better characterize the purview of a particular service, the multidisciplinary nature of key clinical questions requires that these services jointly pursue innovative, comprehensive investigations to advance the VA research mission of total healthcare for veterans.

In this guest editorial, we provide an overview of VA robotics-related research and give a specific example of how the VA has bridged its clinical trials expertise with neurorehabilitation experts in a novel trial that uses robots for stroke rehabilitation. We highlight these studies to demonstrate how collaborative clinical research efforts are helping to build the scientific evidence base for the use of robotics in state-of-the-art care for our veterans.

DEPARTMENT OF VETERANS AFFAIRS ROBOT-BASED STUDIES

VA-supported robot-based investigations aimed at rehabilitative applications primarily stem from the Rehabilitation R&D Service. Several of these efforts are based at seven national Centers of Excellence (COEs) that are dedicated to the development, application, and broad dissemination of emerging technologies that restore and augment impaired function. Engineers and clinician scientists at the Cleveland Functional Electrical Stimulation Center have developed technological solutions to neurological and muscular skeletal impairments. Clinician scientists at the Baltimore VA Medical Center (VAMC) recently established a COE on Task-Oriented Exercise and Robotics in Neurological Diseases to study conditions such as Parkinson's disease and multiple sclerosis. The Boston COE for Visual Innovation is one of a handful of research teams around the world dedicated to retinal prosthesis development. Preliminary findings show restoration of functional sight in patients who had been blind for more than 40 years. The Pittsburgh COE on Wheelchairs and Associated Technology develops mobility aids and performs associated research necessary for evidence-based practices and prescription guidelines for improving quality of life. The Seattle COE for Limb Loss Prevention and Prosthetic Engineering combines clinical investigation of limb-loss prevention with engineered solutions to prosthetic design. Investigators at the Providence Center for Rebuilding, Regenerating, and Restoring Function after Limb Loss are capitalizing on seminal findings from the Seattle COE and others to develop the "Biohybrid Limb" that will use regenerated tissue, lengthened bone, titanium prosthetics, and implantable sensors to allow people with amputations to move their prostheses with nerve and brain signals rather than unnatural compensatory strategies.

Whereas these COEs address a particular condition, deficit, or constellation of associated symptoms, the Advanced Platform Technology Center in Cleveland represents a paradigm shift away from developing customized solutions for singular issues and toward developing off-the-shelf platforms or emerging technologies applicable to a wide variety of dissimilar conditions, such as motor and sensory deficits, wound healing, and limb loss. Investigators are developing a networked neuroprosthetic system of multiple implantable stimulators and sensors that communicate with one other, supply self-contained power, and respond to physiological cues. This system will be adaptable to patients with stroke, spinal cord injury, and other conditions.

In addition to the efforts of dedicated research teams within each Center, VA Rehabilitation R&D Service supports individual investigators who are examining technologies developed outside of VHA. Cochlear implant, limb prosthetics, and virtual reality studies are underway. Future directions include deep-brain stimulation for posttraumatic stress disorder and phantom limb pain.

In the true spirit of collaboration and to transfer technology and resources among ORD services for the development of evidence-based practices, the Clinical Science R&D and Rehabilitation R&D Services have partnered on an exciting clinical trial on upper-limb rehabilitation among patients who have had strokes. VA clinical research is under the direction of the Clinical Science R&D Service, of which the Cooperative Studies Program (CSP) is a key division that specializes in multisite clinical trials and epidemiological studies. CSP is internationally recognized for planning and conducting multisite studies that support important clinical and policy decisions [8] and achieves its mission through a nationwide clinical research infrastructure of statistical, methodological, clinical, and pharmaceutical expertise. In addition, CSP also has a network of health economics expertise to conduct utilization and cost-effectiveness analyses. Currently, the CSP has a portfolio of studies that covers various health conditions and topics, including cardiovascular disease, mental health, cancer, surgery, diabetes, renal disease, genetics, infectious diseases, and neurological disorders. More recently, CSP has initiated trials in spinal cord injury and the aforementioned trial in stroke rehabilitation.

DEPARTMENT OF VETERANS AFFAIRS COOPERATIVE STUDY IN STROKE REHABILITATION

Data from the VA Stroke Quality Enhancement Research Initiative indicated almost 19,000 hospitalizations for acute stroke in 2003. In veterans who have had a stroke, 40 percent have moderate impairment and 15 to 30 percent have severe impairment [9], which equals approximately 11,000 to 13,000 veterans each year. Furthermore, these impairments are persistent: 55 to 75 percent of veterans continue to have significant impairment 3 to 6 months poststroke. Arm deficits are the most significant impairment in 85 percent of patients. A recent survey of stroke patients reported that hand function is considered the most disabling motor deficit [10]. Therefore, identifying effective rehabilitative therapies that target the upper limbs may reduce the impact and associated challenges and costs of disability. The role of neurorehabilitation is an increasingly relevant clinical topic among an aging veteran population at risk for stroke and related neurological injuries. Consequently, research on assisting and improving functional recovery after neurological injury, especially in the upper limbs, can particularly benefit the VHA population.

Innovations in clinical robotics technology, coupled with advances in the understanding of potentially significant neurological recovery in chronic stroke, have led to the testing of a promising new task-specific, robot-assisted neurorehabilitative therapy for the upper limb in chronic stroke patients: the MIT-Manus system [11–14]. The MIT-Manus includes modules for shoulder, elbow, wrist, and grasp training and is the most mature robot available for clinical trials. Therefore, the CSP and Rehabilitation R&D Service are jointly undertaking the first multicenter phase II clinical trial to assess the safety and efficacy of this device for neurorehabilitation in chronic stroke patients with moderate to severe upper-limb impairment. Led by Dr. Albert Lo at the West Haven VAMC, this trial (CSP#558) hypothesizes that MIT-Manus robotic training will improve upper-limb function at 3 months poststroke more than usual care and intensive conventional treatment. Intensive conventional therapy, which will consist of stretching and range of motion exercises provided by a trained therapist, is being used as a second control arm to (1) account for the contact time and activity provided by robot training and (2) address the potential criticism that a trained therapist would be just as effective as robot training. Usual care will consist of the typical chronic stroke care delivered at each participating medical center; at the end of the study, patients in this group will be offered, as compassionate care, their choice of robot training or intensive conventional therapy. The target sample size is 158 patients (26 usual care, 66 intensive conventional therapy, and 66 robot training) to be accrued over 2 years from four VAMCs.

Since the safety and efficacy of the MIT-Manus has not yet been demonstrated in a controlled setting, a phase II trial design for CSP#558 was needed. With limited available data for estimating sample size, an adaptive design will be used. This approach allows for increasing the sample size to achieve the desired power, as well as for halting the trial if results indicate nonsupport of the hypotheses. Specifically, robot training versus usual care will be statistically compared at the midpoint of the trial, and if robot training is not superior to usual care, the entire trial will be stopped. Otherwise, the trial will continue to its scheduled end for the robot training versus intensive conventional therapy comparison. This adaptive design provides a flexible strategy for planning comparative trials of robotic devices in the rehabilitation setting, where further data are needed.

CONCLUSIONS

Use of robotics in medical and rehabilitative care is a prime example of how cutting-edge technology can augment clinical and patient care. However, for acceptance of robots among clinicians, researchers, and healthcare policymakers, their use in clinical practice should be driven by sound scientific evidence. Collaborative multisite clinical trials can significantly contribute to this critical need in rehabilitation research [15]. To enhance care provided to patients who have had a stroke, VA clinical researchers along with rehabilitation experts have designed a novel clinical trial of a promising robotics-based therapy. The prevalence of stroke in an aging veteran population and the need for better rehabilitative therapies further highlight the timeliness of this trial within the VA. Through such efforts, therapeutic and rehabilitative care involving robots can advance from exciting innovations with potential to well-established technologies that advance the standard of care.

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