Neurorehabilitation Research Laboratory at the Providence VAMC

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Although there has been tremendous progress in treating neurological injuries and disorders, there remains ample opportunity to improve recovery and to restore function in chronic and progressive conditions, particularly during the acute and subacute phases. As our understanding of neuroplasticity has advanced along with technology, attention has focused on novel methods to augment more traditional procedures to reverse impairment and regain function.

The field of rehabilitative therapy has recently seen an explosion in the development of robotic technology for rehabilitation. A MEDLINE search for therapeutic robotics yields only 15 results prior to 1990, but as of September 16, 2009, there were 2095 results. The consequent technological and methodological advances[1-3] have been particularly exciting. These devices provide high-volume, repetitive, reproducible, safe therapy and also allow for reliable, instrumented outcomes of motor performance. One of the best examples of such devices with a large quantity of pilot human data is the MIT-Manus[3] (InMotion Technologies, Inc., Watertown, MA), which includes modules for shoulder, elbow and hand. Other upper-extremity robotics include the ARM Guide, the MIME, the InMotion Shoulder-Elbow Robot, and the Bi-Manu-Track.[1,3] There also exist computer-aided non-robotic therapy orthotics such as the T-WREX[4], which allows upper-extremity movement with 5 degrees of freedom and passively eliminates the force of gravity via a system of elastics and metal linkages. For the lower extremities, there exist gait training devices such as the Lokomat (Hocoma, Zurich, Switzerland), a body weight-supported treadmill with robotic orthotics which guide the legs through an idealized gait cycle. The Lokomat has been used in research interventions for neurological disorders such as spinal cord injury,[5] stroke,[6] and multiple sclerosis.[7,8] As with the upper extremity, there also exist more focused devices for the lower extremity, such as the MIT Anklebot[9] (InMotion Technologies, Inc., Watertown, MA), which focuses on training ankle plantar- and dorsiflexion as well as in- and eversion. The data from randomized controlled trials of robotics will yield further improvements in methodology and understanding, allowing rehabilitation centers to provide more efficient and efficacious care. One can imagine an eventual "robotic gym"[1,2] incorporating highly specialized robots capable of addressing every form and degree of physical and cognitive disability, all run in concert with talented therapists.

Despite the enthusiasm for robot-assisted therapy, there is not yet full understanding of how, when, and in which patient populations these devices should be used. In order to gain the full potential of this new technology, careful clinical research is necessary to establish safe, effective protocols and optimal doses, as well as to eventually understand how these robotic devices should be combined with conventional pharmacological and rehabilitative methods. While robots are a new resource for clinicians to deliver therapy and to measure changes in motor performance, they will likely never replace human interaction, but rather enhance interactions with therapists.

The Neurorehabilitation Research Laboratory at the Providence VA Medical Center, established in the summer of 2007, has been conducting several projects examining the efficacy of robotic technology in improving motor function in individuals with stroke, **multiple sclerosis (MS)** and Parkinson's disease. Additionally, our interests have expanded broadly to other projects dealing more inclusively with other aspects of neurological injury, repair, and disability, such as an epidemiological study on MS and another study to develop and improve methods for diagnosis and tracking of cognitive function for mild traumatic brain injury. A summary of our current research is provided below.

Robotic Assisted Upper-Limb Neurorehabilitation in Stroke Patients

A phase II/III multi-center clinical trial funded by the Department of Veterans Affairs is now testing the most advanced MIT-Manus system (including separate shoulder, elbow, wrist and hand modules) in chronic stroke patients with upper extremity impairment. The study was initiated in November of 2006, and enrollment has closed with a total of 127 participants at the VA Medical Centers in Baltimore MD, Gainesville FL, Seattle WA, and West Haven CT. This is the first multicenter randomized-controlled trial to test a robot-assisted rehabilitation device for stroke. The baseline characteristics for the study were just published;[10] final results are expected to be released in early 2010.

Gait & Mobility in Multiple Sclerosis using Robot-Assisted Body Weight Supported Treadmill Training

Impairment in walking is an important source of disability and cause for concern for people with MS. Even at the earliest stages of disease, MS patients have observable gait problems which, in the majority of patients, will progressively worsen.[11] Body weight-supported treadmill training has been identified as a promising gait-specific intervention for MS,[12] and robotic assistance might prove to be a technological enhancement. The inclusion of robotic assistance, such as on the Lokomat, has the added advantage of delivering consistent, guided movement to the legs throughout the gait cycle.

Thirteen MS subjects have completed a randomized, cross-over trial comparing body weight-supported treadmill training with and without robotic assistance on the Lokomat.[8] In that study, participants improved gait velocity and endurance by over 30%. Approximately 20 people have participated in our various research protocols using the Lokomat. Additional studies will continue to refine the optimal dose, treatment regimen, and most relevant outcomes; identify the patients most likely to respond; and explore the characteristics and neurological mechanisms of motor recovery. Dr. Elizabeth Triche from the Department of Community Health at Brown University has collaborated on this project and is closely involved in many of the others presented.

Robot-assisted training and foot drop in multiple sclerosis

Our clinical and research experience has suggested that approximately 30% of MS patients experience foot drop. Although gait rehabilitation using the Lokomat can improve ambulation in MS patients, people with foot drop still have difficulty translating task-repetitive gait training to normative gait patterns over ground. One of the key limitations of the Lokomat is a lack of robotic assistance for the ankle joint. The MIT Anklebot has the potential to address that limitation through focused ankle training, but it does not train the knee or hip.

The results of a case-series with 2 MS subjects with foot drop have been published.[1] Additional subjects with MS and foot drop are being recruited to test whether Anklebot therapy alone or a combination with Lokomat results in better mobility. The project is currently enrolling patients. Collaborators include Dr. Hermano Igo Krebs (MIT) and Dr. Jacob Berger (PVAMC, Department of Neurology; Brown University).

Robot-assisted gait training and freezing of gait in Parkinson's disease

Parkinson's disease, the most common movement disorder in neurology, can present with a wide range of motor manifestations, such as bradykinesia, tremor and postural abnormalities. **Freezing of gait (FOG)** is one of the most disturbing symptoms, but there are no effective treatments for FOG. Studies have shown that uncoordinated, asymmetrical gait and reduced step length are related to FOG,[13] but no group has previously studied the effect of robot-assisted gait training on FOG.

In collaboration with Drs. Joseph Friedman and Victoria Chang, 4 participants have been examined in a pilot study. Pilot data have suggested a reduction in episodes of freezing as well as an improvement in quality of life in Parkinson's disease as a result of robot-assisted gait training. A larger study is planned.

Rhode Island Multiple Sclerosis Study (RIMSS)

The **Rhode Island Multiple Sclerosis Study** (RIMSS) is a community-based epidemiological study of MS in Rhode Island. This project, in collaboration with Dr. Stephen Buka, Brown University Professor of Community Health (Epidemiology), is being conducted as a part of the Brown University BioBank initiative. An initial group of neurologists (Drs. Elaine Jones, Stephen Mernoff, William Stone, Meryl Goldhaber, Mason Gasper, and Syed Rizvi) has generously contributed in a pilot collection of data as well as in gauging potential patient participation. The Rhode Island Neurological Society and the Rhode Island Chapter of the National Multiple Sclerosis Society have also extended enthusiastic support for this project.

Much of MS epidemiology and clinical course has been derived from cohort studies collected outside of the United States or from short-term pharmaceutical clinical trials:[14,15] these sources may have inherent biases that limit their usefulness to typical patients in the United States. The RIMSS study proposes to establish a prospective population-based cohort study of MS, collecting rich epidemiologic and clinical data critical to both scientific understanding and accurate treatment. Overall goals include enumerating and providing accurate data on incident and prevalent cases of MS, as well as collecting demographic and diagnostic data from medical records. Study data will describe the distribution of physical and cognitive disability, symptomatic areas, magnetic imaging changes, disease subtypes, duration of disease, quality of life, and treatment with disease modifying agents. The second phase is a longitudinal examination which will follow a group of recently diagnosed patients with genetic, neuroimaging, clinical and patient-related outcomes. The scope of this multidisciplinary study provides an opportunity to build a unique MS cohort based in Rhode Island to capture critical information and thus better understand the clinical and epidemiological characteristics of MS in the United States.

New rapid assessment of mild traumatic brain injury

As Mernoff and Correia report in this issue, there are no rapid, reliable, valid, and easily administered tests to gauge attention and executive cognitive capabilities following **mild traumatic brain injury (mTBI)**. Multiple investigators at Brown University and the Providence VAMC (Drs. Stephen Correia, Leigh Hochberg, Albert Lo, Stephen Mernoff, Michael Worden) are currently developing an easily administered computerized assessment of attention, cognition and motor reaction.

The aforementioned projects have attracted the interest of neurology residents, fellows, graduate students, and undergraduates, all of whom sense the excitement and importance of applying the best technology and methodology toward restoring function in individuals with severe disability from neurological disorders. In addition to the physicians and scientists with whom we collaborate at Brown and the Providence VAMC, our laboratory includes postdoctoral fellow Tara Patterson, PhD, as well as full time research assistants and program coordinators Milena Gianfrancesco, Douglas Benedicto, and Elizabeth Jackvony, MPH.

Neurorehabilitation research is responsive to the health needs of veterans. The Providence VAMC has supported this unique research, and the Neurorehabilitation Research Laboratory looks forward to completion of the Center for Restorative and Regenerative Medicine which will soon be the new site for this research.

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Disclosure of Financial Interests

The author has no financial interests to disclose.

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