Using robotics and virtual reality to improve functional status

Impairment of controlled body movement is one possible result of traumatic brain injury (TBI) or stroke, often causing a decline in functional capacity that may decrease the person’s sense of well being. Motor dyscontrol often outlives the recovery of some elements of extremity function. Moreover, brain injury itself tends to produce a disparity between real and perceived ability. This disparity has been implicated as a hindrance to the recovery of motor skills.

Therapies to improve functional capacity have met with inconsistent levels of success, and the resources required for these interventions are substantial. An approach that could provide goal-directed sensorimotor feedback might offer unique advantages. Robotic intervention is well suited for this task.

Studies have shown that primates with upper-extremity impairment can regain functional skills using robotic devices. The ideal technique would enable precise recordings of movements as force is applied to an affected limb. Compared to patients receiving human-assisted therapy, those using a robotic technique experience no difference in the amount of force applied to the affected limb. Compared to patients receiving human-assisted therapy, those using a robotic technique experience no difference in the amount of force applied to the affected limb. Compared to patients receiving human-assisted therapy, those using a robotic technique experience no difference in the amount of force applied to the affected limb.

A key shortcoming of currently available robotic systems is that none uses perceptual feedback. As part of our National Institute on Disability and Rehabilitation Research (NIDRR) TBI Model System center grant, we designed and developed a robotic rehabilitation environment. We determined the extent of perceptual gap required to create an optimal level of distortion for the therapeutic environment. In a series of experiments conducted with unimpaired subjects, ages 18 to 35, we identified the just-noticeable difference in the amount of force applied to the index finger and in the degree of change in the finger’s position. In this cohort, the threshold of detection was 18% for applied force and 14% for position change.

We also tested the subjects’ threshold for detecting distortion in a virtual environment. In this setting, participants failed to distinguish distortions up to 36%. We are beginning to recruit from clinical populations for the next phase of this project.

The above photo is a demonstration of the robot-assisted perceptual manipulation system. The robotic device on this person’s left index finger allows for precise recording of movements and application of precise levels of force. The computer display provides “distorted” perceptual feedback, the resulting effect of which is to functionally increase the individual’s range of motion beyond their own initial estimate.

For more information about our clinical services or for assistance with patient referrals, please call UPMC MedCall at 412-647-7000 or 1-800-544-2500.

The University of Pittsburgh Medical Center

CONTINUING EDUCATION

In conjunction with the University of Pittsburgh’s Center for Continuing Education in the Health Sciences, the Department of Physical Medicine and Rehabilitation will host its 15th Annual Electromyography Course March 24 and 25, 2006, in Pittsburgh. Up to 12.0 Category-1 CE credits may be earned. For more information, contact Judy Scheerer at 412-648-6654.
Gender differences in traumatic brain injury pathophysiology

Studies show conflicting evidence of gender differences in pathophysiology and outcomes following traumatic brain injury (TBI), with generally less favorable one-year outcomes and greater disability in women than in men following brain injuries of equal magnitude. Although these clinical observations were confirmed by the work of UPMC physiatrist Amy Wagner, MD, several animal studies have shown that female hormones attenuate excitotoxicity, ischemia, and oxidative stress — which produce secondary injury after TBI.

Using the University of Pittsburgh’s NIH-funded Brain Trauma Research Center database, we completed a retrospective clinical study to assess gender differences in convexal brain injury. Males and females with equal injury mechanisms were confirmed by the work of UPMC through a competitive award for renewal of a CDC center grant: the Center for Injury Research and Control. This grant focuses on the role of sex hormones in mediating gender differences in CSF markers of traumatic brain injury and in an early postinjury marker of ischemia. Female hormones appear to offer some level of protection against excitotoxic and ischemic injury. With hypothermia, however, the same study showed evidence of reduced excitotoxic injury, primarily in men. This finding may be due to an apparent “floor effect” in reducing excitotoxic injury with hypothermia in women.

In a recent study, we examined whether selected wheelchair seat cushions and back supports minimize the transmission of vibrations, which may increase the risk for secondary injury (e.g., low-back pain) among people who use wheelchairs. We examined 22 wheelchair users on an activities-of-daily living wheelchair course at three different times using 16 randomly selected seating systems (i.e., a cushion and back support) as well as the subject’s own preferred seating system. Vibration data were collected using accelerometers positioned at the seat and at the participant’s head. We calculated weighted fore–aft, vertical, and resultant transmissibility based on the vibrational-dose value in order to determine if differences exist among the seat cushions and back supports while traversing different obstacles.

Significant differences in vibration between seat cushions were not observed when all of the obstacles were combined. However, we did detect significant differences in vibration with different back supports when participants traversed curb descents, dimple steps, or rumble strips. No single seat cushion or back support unequivocally produced either the best or the worst results. This observation may be explained by the diversity of physical characteristics in those with disabilities, and supports the possibility that individual wheelchair users could be biased in favor of the seating system most similar to individual body build.


Improving community mobility

The ability of an adult to drive an electric-powered wheelchair (EPW) — functionally and without supervision in a variety of environments — after an event that results in several physical disabilities is a critical determinant of employability, social access, and self-esteem.

The joystick has been the standard device for providing EPW control to a person with a disability. Conventional movement-sensitive joysticks allow many people to make use of EPWs, but some patients with brain injury lack the functional motor skills necessary to operate standard joystick controls. In people with residual effects of brain injury, such as tremor, spasticity, weakness, and attention deficits, safe operation of conventional EPWs is difficult or impossible.

To assess a person’s ability to drive a wheelchair, we used the wheelchair driving simulation and are currently testing, a novel control system that combines a programmable force-sensing joystick with a head-position monitor that can be customized to address the individual’s motor and perceptual deficits. The subject first navigates through a virtual environment while observations are made of the performance time and the number of times that the virtual wheelchair deviates from the correct path.

During the second phase, the participant operates the wheelchair in surroundings that recreate real-world mobility challenges, such as maneuvering around furniture and bathroom fixtures, driving across carpet and pavement, and negotiating curb cuts and ramps (both up and down). By using this novel combination of technologies, we anticipate improving wheelchair safety and community mobility for those with brain injury.

Additional information is available at www.umc.pitt.edu/tbi/professionals/peramo.html

Enhancing access to services after brain injury

Traumatic brain injury (TBI) poses significant and enduring problems for both survivors and caregivers. Chronic problems often require people with TBI to be institutionalized in order to provide a safe environment and 24-hour supervision. For the family member who assumes the role of primary caregiver, the constant demands of meeting the patient’s need for supervision and care exact substantial economic, emotional, and social costs. Families often encounter difficulties in identifying and accessing available resources.

To address a new priority of the National Institute on Disability and Rehabilitation Research (NIDRR) that encourages research to evaluate the impact of innovations in service delivery on TBI patients, we developed an online Client Manager (VCM). This project employs state-of-the-art, Internet-based technology to enhance service support and delivery for TBI patients and their families. Focusing on the needs of people with TBI and their family caregivers, the VCM provides users with a guided learning experience and a framework to receive answers to their questions and concerns. It is designed to enhance utilization of health care and community services. A website has been created specifically for in-home installation and to assist patients with TBI and their caregivers in daily living.

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Dopamine kinetics and TBI

Altered dopamine (DA) neurotransmission is hypothesized to play a role in neurobehavioral deficits after traumatic brain injury (TBI). In the clinical setting, DA agonists have been shown to improve aspects of mental functioning after TBI, and multiple animal studies document that DA levels improve following brain injury.

We recently demonstrated chronic post-TBI reductions in striatal dopamine transporter (DAT) protein and increases in tyrosine hydroxylase (TH), two proteins that are critical in the release and reuptake of DA. However, the effects of these changes in DAT and TH level on DA neurotransmission remain unknown.

The goal of this project was to assess striatal DA neurotransmission by evaluating pre-synaptic striatal DA kinetics in conjunction with neuropotent and neurobehavioral correlates after experimental traumatic brain injury. We evaluated electrophysiologically evoked DA release and DA clearance kinetics two weeks after injury using fast scan cyclic voltammetry (FSCV), which permits real-time, in vivo evaluation of dopamine neurotransmission.

We observed striatal dopamine release during bilateral electrical stimulation of the medial forebrain bundle in anesthetized rats using FSCV in conjunction with Nafion-coated carbon fiber microelectrodes.

We also evaluated rotational behavior prior to FSCV. After FSCV, we evaluated a variety of striatal DA markers, including DAT, TH, dopamine type-2 receptor (DRD2), and vesicular monoamine transporter (VMAT) levels. Our results showed lower striatal evoked overflow of DA in injured rats than in controls. We also showed significant differences in zero- and first-order DA clearance for injured animals, as well as an increase in DAT efficiency after TBI. Decreases in DAT expression were noted posts-injury, with no change in VMAT expression, indicating a regulatory alteration in the concentration of DAT.

Behavioral data in this injury model suggested a low incidence of rotational behavior, and the data correlated well with bilateral changes in presynaptic DA kinetics and DA marker expression. The post-TBI increases in DAT efficiency observed in this study provide one explanation for the potential efficacy of DAT inhibitors (DA agonists) to improve cognitive recovery. Future work will evaluate the effects of DA agonists on striatal neurotransmission.


Body vibration in wheelchair users: Can select seat cushions and back supports make a difference?

In a recent study, we examined whether selected wheelchair seat cushions and back supports minimize the transmission of vibrations, which may increase the risk for secondary injury (e.g., low-back pain) among people who use wheelchairs.

We examined 22 wheelchair users on an activities-of-daily living wheelchair course at three different times using 16 randomly selected seating systems (i.e., a cushion and back support) as well as the subject’s own preferred seating system. Vibration data were collected using accelerometers positioned at the seat and at the participant’s head. We calculated weighted fore–aft, vertical, and resultant transmissibility based on the vibrational-dose value in order to determine if differences exist among the seat cushions and back supports while traversing different obstacles.

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