Guest Editorial

"Stroke, Stroke": A coxswain's call for more work and more innovation

Stroke is the leading cause of permanent impairment and disability. Pending a radical cure, patients recovering from stroke will continue to require study and innovation. Perhaps the need for advances in treating stroke recovery grows more urgent because of the increased incidence and prevalence of stroke. These increases reflect greater life expectancy, aging of the baby boomer generation, and improved medical treatment of the complications caused by acute stroke.

Randomized controlled trials demonstrate that treatment of patients with stroke in a specialized stroke unit cause lower mortality rates, shorter hospitalization, and greater likelihood of discharge home. Most importantly, these positive outcomes persist over a 10-year follow-up period [1–5]. With stroke rehabilitation units established as a standard of care, now is the time to focus on the mechanism of neurological recovery and attempt to use this knowledge to devise new strategies for the recovering stroke patient.

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The current standard of care in stroke units depends as much on the positive influence created by interdisciplinary approaches as it does on a particular protocol. Compassion and a reliance on natural recovery have served as the basis for these recovery treatment protocols for a long time. The challenge is to compare these unproven protocols to rational, novel therapies evolved from a theoretical and experimental base that use the randomized controlled trial design. The improved therapy must achieve statistically increased outcomes and also enhance quality of life. Perhaps with luck and ingenuity, positive outcome data with real-world effects will also meet the administrative challenges of cost efficiency.

Most survivors of stroke experience significant and permanent physical, cognitive, and psychological impairments that translate into functional disabilities. However, current interdisciplinary treatment programs focus more on disability reduction than on impairment. Adapting and learning compensatory techniques to reduce disability—for example, using the unimpaired arm and hand—lead to relatively rapid functional response compared to impairment reduction techniques. Disability reduction with real-world outcome differences remains the goal of any rehabilitation experience, but hasty compensation for a disability may engender a pattern of disuse in the impaired limbs that blunts recovery and mutes the potential for future reduction in impairment and future disability reduction [6]. Some current studies take a balanced approach, focusing on impairment and disability outcomes while using techniques of task-specific training to influence impairment reduction [7–12]. Task-specific training breaks a complex functional movement into component parts, and teaching individual components of a movement with intensive repetition and guidance might improve motor outcome. In the clinic, renewed interest in impairment reduction has stimulated a number of innovative training protocols that use task-specific training to improve outcome.

Task-specific training also plays an important role in studies of animals recovering from neurological deficit. Several groups have demonstrated that animals with focal cortical injury exposed to enriched or challenging sensorimotor environments improved functional outcome dependent on greater neural activity [13–15]. Active and passive movements in novel training protocols likely depend on excitatory and inhibitory synapse interaction, with Gamma-Aminobutyric Acid (GABA) inhibition potentially providing a role for pharmacological intervention [16–19]. Both basic and clinical outcomes studies suggest that activity-dependent plasticity might underlie a basic mechanism in recovery.

Randomized controlled studies using task-specific training are time-consuming and labor-intensive. Robotic devices greatly expand the tools and strategies a therapist might efficiently employ to train and treat impairment of the arm in stroke patients. Currently, several neurological-engineering collaborations training stroke patients exist, resulting in improved motor outcomes with various devices and protocols. We collaborate with Neville Hogan's group at Massachusetts Institute of Technology. The first device designed and built by Hogan and H.I. Krebs had patients rest their impaired arms in a trough so that their hands could be fastened to the end of the robot [20,21]. The impaired upper limb was supported, and the patient moved the end of the robot to points on a surface. A video screen mirrored the movements. If the patient could not move the mechanical arm, the robot motors steered the patient's arm through the complete activity. The robot sensed a patient's directional movement, and not only became silent, but because of the low inertia, was also able to "get out of the way" so that the patient could continue the movement [22]. Randomized controlled studies of over 200 patients firmly support the entry of robotic devices into the lists of novel tools a therapist might use to deliver task-specific training that focuses on impairment reduction [23–28]. We are now testing a new class of robotic devices that allow patients to move their arms without support and against gravity, as well as one that trains wrist movement. Robotic devices are tailor-made to deliver repetitive controlled sensorimotor training that allows precise intensity and duration of training as well as crucial timely responsiveness correlated with sensory experience. Finally, in those patients who demonstrate improving ability, the latest "smart" protocols adapt and alter the task challenge.

Some recent highlights in these studies are worth mentioning. Recent published work from our group and the Spaulding group demonstrated improved motor outcome in pilot studies of patients with chronic stroke [29,30]. The intensity of robotic training (current outpatient protocols provided training three times a week for 6 weeks, in 1-hour sessions during which the patient made over 10,000 movements of the shoulder and elbow in reaching targets from a central start position) would be difficult to match with any typical hands-on method, but it was the latest development in a guidance program that appeared to produce striking improvements [31]. This new protocol estimated directional errors as a patient made point-to-point movements and, by constructing a virtual trough, guided subsequent movements to improve accuracy. Patients learned how to inhibit the preferred shoulder flexion and adduction movements. Remarkably, some patients made new abduction movements of the shoulder with elevation and external rotation of the humerus. These so-called out-of-synergy movements contributed to reduced disability by easing several activities of daily living [29]. These select patients also experienced improved wrist tone. Now we need to test whether we can improve wrist motor power and eventually proceed to training with a hand-and-finger robotic device. We also need to determine the clinical or surrogate markers that might identify patients who will benefit most from this form of task-specific training.

In the quest for innovative stroke recovery treatment, we found that task-specific training with robotic devices produced encouraging new information about impairment reduction. We are currently testing whether building significant motor improvement in the proximal upper limb with additional sequential training in the distal limb will eventually generate significant disability reduction and real-world change. While the degree of impairment depends on the type, size, and location of the brain injury, it may be that task-specific training techniques, perhaps coupled with pharmacological intervention, will influence the physiology of the undamaged motor, premotor, and supplemental motor cortex, in addition to the descending tracts in the capsule, to generate optimal recovery. Our long-term goal involves using task-specific robotic training to develop strategies that will identify subsets of patients who, based on the nature of their injuries and their genetic backgrounds, will experience proven benefit.

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