well as a phone number to schedule paratransit for individuals unable to use public transportation. Care providers will want to closely monitor these patients for signs of depression, self-neglect, and isolation as all can occur as a result of loss of driving privileges (see the AMA guide for specific monitoring methods).  

**Future Directions**

There is much research to be done in the area of assessing older driver safety. As Molnar and colleagues point out, the establishment of empirically validated cut score thresholds for visual functioning, motor skills, and cognition is necessary to help physicians confidently identify truly at-risk drivers.  

A second priority is to establish clinically meaningful outcome measures. Certainly poor performance on a simulated driving test or pre-determined driving route is an indication of concern and monitoring, but there is not a perfect correlation between these measures and crash risk. In this regard, a new study examining risk factors for poor drivers in a naturalistic setting has begun at Rhode Island Hospital. In this study, funded by the National Institute of Health, older drivers both with and without dementia will be examined by video camera recordings in their own cars and driving in their neighborhoods. These recordings will be compared to performance on a standardized road test and computerized office tests. For more information about participation or referrals, contact Lindsay Miller at 444-0789.

A third and final priority is to examine the benefits of driver education programs. If physicians are going to recommend these interventions, as with any other treatment, efficacy trials are necessary.

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**Geriatric Neurorehabilitation In the New Millenium**

**Stephen T. Mernoff, MD**

Rehabilitation interventions have changed little in the last few decades, aside from improvements in materials and medical care. Most neurorehabilitation research involves geriatric patients since most disabling neurologic disease occurs in older populations. Proving rehabilitation intervention efficacy is difficult for methodological reasons.

New technologies and neuroscience advances allow us to foresee development of evidence-based neurorehabilitation interventions improving functional outcomes. The need for such interventions will increase as the population ages. Developing patient-specific rehabilitation programs using selected tools at selected times during recovery now seems within reach.

**Rehabilitation Settings**

Approximately 6-8% of Medicare patients admitted to acute care hospitals will need inpatient rehabilitation. Medicare recipients comprise 75-80% of admissions to acute rehabilitation facilities (ARFs). In 2007, the average age of patients admitted to ARFs in the US was 67 years. After an average stay of 16 days, 73% of these patients returned home. With limited staffing and ill patients, acute care hospitals usually provide one or two brief therapy treatments a day. Immobilization for even only a few days causes deconditioning which takes longer to reverse than to develop; therapy should be initiated as soon as possible. Long-term acute care (LTAC) facilities manage patients with persistent intensive nursing and medical care needs. Acute rehabilitation hospitals admit 50-60% of their patients with neurologic diagnoses, generally providing the most intensive rehabilitation programs available for patients who can tolerate and benefit from at least three hours of therapy per day. Subacute rehabilitation units provide programs for patients who cannot tolerate, or will not benefit from, more intensive therapy. Home therapy may often be suboptimal due to lack of equipment and inefficient scheduling. Outpatient therapy varies between one and five sessions a week for medically stable patients. Patients may move between these settings, depending on medical status and rehabilitation needs.

**Role of Physicians In Rehabilitation**

Primary care physicians and/or physiatrists provide general medical management and help to prevent complications. Immobility increases risks of infection, deep venous thrombosis, and skin breakdown, which can usually be effectively prevented.
Inadequate sleep interferes with therapy, possibly contributing to cognitive impairments. Obesity and depression must be treated early and aggressively. Reassessment of medications is critical; patients often come to rehabilitation on medications they no longer need.

The role of the neurologist has expanded as patients survive acute neurologic disease at progressively higher rates and more is known about neurologic recovery. First and foremost is accurate diagnosis; some patients arrive to rehabilitation with incorrect diagnoses. Patients with traumatic brain injury must be monitored for hydrocephalus and subdural hematomas. The neurologist’s role in educating therapists, patient, and family, by describing impairments, expected course of recovery, and prognosis, is critical to program design and realistic goal-setting.

**Evolution of Neurorehabilitation as a Clinical Specialty**

Rehabilitation Medicine as a medical subspecialty, the disciplines of Physical, Occupational, and Speech Therapies, and dedicated Rehabilitation Units developed in the early to mid 20th century as a result of war injuries (amputations) and polio. The “traditional” rehabilitation model was based on static impairments and compensation for, rather than restoration of, function. In the late 20th century, improved survival from acute neurologic injury and an emphasis on evidence-based practice resulted in improved outcome measures and a “neurologic” model of rehabilitation incorporating pathology and prognosis. Powerful technologies and greater understanding of plasticity present the possibility of enhancing natural recovery processes and evaluating these techniques. Clinicians will be able to develop the rehabilitation “holy grail”: evidence-based patient-specific rehabilitation programs using selected techniques at selected times during recovery.

**Mechanisms of Recovery and the Concept of Neuroplasticity**

A brief summary of recovery mechanisms in stroke with a three-stage model is instructive. In the first stage, reduction of edema (causing mass effect and metabolic depression) over days to weeks improves the function of noninfarcted tissue as intercellular communication improves. The second and third stages of recovery are marked by spontaneous neurophysiologic adaptations referred to as neural plasticity. In the second stage, over weeks to months, cells in the ischemic penumbra recover somewhat. These cells may have greater potential for synaptic plasticity via increased expression of genes for neurotrophins and angiogenesis. The third stage is thought to consist of distant undamaged tissue taking on the functions of lost tissue. Several mechanisms may subserve neural plasticity including synaptogenesis, axonal regrowth, neurotrophins, and neurogenesis (stem cells).

These mechanisms seem to be inhibited in more mature tissue. Enhancing natural mechanisms of plasticity may improve recovery. For example, antibodies to MAG promote axonal regrowth. Although motor control is virtually fixed after adolescence, the reorganization occurring in damaged neurologic tissue may present an opportunity to intervene. Potential interventions, including neurotrophins, stem cells, and pharmacologic potentiation, are technically challenging and expensive. Elegant, noninvasive, and less expensive methods that may enhance neural plasticity are being investigated. Different approaches will likely be applicable in different situations.

**New Neurorehabilitation Technologies Under Investigation**

Neurorehabilitation research is coming of age. Improvements in outcome measures and study design allow new techniques to be investigated in the context of randomized, controlled, often multi-centered trials (RCTs). The EXCITE trial, a study of Constraint-Induced Movement Therapy, demonstrates that multicenter RCTs for rehabilitation interventions are feasible, and is serving as a model for design of future studies.

The Center for Restorative and Regenerative Medicine (a collaboration of Brown University and the Providence VA Medical Center led by Roy Aaron, MD, and John Donoghue, PhD), in collaboration with MIT and Harvard, is becoming a major center for such research. Other local entities, including Cyberkinetics, Inc. (Foxboro, MA), Afferent Corporation (Providence, RI), and Rehabilitation Hospital of Rhode Island (RHRI, North Smithfield), are at the forefront of these efforts. Some of these investigational interventions are briefly described below.

**Low Tech Interventions**

Constraint-Induced Movement Therapy (CIMT) is based on the concept of “learned nonuse” in monkeys, a behavioral suppression in which lack of success with use of an impaired arm leads to preferential use of the unaffected arm. CIMT is a “forced use” paradigm. The use of the unaffected arm is limited (by a sling or mitt) and the affected arm/hand undergoes intense therapy. Multiple animal and human studies, including the landmark EXCITE trial, have demonstrated the technique to be quite effective in certain populations. There is some evidence that measurable cortical reorganization results. CIMT has been investigated mainly in patients with stroke and cerebral palsy, but is also being applied to lower limb impairment, traumatic brain injury, and evenaphasia.

**Stroke Inpatient Rehabilitation Reinforcement of Walking Speed (SIRROWS)**

Gait speed may be a surrogate marker for gait quality, often the major limiting factor for home discharge. Faster gait improvement in the inpatient rehabilitation setting might result in more efficient recovery with shorter lengths of stay. The World Federation of Neurorehabilitation (WFNR), in collaboration with the American Society of Neurorehabilitation (ASNR), is running the SIRROWS trial to determine if this is true. This elegant and simple RCT involves giving patients daily feedback about their walking speed, with encouragement to walk faster, safely. SIRROWS is the first attempt to develop an internationally controlled multicenter trial in neurorehabilitation. Twenty centers, mostly outside of the US, are involved. RHRI will soon become a SIRROWS study site.

**Medium Tech Interventions**

Sensory Enhancement

Afferent Corporation (Providence, RI) has several devices under development. Afferent’s technology involves applying subthreshold mechanosensory stimuli to affected limbs to enhanceafferent information flow to the brain. The premise is that sensory impairment contributes to functional impairment after nervous system injury. Improving sensory function could improve recovery by enhancing plasticity. Studies show the system to be effective in sensory-mediated gait disorders. A pilot study, using the technology in patients with arm weakness after stroke, is being conducted at Spaulding Rehabilitation Hospital in Boston.

**High Tech Interventions**

Robotics

Various robotic devices are being studied for use in rehabilitation settings. The MIT-
that detect and decode brain signals, allowing control of external devices. The BrainGate (Cyberkinetics, Inc, Foxboro, MA) device, developed in John Donoghue’s laboratory at Brown University, is an electrode array implanted on the cerebral cortex. A computer decodes detected signals to determine the individual’s intended movements. A pilot trial with human subjects has demonstrated that patients can operate cursors on computer screens with their thoughts, allowing control of external devices such as televisions and robotic arms.

A less invasive device, the Wadsworth BCI Home System (Laboratory of Nervous System Disorders, The Wadsworth Center, NY State Dept of Health), uses surface electrodes and software to detect and compile EEG signals which patients learn to modulate to select characters on a computer screen. This system has enabled some patients with ALS and other severely disabling disorders to communicate and send email. A multicenter trial is being planned to better assess the effectiveness and efficacy of this system with ALS patients on a larger scale.

CONCLUSIONS

Plasticity exists particularly in the postinjury period, even in the older population. Many possible new treatments are being developed. Particular epochs during the postinjury period may be windows of opportunity for intervention. Optimization of therapies for different types of patients is a major challenge. Ongoing research will determine which treatments should be done for which patients, and when. New models of recovery are under development to enable us to capitalize on advances in neuroscience and technology to improve rehabilitation outcomes.

Several landmark studies (recent, ongoing, and upcoming) are demonstrating that neurorehabilitation research is no longer in the back reaches of anecdotal evidence and unprovable theories. Both low-tech but elegant interventions and sophisticated technologies clearly have roles in improving the functioning of patients with both mild and severe neurologic disabilities, by enhancing the nervous system’s natural plasticity. This goal is a huge challenge, particularly in the geriatric population. We now have techniques to perform valid and reliable studies of these interventions. Neurorehabilitation is worthy of being considered a medical subspecialty subject to the standards of evidence-based medicine.

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Discussion(s) of off-label usage of any products or services: Several devices described in the article are investigational but are approved by the FDA for investigational use: devices by Afferent Corporation, MIT-MANUS robot, Lokomat, Autoambulator, Northstart device, BrainGate (Cyberkinetics, Inc.), and Wadsworth BCI Home System.

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