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# Constraint-Induced Movement Therapy

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**Abstract**—Constraint-induced movement therapy improves outcome after chronic stroke, conforms experimental observations of neuronal plasticity, and proves the efficacy of intensive occupational therapy. More acutely instituted constraint-induced movement therapy has both practical and theoretic risks and benefits that deserve further careful evaluation. (*Stroke*. 2004;35[suppl I]:2699-2701.)

**Key Words:** acute care ■ occupational therapy ■ rehabilitation ■ stroke, acute

Constraint-induced movement therapy (CIMT) provides a vehicle for objectively testing the efficacy and utility of rehabilitation intervention. It also provides a platform for designing and testing further advances in rehabilitation intervention. Finally, by correlating improvements on motor performance after CIMT with functional neuroimaging, CIMT provides the opportunity to demonstrate functional imaging as a surrogate outcome measure to utilize in clinical trials of rehabilitation intervention.

The scientific basis of intensive physical retraining after stroke has recently been validated by the work of Nudo et al,<sup>1</sup> among others. Using microelectrode recordings in primate cortex, these investigators mapped out the motor representation area of the digit, wrist, and proximal upper extremity in animals at baseline and after a cortical lesion, both with and without postinfarct rehabilitation therapy. They were clearly able to demonstrate enlargement of the digit and wrist areas that were represented on the cortex in those animals that had postinfarct rehabilitation therapy compared with those that did not. This work, which has now been replicated in other animal models and in humans by using functional imaging, has provided a strong scientific basis for investigations into enhancing rehabilitation intervention.

CIMT is based on the initial research by Dr Edward Taub,<sup>2-5</sup> which was conducted in the late 1970s and 1980s. In primates, he deprived the upper extremity of somatic sensation by dorsal rhizotomy. After this procedure, the animal immediately stopped using their deafferentated extremity. Restoration of use was induced by immobilizing the intact arm over several days while training the animal to use the affected arm. This work resulted in the formulation of CIMT for humans.

CIMT is based on the theory of “learned non-use.” Learned non-use develops during the early stages following a stroke as

the patient begins to compensate for difficulty using the impaired limb by increased reliance on the intact limb. This compensation has been shown to hinder recovery of function in the impaired limb.

There have been a number of studies evaluating the efficacy of CIMT in patients with chronic stroke.<sup>6-8</sup> In one of the more recent studies, van der Lee et al<sup>9</sup> conducted an observer-blinded, randomized, clinical trial in 66 chronic stroke patients allocated to CIMT or equally intensive reference therapy for 2 weeks. One week after the last treatment session, there was significantly greater improvement in the CIMT group. At 1-year follow up, there still was a small but lasting improvement in the motor function of the affected upper extremity.

Recently, CIMT has been applied to subacute stroke patients with the hypothesis that earlier intervention may prevent learned non-use from developing in the first place and may have a greater impact. Dromerick et al,<sup>10</sup> conducted a pilot, randomized, controlled, single-blind trial of CIMT beginning <14 days poststroke in 23 patients. These investigators found slightly greater improvement in motor function of the affected upper extremity relative to equal intensity of standard therapy. Importantly, there were no adverse effects of CIMT in the subacute phase. This study did not have long-term follow up and no functional imaging was carried out. A larger study with longer-term follow up is now underway.

Some experimental studies in animal models suggest that very early CIMT may not be helpful and may, in fact, be harmful. This is based on studies of “forced overuse.”<sup>11-13</sup> Schallert and colleagues immobilized the contralateral intact forelimb in a plaster cast for 14 days, starting immediately after a sensory motor cortex lesion. They found that such forced overuse of the affected forelimb within the first 7 days

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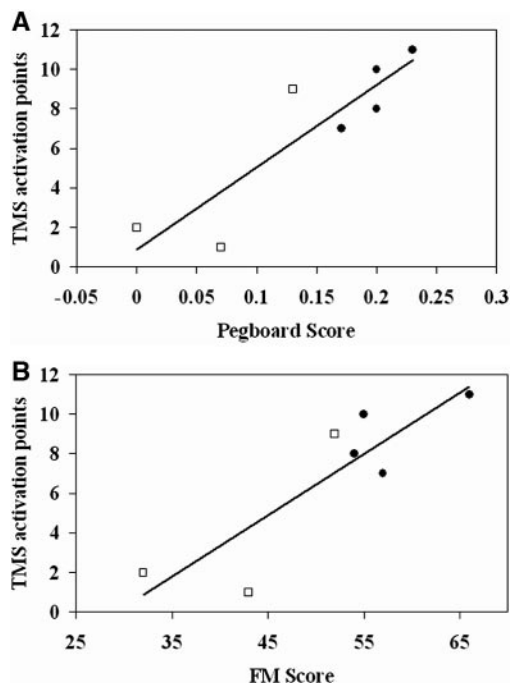
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impeded motor recovery of the affected limb, and enlarged lesion volume. If the casting was delayed until 7 to 14 days after the insult, there was no lesion expansion but there was still a negative impact on behavioral recovery. Bland et al, forced overuse of the affected forelimb immediately after a focal cortical middle cerebral artery stroke, and this increased lesion size and impaired motor recovery as well. Therefore, it is possible that CIMT, if started too early, may be harmful. Adverse histological effects of intensive motor activity started in the first days after stroke may prevent maximal functional benefit from CIMT. Therefore, the relative risks and benefits of "acute" CIMT, and its optimal timing, remain to be determined.

We have carried out a small pilot study of early CIMT in our center. This study was intended to test the feasibility and safety of carrying out a larger efficacy trial in the acute stroke setting, as well as the feasibility of correlating clinical outcome measures with functional imaging. Patients at Memorial Hermann Hospital's Stroke Unit were randomized within 14 days of stroke onset. To be included, the patients had to have weakness in one arm and hand, but at least 10° of preserved movement in the digits of their hand. After baseline testing and transcranial magnetic stimulation (TMS) brain mapping, patients were randomized to CIMT or standard of care physical and occupational therapy for 2 weeks. The CIMT group wore a mitten on the nonaffected upper extremity for 90% of waking hours and at the same time had therapy that reinforced the use of the affected upper extremity. Behavioral "shaping" of the affected upper extremity, using the technique of successive approximations, was carried out for 3 hours a day, training the impaired upper limb in various tasks related to activities of daily living. The control group received treatment aimed at increasing functional use of *both* hands, using compensatory techniques as needed, for 3 hours a day for 2 weeks. At the end of 2 weeks of treatment, and again 3 months after treatment, both clinical and TMS measurements were repeated. Three different measures of hand and arm function were carried out: Motor Activity Log (MAL), Grooved Pegboard Test (GPB), and the upper extremity motor component of the Fugl-Meyer (FM) Test.

One of the early discoveries in this study was that very few acute stroke patients qualified on the basis of motor function. Most patients either had no movement in their hand or excellent recovery during the first 2 weeks. Out of 187 patients screened, 30 had no movement in the hand, 76 had nearly complete recovery of movement in the hand, and 55 had either no movement or complete recovery of movement coupled with some other exclusion such as aphasia. Eight patients (5 men) were randomized, 4 to each group. All had ischemic strokes and were randomized within the first 2 weeks after stroke onset. While there was no change in the MAL in those patients randomized to CIMT versus control, in those patients receiving CIMT there was progressively increased improvement in the GPB test and in the FM assessment, both at 2 weeks and to an even greater extent at 3 months of follow-up.

TMS mapping of the motor cortex hand region was carried out bilaterally in 1-cm increments at baseline, at 2 weeks, and at 3 months. Baseline TMS studies showed few or no regions



The number of transcranial magnetic stimulation (TMS) activated sites in the lesioned hemisphere, plotted as a function of (A) each patient's score on the grooved pegboard test and (B) the patient's respective score on the FM test, demonstrates a high correlation between these measures at 3 months after stroke. Note the high correspondence between these figures. The filled circles represent the CIMT patients and the unfilled squares represent the control patients. Data from 1 control patient, who fell right before the 3 month examination and could not be tested, is not included.

on the affected hemisphere that could be stimulated resulting in contralateral hand movement in either group. However, in the CIMT group, a greater number of regions could evoke a response in the contralateral affected hand both at 2 weeks and 3 months. There was a strong correlation between the number of TMS activation points and GPB and FM test scores (Figure).

In conclusion, CIMT probably improves upper extremity function in chronic stroke patients. If instituted in the first 2 weeks after stroke, it is probably not harmful and it may accelerate recovery. TMS noninvasively demonstrates the biological effect of CIMT on brain reorganization. Currently, we are enrolling in a confirmatory study to determine the efficacy of CIMT in acute stroke patients. Based on the magnitude of efficacy seen in our pilot study of 8 patients, we anticipate that we will need 24 patients to detect a difference with 90% confidence.

CIMT is not without its problems. Most patients in the acute setting do not qualify, and it imposes substantial demands both on therapists and the resources of a rehabilitation unit. Furthermore, CIMT probably has limited effect and may not be cost-effective. In the future, it may be advantageous to improve the cost benefit of CIMT by employing a less intense method and combining CIMT with pharmacologic interventions, particularly neurotropic drugs, or with robotics. Furthermore, functional imaging such as TMS, magnetoencephalography, or magnetic resonance im-

aging, may provide a surrogate outcome measure that will help in the more efficient and cost-effective assessment of the efficacy of CIMT and other rehabilitation techniques.

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