An Application of Upper-Extremity Constraint-Induced Movement Therapy in a Patient With Subacute Stroke

Background and Purpose. The purpose of this case report is to demonstrate the application of constraint-induced movement therapy with an individual with upper-extremity hemiparesis within 4 months after sustaining a cerebrovascular accident (stroke). Such patients often fail to develop full potential use of their affected upper extremity, perhaps due to a "learned nonuse phenomenon." **Case Description.** The patient was a 61-year-old woman with right-sided hemiparesis resulting from an ischemic lacunar infarct in the posterior limb of the left internal capsule. The patient's less-involved hand was constrained in a mitten so that she could not use the hand during waking hours, except for bathing and toileting. On each weekday of the 14-day intervention period, the patient spent 6 hours being supervised while performing tasks using the paretic upper extremity. Pretreatment, posttreatment, and 3-month follow-up outcome measures included the Wolf Motor Function Test and the Motor Activity Log (MAL). **Outcomes.** For the Wolf Motor FunctionTest, both the mean and median times to complete 16 tasks improved from pretreatment to posttreatment and from posttreatment to follow-up. Results of the MAL indicated an improved self-report of both "how well" and "how much" the patient used her affected limb in 30 specified daily tasks. These improvements persisted to the follow-up. **Discussion.** Two weeks of constraining the unaffected limb, coupled with practice of functional movements of the impaired limb, may be an effective method for restoring motor function within a few months after cerebral insult. Encouraging improvements such as these strongly suggest the need for a group design that would explore this type of intervention in more detail. [Blanton S, Wolf SL. An application of upper-extremity constraint-induced movement therapy in a patient with subacute stroke. *Phys Ther.* 1999;79:847–853.]

Key Words: *Constraint-induced movement therapy, Learned nonuse, Physical therapy, Rehabilitation, Stroke.*

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Treatment of the upper extremity (UE) of people with hemiplegia continues to be a challenging and often frustrating experience for clinicians. Investigators in the Copenhagen Stroke Study noted that "recovery of UE function in more than half of [their] patients with stroke having severe UE paresis can be achieved only by compensation using the unaffected UE."[1(p852)] Shortened lengths of rehabilitation stays in current health care practice have forced clinicians to focus on the primary functional activity essential for a patient to safely return home. Some therapists believe that maximizing of functional outcomes may, at times, come at the expense of facilitating motor and sensory recovery of the hemiplegic limb. Consequently, in the midst of making the decision between teaching compensatory mechanisms to accomplish daily life skills and working to improve motor control in the affected extremity, the clinician must ask the following questions: Can these compensatory skills be taught without jeopardizing potential recovery in the hemiplegic arm? If so, how can the patient's resources be best allocated for hemiplegic UE management?[2] Finding an effective and functionally based intervention to improve motor control in individuals with UE hemiplegia becomes even more vital in light of the changing health care environment. The purpose of this case report is to review the application of one such intervention: constraint-induced movement therapy (CIMT).

For 70 years, studies involving animal and human subjects have documented a phenomenon referred to as "learned nonuse."[3] Tower[4] noted that following unilateral lesions of the pyramidal tracts at the spinal cord level, monkeys would fail to use the affected side. Efforts to move the affected limb were often unsuccessful and frustrating, causing the monkeys to quit attempting to use the affected side after just a short period of time. Taub et al[5] explained the learned nonuse behavior as resulting from the animal's inability to move the deafferented extremity due to the presence of a shock-like condition that persists weeks or months after removal of sensory input through all cervical dorsal roots. When the animal successfully uses compensatory techniques with the nonaffected limb, the strategy reinforces the nonuse. This strategy persists, reinforced by the negative consequences from unsuccessful efforts to use the affected limb (eg, poor balance, loss of food). Consequently, when depression of neural activity has passed several months after surgery, the monkey never learns that the limb could be useful. Studies by Taub and colleagues[6,7] revealed that by restraining the uninvolved UE for more than 3 days, deafferented, adolescent monkeys could learn to use the involved limb.

Evidence suggests that approximately 20% to 25% of patients with chronic stroke may benefit from constraint-induced movement therapy.

These observations led to research into application of this model to patients following a cerebrovascular accident (CVA) or traumatic brain injury (TBI) of greater than 1 year's duration. In a single-subject study of this model, Ostendorf and Wolf[8] used an ABA design with a subject who, despite previous rehabilitation efforts, was unable to perform functional tasks outside of synergistic patterns with her hemiplegic UE at 18 months post-CVA. The researchers measured the effect of restraining the unaffected arm and hand in a sling during all waking hours on quantity, quality, and efficiency of functional movement with the affected UE. Although the time required to perform purposeful behaviors such as picking up a pencil or a can decreased during the period of UE restraint, it increased after restraint removal, but was still faster than during the initial baseline measurement. Lack of change in quality of movements was attributed to the fact that each rater may have been focusing on different joint motions during these multisegmental tasks. Although the results of the study were not conclusive, they provided a basis for further exploration of this treatment approach.

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A later study by Wolf et al[9] examined forced use in 25 individuals with chronic hemiplegia due to CVA and TBI. The researchers looked at the effectiveness of restraining the arm and hand of the unaffected UE during waking hours in the subjects' home over a 2-week period. These subjects met the inclusion criteria of (1) 1 year post-insult, (2) no visual-perceptual problems, (3) no communication barriers, (4) adequate balance and safety while wearing the restraint, and (5) ability to initiate at least 20 degrees of wrist extension and at least 10 degrees of extension at all digits in the involved hand. Results showed improvement in movement of the UE in 19 of 21 functional task measures, and improvements persisted at the 1-year follow-up. The continued improvement through the follow-up period provides evidence that, not only does learned nonuse exist in patients with chronic hemiplegia, but forced use of the extremity appears to reverse the phenomenon.

To further evaluate this approach in patients with chronic strokes, Taub et al[5] did similar work, but added 6-hour supervised practice sessions for 10 of the 14 days of restraint. Four of the 9 subjects in that study underwent unaffected UE restraint, and 5 subjects were assigned to a comparison group. The inclusion criteria were similar to those of Wolf et al,[9] but all subjects had right-hand dominance, were medically stable, and were less than 76 years of age. The subjects who were restrained improved on each of the laboratory measures of motor function. When Taub et al compared the greater changes in their subjects' Wolf Motor Function Test (WMFT)[10] scores with those of the subjects in the study by Wolf et al,[9] they attributed their subjects' greater improvements to the added laboratory-based training of the affected limb in combination with the restraint procedure.

The effectiveness of CIMT in patients with chronic stroke led Taub and Wolf to consider the application to patients 3 to 7 months postinjury. This case report describes the use of CIMT as a treatment for UE hemiplegia in one individual 4 months after stroke. The following data were collected as part of a preliminary study for a national, randomized clinical trial.

Case Description

Patient

Criteria from studies by Taub et al[5] and Wolf et al[9] were used to determine this patient's appropriateness for the intervention. The criteria included the ability to actively extend the wrist of the limb with hemiplegia greater than 10 degrees and to actively extend the metacarpophalangeal (MCP) and interphalangeal (IP) joints of the thumb and at least 2 additional digits 10 degrees. These movements had to be repeated at least 3 times in 1 minute. Other inclusion criteria included: (1) passive range of motion of at least 90 degrees of shoulder flexion and abduction, 45 degrees of shoulder lateral (external) rotation, no more than −30 degrees of elbow extension, 45 degrees of forearm supination and pronation, wrist extension to neutral, and finger extension (all digits) with no greater than 30 degrees of flexion contracture at the MCP and IP joints, (2) 3 to 7 months since stroke, (3) scoring of at least 24/30 on the Folstein Mini-Mental State Examination,[11] (4) ability to independently and safely transfer to and from the toilet, stand from a sitting position, and maintain standing balance for 2 minutes with UE support, (5) age of 18 years or older, and (6) not participating in any experimental drug field study or in any formal physical rehabilitation program.

Prior to participating in the intervention, the patient signed an informed consent form approved by the Emory University Human Investigation Committee. She was a 61-year-old African-American woman with a past medical history of hypertension who had a sudden onset of right-sided weakness and slurred speech approximately 4 months previously. An initial head computed tomography scan and follow-up magnetic resonance imaging showed a left ischemic lacunar infarct in the posterior limb of the internal capsule. When admitted to the rehabilitation center, gross motor tests revealed 5/5 in the left extremities, 0/5 in the right UE, and 3+ to 4− in the right lower extremity. These measurements were taken during a standard inpatient clinical evaluation; therefore, there were no reliability measures, and validity was not assessed. She received 19 days of inpatient rehabilitation, including physical therapy, occupational therapy, speech-language-hearing pathology services, and recreational therapy. When discharged from the center, she was independent with bed mobility, but she required supervision with transfers and ambulated household distances with a straight cane. Motorically, she exhibited a predominant flexor synergy in her right UE through approximately 3/4 of the range against gravity at the shoulder and elbow, with trace movement at the wrist and finger flexors. When seen 4 months post-CVA, she was independent with all activities of daily living, ambulated without an assistive device, and did not exhibit any residual speech deficits. She was living with her daughter who worked, but could provide some assistance with meal preparation and cleaning. She did not drive, and thus was limited in her activities outside the home. She displayed no effort to initiate any activity with her impaired limb, suggesting that learned nonuse had occurred.[3] She was chosen for the CIMT intervention, and consequently this case report, because she met the criteria established previously by Taub et al[5] and Wolf et al[9] and was motivated and willing to follow through with the intervention guidelines.

Measurements

The following tests were administered: (1) the WMFT, which includes a series of 14 timed activities and 2 strength tests, and (2) the Motor Activity Log (MAL), a structured interview that identifies performance on 30 daily activities.[10] The WMFT is designed to combine the examination of voluntary movement capabilities in a joint-by-joint manner. The test starts proximally and moves distally, then combines all the joint motions within the context of functional tasks. The tasks are measured in a clinical environment, in contrast to the MAL, which is an ordinal scale that measures how subjects perceive their function in the home environment.

The MAL evaluates "how much" (quantity) and "how well" (quality) the affected extremity was used in specific daily activities, such as turning on a light switch or donning shoes. The quality ("how well") scale consists of the following values: 0=affected arm not used for the activity; 1=affected arm was moved during that activity, but was not helpful (very poor); 2=affected arm was of some use during the activity, but needed help from the unaffected arm and moved very slowly or with difficulty (poor); 3=affected arm was used for the purpose indicated, but movements were slow or made only with some effort (fair); 4=movements made by the affected arm were almost normal, but not quite as accurate or as fast (almost normal); and 5=affected arm was used for the activity as well as before the stroke (normal). The quantity ("how much") scale consists of these values: 0=did not use the affected arm for the activity (not used); 1=affected arm was occasionally used (very rarely); 2=affected arm was used sometimes, but most of the activity was done with the unaffected arm (rarely); 3=affected arm was used about half as much as before the stroke for the activity (half prestroke); 4=affected arm used almost as much as before the stroke for the activity (3/4 of prestroke); and 5=affected arm was used as much as before the stroke for the activity (same as prestroke). The interrater reliability range for the WMFT is .95 to .97.[12] The "how well" (quality of movement) portion of the MAL has been shown to have an interrater reliability of .94.[13] The reliability of the "how much" portion of the MAL was not provided. Both investigators, experienced in administration of these tests, applied the WMFT and MAL based on schedule availability. Our patient possessed movement capabilities similar to those of the patients evaluated by Uswatte and Taub[12]; however, interrater reliability measurements were not taken.

Measurement Procedures

The WMFT was administered and videotaped before and after the intervention and at the 3-month follow-up. Activities of the WMFT were timed up to a maximum value of 2 minutes. Improvement was indicated by the decreased time needed to complete each task. Components of the MAL were given daily during training, immediately before and after the intervention, and at 3 months post-intervention. The MAL data gathered during the training period were stored for group analysis with data collected from the other sites involved in the preliminary project. The patient's caregiver was also given the MAL before and after intervention and at the follow-up.

Intervention

The intervention consisted of the patient wearing a mitt on her uninvolved hand during all waking hours, except for water-based activities such as washing hands and toileting, for the entire 14-day treatment period. The use of the mitt versus a sling or other restraint was chosen for safety of the patient and to encourage her to wear the mitt. During 10 treatment days, the patient participated in supervised task practice in an outpatient setting, for 6 hours a day. The 2-week treatment period with supervised activities during the weekdays was based on previous work by Taub et al[5] and Wolf et al.[9] Everyday use of the hand and return to activities of daily living, including leisure interests, were the primary focus. Initially, the patient was asked what activities she had participated in prior to the stroke and whether she had a preference of tasks she would like to practice. These activities included grooming, writing, dressing, playing board games, gardening, computer work, and sewing. Each task was subdivided by the trainer into a hierarchy of component movements that progressed in complexity to minimize failure or frustration.

A typical day started out with practicing a task related to her activities of daily living for 45 minutes to an hour, followed by a rest break, then playing a board game for the next hour, followed by another rest break, then using the computer for approximately 30 minutes. Lunch usually lasted an hour (including food preparation) and was followed by 3 more 30-minute sessions separated by rest breaks. During these sessions, she practiced sewing, gardening, and simple household cleaning. The patient was also monitored during meals and asked to bring finger foods for lunch, such as sandwiches, precut vegetables, and fruit. She was encouraged to keep an activity log that described all tasks performed with the paretic limb while away from the rehabilitation facility. Each morning, the trainer reviewed the activity log with the patient, discussing performance and use of the mitt during the previous evening. Typically, the patient would document use of her paretic limb in activities such as dinner (including preparation and cleanup) for approximately an hour, using the remote control while watching television for 2

Table 1.
Distribution of Mean, Median, and Minimum to Maximum Values in the Wolf Motor Function Test (Measured Over Time in Seconds Across Tasks)

	Pretreatment	Posttreatment	3-Month Follow-up	Change Score: Pretreatment to Posttreatment	Change Score: Posttreatment to 3-Month Follow-up
Median	5.1	2.4	1.5	−2.7	−0.9
Mean	30.8	18.8	2.9	−12.0	−15.9
Minimum-maximum	1.13–120	2.35–120	1.55–11.88		

Table 2.
Mean and Change Scores on the Motor Activity Log (Ordinal Units Ranging From 0 to 5)

	Pretreatment	Posttreatment	3-Month Follow-up	Change Score: Pretreatment to Posttreatment	Change Score: Posttreatment to 3-Month Follow-up
Patient response					
Amount of use	0.1	2.8	3.8	+2.7	+1.0
How well limb used	0.1	2.1	3.2	+2.0	+1.1
Caregiver response					
Amount of use	0.27	2.33	3.90	+2.06	+1.57
How well limb used	0.20	2.07	3.17	+1.87	+1.10

hours, dressing and grooming for 30 minutes, and conversing on the telephone.

Volunteers from the community and students completing internship requirements at the rehabilitation center were recruited to supervise daily tasks. Each trainer went through 2 to 4 one-hour orientation sessions. At these times, the trainers learned about the CIMT paradigm and safety procedures and how to sequence components of the functional tasks selected by the patient. The trainers supervised the patient during the entire day, monitoring wearing of the mitt and providing verbal encouragement.

During the 2-week intervention period, the patient seemed to tolerate wearing the mitt fairly well. The tasks chosen to practice were structured in such a manner that she encountered enough success to maintain concentration and continue working. Rest periods occurred every 1 to 2 hours to prevent fatigue. Although she was motivated to improve, the patient stated that she grew tired of wearing the mitt and had difficulty with full adherence at home. After leaving the rehabilitation center, she was instructed to wear the mitt for all activities agreed on in the original behavior contract. Often, she said she was so fatigued after the day of training that her activities at home were limited to eating dinner, watching television, and going to bed earlier than she normally would. "Cheating" with the uninvolved hand was a frequent temptation for the patient, but she responded well to verbal encouragement and gentle reminders to use the affected limb appropriately.

Outcomes

Comparisons of pretreatment and posttreatment measurements were used to indicate change (Tabs. 1 and 2). Both the median and mean values for the WMFT (calculated across tasks for each measurement period) illustrated improvement in time to complete tasks, not only from the pretreatment measurement to the posttreatment measurement but also from the posttreatment measurement to the 3-month follow-up (Tab. 1). All of the 16 functional, timed evaluation items of the WMFT (Tab. 3) showed faster speeds after treatment and continued to show improvement to the follow-up session. The patient could not complete the 2 most difficult tasks of folding a towel and lifting a basket until the follow-up session.

The MAL evaluation indicated improvement in the use of the affected limb in daily functional activities. Table 2 shows the average score (of all 30 functional items) on the 2 components of the MAL (amount of use, how well the limb was used) at 3 time points, including the change in scores. Prior to treatment, the patient stated that she used her affected limb for only 1 of the 30 activities. After treatment, she was using her limb at least half as much as before the stroke in all except 5 of the activities. At the 3-month follow-up, she not only was using the limb in all the activities, but described this use

Table 3.
Components of the Wolf Motor Function Test and Subject Scores Over Time[a]

Task	Pre-treatment	Post-treatment	3-Month Follow-up
Forearm to table (side)	1.76	0.52	0.47
Forearm to box (side)	1.16	0.76	0.76
Extend elbow (side)	5.04	0.42	0.36
Extend elbow (weight)	2.10	0.52	0.52
Hand to table (front)	2.53	0.53	0.47
Hand to box (front)	1.67	0.75	0.70
Reach and retrieve	1.13	0.73	0.48
Lift can	20.17	2.35	1.55
Lift pencil	5.09	5.41	2.61
Lift paper clip	Unable	4.83	2.28
Stack checkers	17.44	7.52	6.50
Flip cards	23.09	12.48	7.64
Turn key in lock	20.77	5.13	4.34
Fold towel	Unable	Unable	11.88
Lift basket	Unable	Unable	2.30
Weight to box (lb[b])	5.0	6.5	7.5
Grip strength (kg)	4.9	5.3	6.1

[a] All measurements expressed in seconds, unless otherwise indicated. A maximum score of 120 seconds was given when patient was unable to complete task. One trial was given for each task.
[b] 1 lb=0.4536 kg.

as at least 3/4 as much as before the stroke in all except 11 of the 30 activities. Those activities that were more difficult included writing and buttoning a shirt. The caregiver (daughter) described similar improvements over a similar range (Tab. 2). The caregiver commented that her mother "seemed like a different woman," paying more attention to her appearance, interacting more socially, and driving again.

Discussion

Following a 2-week period of CIMT (ie, 4 months post-CVA), using supervised task-specific practice, this patient's motor abilities improved. This case report is one of the first documented applications of this procedure to patients less than 1 year post-stroke. These outcomes suggest that the patient had exhibited a learned nonuse phenomenon. Because she was not using a limb prior to CIMT, she was capable of also moving outside of flexion synergy into extension. The patient's improvement in scores for both the WMFT and the MAL suggests that this intervention may help to overcome the effects of learned nonuse.

Within the framework of this case report, the indications for improvement are based on the patient's ability to complete tasks that she could not do previously, improvement of speed of activity or force generated during an activity, or improved perception of how often or how well the patient performed functional tasks. An explanation for these improvements could possibly be obtained by relating these measured changes to measurements of change in cortical function obtained through functional magnetic resonance imaging or nuclear magnetic resonance studies.

The outcomes for our patient, as well as the results of previously mentioned studies,[5,9] are difficult to explain with certainty, but seem to be related to the effects of learned nonuse. This conditioned suppression of movement is thought to occur because of a natural and spontaneous reliance on the contralateral, relatively unimpaired limb to perform most tasks of daily living. During the acute post-stroke phase of rehabilitation, unsuccessful attempts to move the affected limb or inadequate rehabilitation of the limb may augment this phenomenon. Once the cortical suppression related to the shock-like phenomenon that occurs after a substantial neurological injury subsides, motoric activity should become increasingly possible.[14–17] The behavioral response tendency not to use the limb, however, often persists, continuing to inhibit use of the limb. Evidence suggests that individuals who are encouraged to use the limb are often able to do so.[18,19] Consequently, CIMT may not be changing actual movement potential, but may be changing behavior so that individuals are willing to use their limb more, thus achieving their real movement capabilities.

Another possible explanation for improved use may lie in the theory of neural reorganization, perhaps due to axonal sprouting as a precursor to improved motor performance.[20] This explanation remains improbable because of the short duration of treatment and rapid improvement of the subject. As Taub et al stated, "This has the appearance of an unmasking of an ability that is already present, rather than the initiation of a neural restitution process."[5(p353)] Alternatively, one cannot dismiss the importance of long-term potentiation (ie, persistence of a response once it is removed)[21] or enhanced synaptic efficacy[22] as mechanisms that can be engaged with repetitive activity to promote improved task-specific limb usage. Thus, perhaps the constraint portion of the intervention addresses the behavioral issues of learned nonuse, and the supervised task practice portion incorporates the theories of long-term potentiation or enhanced synaptic efficacy. In combination, these interventions may be effective in improving motoric capabilities after neurological insult.

The outcomes of this case report and previous research justify further exploration of the effect of CIMT in people with stroke. Based on the criteria established by Taub et al[5] and Wolf et al,[9] approximately 20% to 25% of patients with chronic stroke, roughly equivalent to 40,000 patients a year, may benefit from this type of intervention. Future studies including large sample sizes within a randomized clinical trial should be considered.

In light of current health care trends that limit lengths of rehabilitation stay as well as the amount of therapy an individual may receive after a stroke, clinicians should seek cost-efficient and effective means to improve function in the hemiplegic arm. Constraint-induced movement therapy may eventually prove to be one such approach.

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