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Auto-Therapy in Constraints and Bimanual Practice with Rehabilitation Actuators

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Abstract: The majority of stroke survivors are left with persistent impairment. During the first three to six months following stroke, rehabilitation efforts should focus on optimizing patients' physical, communicative, and cognitive capabilities. Regular, incremental skill practice of goal-directed tasks in the home can result in continued improvement during the chronic period of stroke. Numerous new rehabilitation techniques, founded on the premise of using technology advancements to magnify the benefits of practice, are providing novel pathways for amplifying performance improvements at any point following stroke. Stroke rehabilitation's future remains both promising and challenging in terms of addressing residual impairments, particularly in terms of trying biological treatments for brain repair in the most severely afflicted patients.
Keywords: Rehabilitation devices, Pharmacological Interventions,

1. INTRODUCTION

Therapy for the hemiparetic arm may begin with single-joint movements, progressing to more complicated, multi-joint motions, and finally task-specific practice, such as reaching to grasp a coffee cup, a process called shaping. Facilitating upper extremity professional motor practice can take various forms, including shaping combined with constraint-induced movement therapy (CIMT). For two weeks, this approach entails six hours per day of increasing task-related practice while the unaffected limb is restrained throughout the day. Increased usage and more skillful motions of the afflicted limb may occur and last up to two years [1]. However, the intervention is effective only in individuals who can somewhat extend their wrists and fingers, indicating that they have enough motor control and at least some corticospinal tract sparing. Extensive restriction may not be as crucial to improvements as high-intensity practice with a therapist; benefits have been reported with as little as two hours of daily practice and without restricting the unaffected hand throughout the day [2-3]. When the hand is chronically weak, commercially accessible forearm-hand orthotics with integrated FES electrodes can facilitate practical usage by enabling a hand grip or finger pinch. Bimanual exercise with concurrent arm motions attempts to stimulate bilateral motor cortices and boost input to the afflicted upper extremity, resulting in greater functional use of the paretic arm and hand. The bimanual practice has been shown in limited studies to result in a similar degree of functional recovery as CIMT [4].

2. MECHANICAL ASSIST DEVICES FOR ARM MOVEMENTS

Mechanical devices range from spring-loaded orthotics that aid with a particular action, such as wrist extension, to fully automated robotic limb prosthesis that assists with shoulder, elbow, and wrist motions when prompted by the patient. Patients practice a sequence of precise joint motions by directing a virtual item through a maze on a computer screen. As is the case with electromechanical assistance devices for gait training, robotic arm devices may allow for increased practice with more normalized limb kinematics. While such devices may be beneficial when used with regular therapy [5-6], a comparable degree of function can generally be attained with traditional therapies at the same intensity [7]. Additionally, the majority are too costly for household use. These devices may be more effective when combined with other rehabilitative treatments, such as noninvasive brain stimulation [8], but further study is necessary. Fourteen randomized controlled trials comparing robot-as- sisted therapy that use end-effector-type devices with conven- tional therapies for improvement of upper limb motor function after stroke were selected for review (Table 2).

Authors	Robotic device	Number of participants	Stroke stage	Intensity	Concomitant therapy	Summary of results in comparison with conventional therapies	
						Upper limb function	Activities of daily living
End-effector-type devices							
Lum et al., 2002	MIME	27	Chronic	55 minutes, 24 sessions total over 8 weeks	No	No difference	Not assessed
Fasoli et al., 2004	MIT-MANUS	56	Subacute	1 hour, 5 times per week for 5 weeks	No	More effective	More effective
Hesse et al., 2005	Bi-Manu-Track	44	Subacute	30 minutes, 5 times per week for 6 weeks	Yes	More effective	No difference
Daly et al., 2005	InMotion	12	Chronic	5 hours per day, 5 days per week for 12 weeks	Yes	No difference	Not assessed
Lum et al., 2006	MIME	30	Subacute	1 hour, 15 sessions over 4 weeks	No	No difference	No difference
Masiero et al., 2007	NeReBot	35	Subacute	4 hours per week for 5 weeks	Yes	No difference	More effective
Volpe et al., 2008	InMotion2	21	Chronic	1 hour, 3 times per week for 6 weeks	No	No difference	No difference
Lo et al., 2010	MIT-MANUS	127	Chronic	a maximum of 36 sessions over 12 weeks	No	More effective	Not assessed
Burgar et al., 2011	MIME	54	Subacute	1 hour, 5 times per week for 3 weeks	No	No difference	No difference
Conroy et al., 2011	InMotion 2.0 Shoulder/Arm Robot	57	Chronic	1 hour, 3 sessions per week for 6 weeks	No	No difference	More effective
Liao et al., 2011	Bi-Manu-Track	20	Chronic	90 to 105 minutes, 5 days per week for 4 weeks	Yes	No difference	More effective
Masiero et al., 2011	NeReBot	21	Chronic	Twice a day for 20 minutes, 5 days per week for 5 weeks	Yes	No difference	No difference
Hsieh et al., 2012	Bi-Manu-Track	54	Chronic	High intensity: 20 sessions for 90 to 105 minutes, 5 days per week for 4 weeks Low intensity: same amount assessed, but only half of the number of repetitions	Yes	High: More effective Low: No difference	No difference
Wu et al., 2013	Bi-Manu-Track	42	Chronic	90 to 105 minutes, 5 days per week for 4 weeks	Yes	More effective	Not assessed
Exoskeleton devices							
Kahn et al., 2006	ARM-Guide	19	Chronic	45 minutes, 24 sessions over 8 weeks	No	No difference	Not assessed
Fazekas et al., 2007	REHA ROB	15	Chronic	30 minutes, 20 consecutive work days (5 weeks)	Yes	More effective	Less effective
Mayr et al., 2008	ARMOR	8	Chronic	5 times per week for 6 weeks	No	No difference	Not assessed
Houseman et al., 2009	T-WREX	28	Chronic	30 minutes, 5 times per week for 8-9 weeks	No	No difference	No difference

Table 1: Robot-assisted therapy for upper limb motor function



Figure 1: The Armeo Spring is designed for patients with impairments of hand and arm function. The combination with a computer game makes the therapy more motivating than conventional methods.

In summary, robot-assisted therapy for upper limb motor function provides an additional effect on ADL function only in patients with subacute stroke. Further studies may be needed to draw a definite conclusion about the effect of robot-assisted training on ADL in patients with chronic stroke. Three randomized controlled trials concerning hand motor function in patients with stroke were selected for review (Table 3).

Authors	Robotic device	Number of participants	Stroke stage	Intensity	Concomitant therapy	Summary of results in comparison with conventional therapies
End-effector-type devices						
Fischer et al., 2007	Cable orthosis/ Pneumatic orthosis	15	Chronic	1 hour, 3 times per week for 6 weeks	No	No difference
Connelly et al., 2010	PneuGlove	14	Not described	1 hour, 3 times per week for 6 weeks	No	No difference
Hwang et al., 2012	Amadeo	17	Chronic	20 minutes, 20 sessions total over 4 weeks	No	More effective
Exoskeleton devices						
Takahashi et al., 2008	HAWARD	13	Chronic	1.5 hours, 5 times per week for 3 weeks	No	More effective
Kutner et al., 2010	Hand Mentor	17	Chronic	60 hours over 3 weeks	Yes	No difference

Table 2: Robot-assisted therapy for hand motor function

All three trials were single-center studies with relatively small numbers of participants, all in the chronic stage of stroke, and there was no randomized controlled trial that included subacute stroke patients as participants Furthermore, there was no assessment of ADL function after robot-assisted therapy for hand motor function. Therefore, these results suggest that robot-assisted therapy with end-effector devices may yield similar or greater improvement in hand motor function in patients with chronic stroke, but there is insufficient research to support an effect in patients with subacute stroke. Therefore, well-designed studies are needed to draw clear conclusions regarding the effect of robot- assisted therapy that use end-effector devices on improvement of the hand motor function of patients in both the sub- acute and chronic stages of stroke.

3. PHARMACOLOGICAL INTERVENTIONS TO REDUCE SPASTICITY

Treatment of increased muscular tone is frequently not medically essential until spasms or flexor postures of the upper extremity cause discomfort, skin disintegration, or interfere with hygiene. Baclofen and tizanidine are commonly used as first-line treatments, and the effects of dantrolene on calcium action may also help decrease hypertonicity. Botulinum toxin injections into specific muscle groups diminish flexor or extensor postures around a joint for approximately three months but do not often enhance functional use of a severely paretic hand [9,10]. Shoulder discomfort is frequent following hemiplegic stroke and is caused by subluxation and joint strains [11]. Rapid pain relief with mild exercise, range of motion exercises, and anti-inflammatory medicines can help avoid pain-induced stiffness in the arm and hand. Additionally, medicines and botulinum toxin can be used to reduce inversion and plantar flexion of the foot to enhance stepping. When a toxin partly paralyzes a muscle, regular stretching and range of motion exercises of the afflicted joint are required to sustain the improvement.

4. APHASIA INTERVENTIONS

A. Therapeutic Use Of Melodic Intonation And Constraint-Induced Intonation

Individualized speech and language treatment approaches have been developed to address the broad diversity of post-stroke aphasic disorders [12]. The majority of patients require a multimodal strategy to capitalize on their abilities and minimize frustration with word discovery and fluency. Melodic intonation treatment was created for individuals who have difficulty expressing themselves but have a high level of comprehension. This approach employs basic melodies and rhythmic tapping to activate networks that support language's prosody [13]. Constraint-induced aphasia treatment was created to improve linguistic output about the massed-practice paradigm of CIMT [14]. Where understanding is inadequate, and output is persistent, treatments are ineffective. Regardless of the therapy approach used, consistent home-based practice with the family is critical for social communication development.

B. Information And Communication Technologies

Advances in digital communication technologies have enabled the development of tailored and in-home therapies for aphasia [15]. For example, recent research of speech entrainment revealed a substantial increase in verbal output for chronic stroke patients with Broca's aphasia when an audiovisual intervention was provided via an iPod screen [16]. Additionally, some beneficial computer tools for at-home practicing are accessible. Therefore, the treatment of speech and cognitive impairments is anticipated to be increasing the use of smartphones, telerehabilitation, and other Internet-enabled practice and cueing paradigms.

C. Visual Field Deficits And Inattention Interventions

Visual field loss and visual hemi-inattention both have a detrimental effect on long-term functional results in stroke patients [17]. While rehabilitation is unlikely to result in hemianopia recovery, computer-based compensatory treatment may assist in refocusing visual search and attention on the region of loss [18]. For example, the direct dopamine agonist rotigotine significantly reduced hemispatial neglect in individuals with subacute stroke [19]. In the case of spatial hemineglect, a prism in spectacles can be used to move the center of vision toward the abnormal field, therefore improving reading and some self-care skills [20].

5. LOCKED-IN SYNDROME INTERVENTIONS

Brain-machine interfaces permit communication or goal-directed actions by establishing direct connectivity between the nervous system and devices external to the body. The gadgets are essential for patients who have locked-in syndrome as a result of a brainstem stroke and are unable to control their limbs on their own. Electroencephalography electrodes are used to capture changes in the amplitude of the mu rhythm caused by thoughts about an action. These changes are processed by a computer program, allowing patients to pick letters or words on a computer screen for conversation or to search the Web [21]. Advanced systems are capable of recording directly from microelectrodes implanted in several cortical areas. The direction of movement of a prosthetic limb is then controlled via an interface [22]. While some of these technologies are becoming more widely adopted, several issues about cost and dependability persist.

A. Brain Stimulation Without Invasive Procedures

Apart from being utilized to investigate brain physiology and neuroplasticity [23], TMS and transcranial direct current stimulation (tDCS) have been used to modify cerebral plasticity in conjunction with physical exercise. While the majority of studies focus on arm function recovery [24], the approaches are also being used to enhance verbal output in aphasia [25], swallowing [27], and walking speed [28], to name a few examples. TMS has been shown to improve some motor control elements when coupled with other rehabilitative treatments [29]. tDCS methods have shown similarly ambiguous findings [30]. Consensus on optimal patient selection, stimulation strategy, location, and duration continues to be lacking [31]. Except for some forms of depression, the Food and Drug Administration has not approved their usage outside of study. These approaches appear to be most effective in patients who retain some voluntary movement.

Modulation of sensorimotor cortex excitability may also be accomplished by peripheral nerve stimulation, either alone or with cortical stimulation [32, 34, 35]. However, there is no conclusive evidence that peripheral nervous system stimulation improves functional results [36].

B. Therapies Utilizing Mirrors And Virtual Reality

Both action observation and mirror treatment have been shown to influence the connections between the parietal cortex and the pre-and primary motor areas [37]. These approaches include patients observing the motions of healthy persons or the unaffected limb through a mirror. The participant attempts to replicate the motions witnessed. Compared to other rehabilitative treatments such as CIMT, action observation, and mirror therapy can be used with patients with more severe limb paresis [38]. A meta-analysis of small studies revealed clinical benefit, although the effect depends on the comparator therapy used [39].

Virtual reality (VR) treatments combine action observation and repetitive skill practice via the use of technology. This technique, it is hoped, would be particularly engaging and reinforce practice paradigms. VR has generated considerable excitement in the rehabilitation community to promote and monitor skill practice [40]. It can be as simple as a commercially available video game that can be played at home or as complex as a system that measures joint angles in the arm and provides visual corrective feedback. Individual studies have indicated benefits [41], but due to the variety of treatments and outcomes studied, effectiveness for a specific kind or degree of impairment has not been established [42].

C. Medico-Legal Interventions

Medications may also be used to aid in stroke recovery by altering the central nervous system's neurotransmitter pathways. Although amphetamine showed promise for motor improvements in highly chosen individuals, no adequately powered trial has been performed despite two decades of tiny investigations [43]. Attempts to augment dopaminergic activity in the brain with ropinirole were unsuccessful in individuals with chronic stroke [44]. Memantine has been shown to enhance spontaneous speaking and naming abilities in chronic stroke patients with aphasia [45]. While some individuals appear to benefit from neurotransmitter-related medications on occasion, no precise recommendations can be given. The FLAME experiment [46] evaluated fluoxetine in conjunction with typical rehabilitative treatments and found that patients who took the medication had improved Fugl-Meyer motor scores, which measure voluntary movements against gravity. This study should be repeated [47]. In addition, the medication may potentially have antidepressant properties, as depression affects at least 30% of patients within a year following a stroke.

D. Cell- And Biologic-Based Therapies

Embryonic and mesenchymal stem cells, neuronal and oligodendrocyte precursor cells, and other autologous and marketed cells are investigated as possible stroke therapies. Cells may replace missing neurons or glial cells, remyelinate injured axons, or generate growth factors that contribute to network function and plasticity [48]. However, numerous published trials failed to demonstrate therapeutic effectiveness, although they planned further trials [49, 50]. To be effective, cellular and biological treatments must be coupled with appropriate rehabilitative techniques to enhance their integration and activity in brain networks. On the Internet, offshore stem cell clinics are all too simple to locate. For patients with neurologic illness, these high-priced cellular treatments can have a strong placebo effect. Organizations that examine stem cell research regulations propose that no patient should engage in or pay for a cellular intervention outside of a registered trial with a formal safety monitoring committee to allow the trial to generate scientifically meaningful data [51, 52].

E. Diverse Approaches

Acupuncture is commonly used to treat strokes in Asian nations. While some patients may claim improvement, controlled trials have usually discovered little or no added value for addressing specific impairments and disabilities [53, 54]. Hyperbaric oxygen treatment may enhance functional outcomes following stroke, according to a recent trial [55]. However, the study's design was less than optimum. The cost of this medication is considerable, there are dangers associated with its usage, and the evidence supporting its use in chronic stroke is debatable. Etanercept, which the FDA has authorized to treat psoriatic and rheumatoid arthritis, has been given in several clinics as a therapy for chronic stroke. Amgen, the producer, expressly states that there is insufficient data to support its use in stroke, and the few published papers by a single dermatologist are highly biased and lack adequate scientific theory, methodology, and interpretation of outcomes [56].

6. CONCLUSIONS

The majority of stroke survivors are left with persistent impairments. During the first three to six months following a stroke, rehabilitation efforts should optimize patients' physical, communicative, and cognitive capabilities. Consistent, incremental skill practice of goal-directed tasks in the home can result in continued improvement during the chronic period after stroke [12]. Numerous new rehabilitation techniques, founded on using technology advancements to magnify the benefits of the practice, provide novel pathways for amplifying performance improvements at any point following stroke. Thus, stroke rehabilitation's future remains both promising and challenging in addressing residual impairments, particularly in trying biological treatments for brain repair in the most severely afflicted patients.

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