Effect of Central Versus Peripheral Stimulation on Hand Function in Stroke Patients

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Abstract

Background and Purpose: More than 60% of stroke survivors suffer from persistent neurological deficits that impair activities of daily living. Electrical stimulation is shown to be effective in enhancing the upper extremity functional recovery in stroke patients. The goal of this study was to compare between the effect of central and peripheral stimulation on hand function in these patients.

Patients and Methods: This study was conducted on forty five stroke patients from both sexes, their ages ranged from 45 to 60 years. The patients were divided into three equal groups. The study group (I) received anodal transcranial direct current stimulation in addition to the selected physical therapy program. The study group (II) received neuromuscular electrical stimulation in addition to the selected physical therapy program and the control group (III) received the selected physical therapy program only. Hand function was measured using Jebsen Taylor Hand Function Test (JTT).

Results: There was a statistically significant decrease of the mean values of JTT test score in group I and group II post treatment while the changes in group III were not significant. There was a significant decrease in the mean value of JTT test in group I compared with group II and group III.

Conclusion: Both Central and peripheral stimulation are effective modalities in improvement of hand function post stroke while the central stimulation is more effective than the peripheral one.

Key Words: Stroke – Hand function – Electrical stimulation.

Introduction

STROKE is the leading cause of long-term disability, and is responsible for 2-4% of total healthcare expenses [1]. Distal limb impairment is especially problematic, because proper hand function is crucial to manual exploration and manipulation of the environment. Indeed, loss of hand function is a major source of impairment in neuromuscular disorders, frequently preventing effective occupational performance and independent participation in daily life [2]. Hand motor impairments may be caused by a deficit in motor execution, resulting from weakness, spasticity, and abnormal muscle synergies, and/or a deficit in higher-order processes, such as motor planning and motor learning. These lead to poorly formed sensorimotor associations that lead to impaired motor control [3].

Transcranial direct current stimulation (TDCS) is one of non invasive brain stimulation techniques that involve application of very low-amplitude direct currents (2mA or less) via surface scalp electrodes [4]. The applied current modifies the transmembrane neuronal potential and thus influences the level of excitability. Depending on the polarity of active electrodes over the primary motor cortex (M1) contralateral to the target muscles, TDCS can increase or decrease corticomotor excitability [5].

Cathodal TDCS leads to hyperpolarization and reduces the size of the TMS-induced motor evoked potentials (MEPs), indicating decreased motor cortex excitability. On the other hand anodal TDCS (a-TDCS) results in corticomotor depolarization and increases the size of MEPs, indicating increased motor cortex excitability [6]. Previous studies indicated that any improvement in corticomotor excitability coincides with functional improvement [7,8].

Neuromuscular electrical stimulation (NMES) refers to the electrical stimulation of lower motor neurons to cause muscle contraction [9]. In stroke patients, NMES has been used to facilitate return of function and prevent complications in the upper limb [10]. It has been recommended as a safe method to improve upper limb outcomes after stroke with
claims that it can reduce spasticity, strengthen muscles, and increase the range of movement with prevention of contractures [11].

This study was designed to compare between the effect of central and peripheral stimulation in the form of transcranial direct current stimulation and neuromuscular electrical stimulation respectively on hand function in stroke patient.

**Patients and Methods**

This study was conducted on forty-five stroke patients from both sexes (27 males, 19 females). The patients were selected from the Out-Patient Clinic, Faculty of Physical Therapy, Cairo University in the period from October 2013 to March 2014. The patients were diagnosed as having stroke based on careful neurological assessment and radiological investigations including computed axial tomography (CT) and/or magnetic resonance imaging (MRI) of the brain. Patients participated after signing a written consent forms approved by the Ethics Committee of the Faculty of Physical Therapy, Cairo University.

The patients were divided into three equal groups. The first group (Group I) received anodal transcranial direct current stimulation (a-TDCS) applied on ipsilesional hemisphere in addition to a selected physical therapy program. The second group (Group II) received neuromuscular electrical stimulation (NMES) applied to wrist extensors of the affected side in addition to the selected physical therapy program and the third group (Group III) received the selected physical therapy program only.

Inclusion criteria were duration of illness ranged from six to eighteen months post stroke, Spasticity of the muscles of the affected hand (wrist flexors, fingers flexors and adductors) was ranged from 1: 1 according to Modified Ashworth Scale (MAS). Patients had active range of antigravity motion of the affected side of at least 60 degrees shoulder elevation and 10 degrees wrist extension.

Exclusion criteria include any other neurological or orthopedic diseases that may affect upper limb movement, patients with moderate or severe spasticity of the muscles of the affected hand (wrist and fingers flexors, adductors), blindness, deafness, severe cognitive impairment, or language deficits that impair patient’s cooperation. An EEG suspect of elevated cortical excitability, metallic implants within the brain, skin irritation, previous brain surgery and medications altering the level of cortical excitability (e.g. antiepileptics, neuroleptics, benzodiazepines, antidepressants).

**Instrumentations:**

- Hand function was evaluated by Jebsen Taylor Hand Function Test (JTT) which is a widely used assessment scale of functional hand motor skills. It has a good validity and reliability, and normative data that are available for different ages and both genders [12]. It provides a short, objective test of hand functions that are commonly used in activities of daily living [13].

- The electrical stimulation device used for TDCS was (D64 camera Inter-channel device). It has the possibility of therapeutic currents interference of various types. This apparatus was used to deliver direct current with stimulation intensity of one mA for 20 minutes.

- The electrical stimulation device that used to deliver NMES was (Gymna Duo 200, Made in Belgium).

**A- Evaluation protocol:**

*For assessment of hand function:* The patients were examined using JTT test pre and post treatment. This test consists of seven items include a range of fine motor, weighted and non-weighted hand function activities which are timed: 1- Writing (copying) a 24-letter sentence, 2- Turning over 3x5” cards, 3- Picking up small common objects such as a paper clip, bottle cap and coin 4- Simulated feeding using a teaspoon and five kidney beans, 5- Stacking checkers, 6- Picking up large light objects (empty tin can) and 7- Picking up large heavy objects (full tin can x 1 lb). Since some patients were unable to perform writing tasks (the seventh JTT subtest) due to dominant hemisphere strokes, we excluded this particular subtest from the study. Patients were instructed to perform the tasks as rapidly and accurately as possible according to written standardized instructions in the testing set according to Stern [13] protocol.

**B- Treatment protocol:**

The patients in the study group (GI) received anodal TDCS applied on ipsilesional hemisphere in addition to a selected physical therapy program, patients in the study group (GII) received NMES applied to wrist and finger extensors (extensor carpi radialis longus and brevis, extensor carpi ulnaris, and extensor digitorum communis) of the affected side in addition to a selected physical therapy program, the patients in the control group (GIII) received the selected physical therapy program only.
Application of TDCS: TDCS was applied via saline-soaked surface sponge electrodes (5cmx7cm) connected to a constant current stimulator. The anodal electrode was placed over the presumed hand area of the lesional hemisphere (C3, C4 according to the EEG 10-20 system), while the cathodal electrode was placed above the contralateral supra orbital ridge. The patients received 20min. of anodal TDCS three times per week for successive four weeks according to Schlaug and Renga [14] protocol.

Application of NMES: NMES was delivered by surface electrodes positioned on the dorsal surface of the forearm to stimulate the wrist and finger extensors of the affected side (inactive electrode placed slightly inferior to the common extensor origin below the elbow and the active electrode placed below it few inches above the wrist). The stimulation parameters used to produce slow movement through the full range of motion at maximum patient comfort were as follows: Pulse width = 300ms; ON time = 15sec; OFF time = 15sec. The frequency of stimulation was set to 40Hz and the intensity of stimulation was adjusted to obtain maximum possible range of wrist and finger extension with an intensity that was tolerated by the patient and without inducing fatigue [15]. The patients received 30min. of NMES stimulation three times per week for successive four weeks.

All patients in the three groups received physical therapy program in the form of task specific training, postural control and balance training, upper extremity control, Proprioceptive Neuromuscular Facilitation (PNF), weight bearing and weight shifting, facilitation for weak muscles in the upper extremity.

The task specific training includes: Grasp and release objects like a bottle, extend fingers while resist pen, performance of fine motor tasks like placing items i.e.; placing small ball in a basket. Each patient performed the three tasks at the same session, each task ten minutes. In each task the patient asked to position it independently without the therapist assistance. The training session for the selected physical therapy program was about one hour, three sessions per week, for successive four weeks.

Statistical analysis:
Descriptive statistics were done in the form of mean and standard deviation for age, weight, height, BMI, duration of illness, total time of JTT test. Paired t-test was used to assess changes within groups pre and post treatment and one way ANOVA was conducted to compare between the three groups pre and post treatment. Analysis was done using SPSS version 19. The alpha point of 0.05 was used as a level of statistical significance (when p=0.05 is usually classed as “significant” and p=0.01 as “highly significant” [16].

Results

Demographic and clinical characteristics of the patients in the three groups:
By comparing the general characteristics of the patients in three groups, the results showed that there was no significant difference between three groups regarding mean age, weight, height, BMI and duration of illness (p=0.79, p=0.9, p=0.71, p=0.76 and p=0.8 respectively) (Table 1). In GI, eight patients had right sided hemiparesis and seven patients had left sided hemiparesis while in GII, nine patients had right sided hemiparesis and six patients had left sided hemiparesis and in GIII eight patients had right sided hemiparesis and seven patients had left sided hemiparesis.

Comparison of total time of JTT test pre and post treatment within each group (Table 2, Fig. 1):
The mean total time of JTT test pre treatment for group I was 165.95±39.56sec while post treatment was 110.26±30.77sec. There was a highly significant decrease in the post treatment mean values of total time of JTH test compared with the pre treatment values with p=0.0001. The mean difference was 55.69sec and the percent of improvement was 33.55%.

The mean total time of JTT test pre treatment for group II was 168.87±25.54sec while post treatment was 138.29±33.57sec. There was a highly significant decrease in the post treatment mean values of total time of JTH test compared with the pre treatment values with p=0.0001. The mean difference was 30.58sec and the percent of improvement was 18.1%.

The mean total time of JTT test pre treatment for group III was 159.75±25.33sec while post treatment was 157.14±22.67sec. There was no significant difference in mean values of total time of JTT test between pre and post treatment measurements (p=0.07). The mean difference was 2.61 sec and the percent of improvement was 1.63%.
Comparison among the three groups pre and post treatment:

The mean total time of JTT pre treatment for group I, II, and III were 165.95 \pm 39.56, 168.87 \pm 25.54, and 159.75 \pm 25.33 sec respectively. There was no significant difference among the three groups in total time of JTT pre treatment ($p=0.71$) (Table 3, Fig. 2). While the mean total time of JTT post treatment for group I, II, and III were 110.26 \pm 30.77, 138.29 \pm 33.57, and 157.14 \pm 22.67 sec respectively. There was a highly significant difference between the three groups in total time of JTT post treatment with $p=0.0001$ (Table 3, Fig. 3).

Post hoc comparison revealed that there was a significant decrease in the mean value of total time of JTT test post treatment in group I compared with group II ($p=0.03$), and compared with group III ($p=0.0001$). However, there was no significant difference between group II and group III post treatment ($p=0.25$) (Table 4, Fig. 3).

Table (1): General characteristics of the patients in the three groups.

<table>
<thead>
<tr>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>F value</th>
<th>$p$ value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>53.53 \pm 4.99</td>
<td>53.06 \pm 5.22</td>
<td>52.33 \pm 4.27</td>
<td>0.23</td>
<td>0.79</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>80.06 \pm 10.39</td>
<td>81.06 \pm 12.52</td>
<td>79.13 \pm 11.51</td>
<td>0.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165.8 \pm 4.31</td>
<td>164.73 \pm 4.6</td>
<td>166 \pm 4.78</td>
<td>0.33</td>
<td>0.71</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>29.14 \pm 3.87</td>
<td>29.84 \pm 4.39</td>
<td>28.74 \pm 4.16</td>
<td>0.27</td>
<td>0.76</td>
</tr>
<tr>
<td>Duration of illness</td>
<td>12.46 \pm 3.68</td>
<td>13.13 \pm 3.73</td>
<td>13.33 \pm 3.95</td>
<td>0.21</td>
<td>0.8</td>
</tr>
</tbody>
</table>

$X$ : Mean.  
SD : Standard deviation.  
F-value : F-value.  
$p$-value : Probability value.  
NS : Non significant

Table (2): Comparison between pre and post treatment mean values of total time of JTH test within each group (I, II & III).

<table>
<thead>
<tr>
<th>Total time of JTT</th>
<th>Pre-treatment</th>
<th>Post-treatment</th>
<th>Mean difference</th>
<th>Percentage of improvement</th>
<th>t value</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X\pmSD</td>
<td>X\pmSD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group I</td>
<td>165.95\pm39.56</td>
<td>110.26\pm30.77</td>
<td>55.69</td>
<td>33.55</td>
<td>9.84</td>
<td>0.0001**</td>
</tr>
<tr>
<td>Group II</td>
<td>168.87\pm25.54</td>
<td>138.29\pm33.57</td>
<td>30.58</td>
<td>18.1</td>
<td>6.3</td>
<td>0.0001**</td>
</tr>
<tr>
<td>Group III</td>
<td>159.75\pm25.33</td>
<td>157.14\pm22.67</td>
<td>2.61</td>
<td>1.63</td>
<td>1.9</td>
<td>0.07</td>
</tr>
</tbody>
</table>

$X$ : Mean.  
SD : Standard deviation.  
$p$ : Probability.  
** : Highly significant at $p \leq 0.01$.

Table (3): Comparison of the mean values of total time of JTT test among the three groups (I, II & III) pre and post treatment.

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>F value</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X\pmSD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>165.95\pm39.56</td>
<td>168.87\pm25.54</td>
<td>159.75\pm25.33</td>
<td>0.34</td>
<td>0.71</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>110.26\pm30.77</td>
<td>138.29\pm33.57</td>
<td>157.14\pm22.67</td>
<td>9.67</td>
<td>0.0001**</td>
</tr>
</tbody>
</table>

$X$ : Mean.  
SD : Standard deviation.  
p : Probability.  
** : Highly significant at $p \leq 0.01$.  

Effect of Central Versus Peripheral Stimulation
Table (4): Comparisons of mean values of total time of JTT test post treatment between the patients’ groups (I, II & III).

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Mean difference</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I vs. Group II</td>
<td>28.03</td>
<td>0.03 *</td>
</tr>
<tr>
<td>Group I vs. Group III</td>
<td>46.88</td>
<td>0.0001 **</td>
</tr>
<tr>
<td>Group II vs. Group III</td>
<td>18.85</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Vs. = Versus. Significant at p≤0.05.  
p : Probability. Highly significant at p≤0.01.

Discussion

In the present study there was a statistically significant decrease of the mean values of JTT score in the study group (I) and (II) post treatment with greater improvement in study group (I) while there was no significant difference pre and post treatment in control group (III).

These results come in agreement with Hummel et al., [17] who tested the effect of transcranial direct current stimulation on skilled motor function in chronic stroke. The results showed that functions in the paretic hand improved significantly. The effect was correlated with an increment in motor cortical excitability within the affected hemisphere, expressed as increased recruitment curves and reduced short-interval intracortical inhibition.

Frenigi et al., [18] mentioned that both cathodal stimulation of the unaffected hemisphere and anodal stimulation of the affected hemisphere improved significantly the motor performance of the paretic hand in chronic stroke patients.

Similarly, Boggio et al., [19] tested the motor performance improvement in stroke patients using (JTT) following four weekly sessions of sham, anodal and cathodal tDCS. The results showed that there was a significant motor function improvement after either cathodal tDCS of the unaffected hemisphere or anodal tDCS of the affected hemisphere when compared to sham tDCS application.

Kim et al., [20] applied anodal tDCS to the ipsilesional cortical region of ten subacute stroke patients approximately 12 weeks after the infarct. The results showed that anodal tDCS significantly improved motor performance as well as finger acceleration measurement.

The explanation of hand function improvement following application of anodal TDCS to the ipsilesional hemisphere may be due to increase the spontaneous firing rate and the excitability of cortical neurons by depolarizing the membranes [21-23]. The excitation of the affected hemisphere may normalize the poststroke bihemispheric imbalance [24]. Functional improvement can result from either structural regeneration in the impaired hemisphere which possibly gives rise to restoration of the original function [25] or plastic rearrangements of intact fibers to facilitate compensatory strategies. The latter process is presumably associated with the development of compensatory and new movement that differs from original performance [26].
The results of this study showed a statistically significant decrease of the JTT test score in the study group (II) that received NMES in addition to the selected physical therapy program. These results come in agreement with Chipchase et al., [27] who concluded that Peripheral electrical stimulation is commonly used as an intervention to facilitate movement in a variety of conditions as it induces rapid plastic change in the motor cortex.

This improvement could be explained by Ridding et al., [28] findings. The authors found that there was a modification in the human motor cortex organization by changes in an afferent input as increases in motor cortical excitability are seen following electrical stimulation of peripheral nerves. Peripheral nerve stimulation, which activates group Ia large muscle afferents, group Ib afferents from Golgi organs, group II afferents from slow and rapidly adapting skin afferents and cutaneous afferent fibers, elicits an increase in motor cortical excitability of body part representations that control the stimulated body part and results in reorganization of the motor and somatosensory cortices.

The results of the current study are supported by Geraldine et al., [29] who compared the effect of NMES of the forearm and elbow extensor muscles with passive stretching exercises on hand functions following stroke. Stimulation was applied to the elbow and forearm extensor muscle groups of the hemiplegic arm for 12 weeks. Patients in the control group were taught passive stretching exercises for the same period. The outcome measure was the action research arm test. The results demonstrated that there were improvement in pinch, grasp, sensation and gross movement scores.

Zahner et al., [30] studied the efficacy of NMES for reducing severe hand impairments. Patients with chronic stroke received ten sessions of NMES. In one intervention, NMES (active) was applied as a novel fashion using multiple stimulators on the forearm flexors and extensors to assist patients with grasping and releasing a tennis ball. In the other intervention, the NMES (passive) was applied on wrist extension and flexion without grasp and release of an object. Upper extremity Fugl-Meyer (FM) scores were significantly improved. It was revealed that NMES may assist during task practice and appeared more beneficial than activating the wrist flexors and extensors in a passive mode.

The results of the current study contradicted with Chae et al., [31] who stimulated the wrist-finger extensors for only three weeks, whereas Powell et al., [32] stimulated the same muscle groups for eight weeks. Chae and colleagues results reflected significant recovery of motor control but not actual functional use of the upper extremity. Powell et al., [32] showed significant effects of NMES program on hand function. However, these benefits were no longer evident at the 24-week follow-up. The contradiction between results may be attributed to different methodology and training methods used.

**Conclusion:**

The present study showed that central stimulation in the form of transcranial direct current stimulation (tDCS) and peripheral stimulation in the form of neuromuscular electrical stimulation (NMES) resulting in greater improvement of hand function in chronic stroke patients while central stimulation is more effective than the peripheral one so the electrical stimulation is shown to be effective in reducing hand impairment in chronic stroke patients.

**References**


