Effect of Transcranial Direct Current Stimulation on Pinch Strength in Stroke Patients

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Abstract

Background and Purpose: Stroke is the main cause of long-term disability among adults, results in a well-documented impairment of activities of daily living (ADL). Noninvasive brain stimulation modulates motor cortical function and can enhance cortical plasticity. The goal of this study was to determine the effect of transcranial direct current stimulation on pinch strength in stroke patients.

Patients and Methods: Thirty chronic stroke patients from both sexes with age ranged between 45-60 years participated in this study. Patients were divided randomly into two equal groups (Group I and Group II), the study group (Group I) received anodal transcranial direct current stimulation applied on ipsilesional hemisphere in addition to the selected physical therapy program. The control group (Group II) received the selected physical therapy program only.

Results: The study group showed a statistically significant increase in pinch strength post treatment compared to the control group.

Conclusion: Anodal Transcranial direct current stimulation can be suggested as an effective method in improvement of pinch strength in patients with stroke.

Key Words: Stroke – Pinch strength – Transcranial direct current stimulation.

Introduction

STROKE is the clinical term for acute loss of perfusion to vascular territory of the brain, resulting in ischemia and a corresponding loss of neurologic function. It typically manifests with sudden onset of focal neurologic deficits, such as weakness, sensory deficit, or difficulties with language [1].

Hand motor impairment after stroke may result from spasticity and abnormal coactivation of muscle groups during isolated movements (muscle synergies). Impairment may result from a deficit in higher-order processes, such as motor planning and motor learning, which lead to poorly formed sensorimotor associations or internal representations that lead to impaired motor control [2].

Pinch strength is a prerequisite for fine motor manipulation activities of daily living, especially in a patient who had a deficit in the dominant hand. Therefore, any strategy to increase the pinch strength in stroke patients may facilitate the use of the paretic hand [3].

Several non-invasive strategies aimed at modifying corticotor excitability have emerged. These include transcranial magnetic stimulation (TMS), repetitive transcranial magnetic stimulation (rTMS) [4] and transcranial direct current stimulation (TDCS) [5]. Transcranial direct current stimulation has a number of advantages: First of all, it is a painless corticotor modulatory technique with no or minimal side effects and it can be applied by an inexpensive battery-operated device [6,7].

The TDCS modifies the transmembrane neuro- nal 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 corticotor excitability [8]. 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 [5,9]. The literatures indicate that any improvement in corticomotor excitability coincides with functional improvement [10-12]. In this regard, purposeful modulation of corticomotor excitability with a-TDCS can be used as
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a therapeutic technique for promotion of functional performance [12]. This study was designed to investigate the effect of anodal transcranial direct current stimulation on pinch strength in stroke patients.

**Patients and Methods**

This study was conducted on thirty stroke patients from both sexes (17 males, 13 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 two equal groups. The study group (Group I) received anodal TDCS applied on ipsilesional hemisphere in addition to a selected physical therapy program and the control group (Group II) received the same 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 and fingers flexors, adductors) was ranged from 1: 1+ according to Modified Ashworth Scale, 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, 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:**

- The electrical stimulation device used for transcranial direct current 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.

**A- Evaluation protocol:**

For measurement of pinch strength: Patients were seated in an armchair with both arms relaxed. A maximal pinch force was measured by pinching the gauge between the thumb and the index finger of the paretic hand and the patients were instructed to squeeze the gauge as hard as they could for 1-3 seconds without receiving any feedback about their performance. The measurements were performed pre and post treatment.

**B- Treatment protocol:**

Patients in the study group (GI) received anodal TDCS applied on ipsilesional hemisphere in addition to a selected physical therapy program while patients in the control group (GII) received the same physical therapy program only.

**Application of TDCS:**

TDCS was applied via saline-soaked surface sponge electrodes (5cmx7cm) connected to a constant current stimulator. The intensity used was one mA. The anodal electrode was placed over the presumed hand area of the lesionel 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 et al., [13] protocol.

**The selected physical therapy program:** It includes task specific training in addition to (Postural control and balance training, upper extremity control, Proprioceptive Neuromuscular Facilitation (PNF), weight bearing and weight shifting, facilitation for weak muscles in upper extremity).

**The task specific training includes the following exercises:** Grasp and release objects like a bottle, Extend fingers while resist pen and performance of fine motor tasks likes 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 extended for 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, Pinch strength. Paired t-test was used to assess changes within groups and unpaired t-test used to assess the changes between the two groups. 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”) [14].

Results

Demographic and clinical characteristics of the patients in both groups:

By comparing the general characteristics of the patients in both groups, the results showed that there was no significant difference between both groups regarding mean age, weight, height, BMI and duration of illness (\( p = 0.485, p = 0.817, p = 0.905, p = 0.787 \) and \( p = 0.539 \) respectively) (Table 1). In GI, nine patients had right sided hemiparesis and six patients had left sided hemiparesis while in GII, eight patients had right sided hemiparesis and seven patients had left sided hemiparesis.

Comparison of pinch strength pre and post treatment within each group (Table 2, Fig. 1):

The mean pinch strength pre treatment for group I was 14.06±2.84 while post treatment was 16.46±2.69. There was a highly significant increase in the post treatment mean value of pinch strength compared with the pre treatment value with \( p = 0.0001 \). The mean difference was 2.4 and the percent of improvement was 17.06%.

The mean pinch strength pre treatment for group II was 13.8±2 while post treatment was 14.06±2.05. There was no significant difference between pre and post treatment (\( p = 0.16 \)). The mean difference was 0.26 and the percent of improvement was 1.88%.

Comparison of pinch strength pre and post treatment between both groups:

The mean pinch strength pre treatment for group I and II were 14.07±2.84, and 13.80±2.007 respectively. There was no significant difference between both groups in pinch strength pre treatment (\( p = 0.77 \)). The mean values of pinch strength post treatment for group I and II were 16.47±2.69 and 14.07±2.052 respectively. There was a significant difference between both groups in pinch strength post treatment with \( p = 0.01 \) (Table 3, Fig. 2).

Table (1): General characteristics of patients in both groups (GI and GII).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>GI (Mean±SD)</th>
<th>GII (Mean±SD)</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>53.53±4.99</td>
<td>52.33±4.27</td>
<td>0.71</td>
<td>0.48</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>80.06±10.39</td>
<td>79.13±11.51</td>
<td>0.23</td>
<td>0.82</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165.8±4.31</td>
<td>166±4.78</td>
<td>0.12</td>
<td>0.90</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>29.14±3.87</td>
<td>28.74±4.16</td>
<td>0.27</td>
<td>0.79</td>
</tr>
<tr>
<td>Duration of illness</td>
<td>12.46±3.68</td>
<td>13.33±3.95</td>
<td>0.62</td>
<td>0.54</td>
</tr>
</tbody>
</table>

SD: Standard deviation. P: Probability. Significant at \( p \leq 0.05 \).

Table (2): Comparison between pre and post treatment mean values of pinch strength within each group (I &II).

<table>
<thead>
<tr>
<th>Pinch strength</th>
<th>Pre-treatment (Mean±SD)</th>
<th>Post-treatment (Mean±SD)</th>
<th>Mean difference</th>
<th>Percentage of improvement</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>14.06±2.84</td>
<td>16.46±2.69</td>
<td>2.4</td>
<td>17.06</td>
<td>8.29</td>
<td>0.0001 **</td>
</tr>
<tr>
<td>Group II</td>
<td>13.8±2</td>
<td>14.06±2.05</td>
<td>0.26</td>
<td>1.88</td>
<td>1.46</td>
<td>0.16</td>
</tr>
</tbody>
</table>

SD: Standard deviation. P: Probability. **Highly significant at \( p \leq 0.01 \).

Table (3): Comparison between pre and post treatment mean values of pinch strength between both groups (I & II).

<table>
<thead>
<tr>
<th>Pinch strength</th>
<th>GI (Mean±SD)</th>
<th>GII (Mean±SD)</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>14.07±2.840</td>
<td>13.80±2.007</td>
<td>0.2970</td>
<td>0.77</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>16.47±2.696</td>
<td>14.07±2.052</td>
<td>2.744</td>
<td>0.01 *</td>
</tr>
</tbody>
</table>

SD: Standard deviation. P: Probability. Significance at \( p \leq 0.05 \).
In the present study, there was a statistically significant increase in the mean values of pinch strength of the affected hand post treatment in the study group (group I) while the control group (group II) showed no significant improvement. These results come in agreement with Hummel et al., [15] who tested the effects of tDCS on pinch force (PF) and simple reaction time (RT) tasks in patients with chronic stroke. The results of this study showed that anodal tDCS shortened reaction times and improved pinch force in the paretic hand relative to sham stimulation.

These results are supported by Hummel and Cohen [16], who studied the effects of non invasive brain stimulation, transcranial direct current stimulation (tDCS) on three measures of motor performance (Jebsen-Taylor Hand Function Test, pinch force task, and simple reaction time task performed with the paretic hand) and on motor cortical function tested with transcranial magnetic stimulation (TMS) in patients with chronic subcortical stroke.

The results of this study showed that tDCS led to improvements in pinch force, Jebsen-Taylor Hand Function Test scores, and simple reaction times in the paretic hand that outlasted the stimulation period for at least 40min. These changes were accompanied by increased corticomotor excitability identified by enhanced recruitment curves and reduced intracortical inhibition to transcranial magnetic stimulation. These results document a beneficial effect of noninvasive brain stimulation on motor function in a human patient with stroke and raise the hypothesis of its potential application in neurorehabilitation.

Tanaka et al., [17] performed a study to investigate whether tDCS could also improve leg motor function. In this study ten healthy subjects performed pinch force (PF) and reaction time (RT) tasks using the left leg before, during and after anodal, cathodal or sham tDCS over the leg motor cortex. The results revealed that anodal tDCS transiently enhanced the maximal leg PF but not RT during its application. However, neither cathodal nor sham stimulation changed the performance.

The explanation of such improvement in pinch force after application of tDCS over the primary motor area (M 1) of the hand may be due to increase the spontaneous firing rate and the excitability of cortical neurons by depolarizing the membranes [18,19]. Another possibility is that tDCS increase intermuscular coupling. Anodal tDCS over the hand motor cortex has been reported to increase beta-band intermuscular coherence in the first dorsal interosseous and extensor digitorum communis muscles [20].

The results of the current study contradicted with Au-Yeung et al., [21] who performed a study to determine whether transcranial direct current stimulation (tDCS) applied to the primary motor hand area modulates hand dexterity and selective attention after stroke. Ten stroke survivors with some pinch strength in the paretic hand received three different tDCS interventions assigned in random order in separate sessions-anodal tDCS targeting the primary motor area of the lesioned hemisphere (M1 lesioned), cathodal tDCS applied to the contralateral hemisphere (M1 nonlesioned), and sham tDCS-each for 20mins. The primary outcome measures were Purdue pegboard test scores for hand dexterity and response time in the color-word Stroop test for selective attention. Pinch strength of the paretic hand was the secondary outcome. The results showed that application of cathodal tDCS to M1 nonlesioned significantly improved affected hand dexterity and selective...
attention, but not pinch strength. The outcomes were not improved with anodal tDCS to M1 lesioned or sham tDCS. The contradiction between results may be attributed to different methodology and training methods used.

Recovery of motor function after stroke starts first with improvements in performance of repetitive, relatively simple motor activities like force production, evolving later to relearning of more complex motor synergies and skillful tasks. It is a common finding that while most chronic stroke patients are able to generate various levels of force, only a fraction of them are able to perform skilled motor tasks like those involved in activities of daily living tested with the Jebsen-Taylor test. Since the ability to control properly force production and visuomotor integration represents a prerequisite to meaningful skilled complex motor activity, it can be speculated that a first rehabilitative step to promote functional recovery after stroke might focus on reacquisition of these motor primaries. Subsequent training could then utilize these basic skills to train more complex actions, such as proposed in sports and musical practice programs. In this way, motor training of these primaries could be utilized to orchestrate more complex skillful motor tasks [22,23].

Conclusion:
Non invasive brain stimulation in the form of transcranial direct current stimulation (tDCS) resulting in greater improvement in pinch strength in chronic stroke patients. Because the technique of tDCS is simple, safe and non-expensive; the findings of this study support further research on the use of this technique for the rehabilitation of patients with stroke.

References


