Effect of Tongue Stimulation on Upper Extremity Recovery in Stroke Patients – A Randomized Controlled Trial

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Abstract Recovery of upper extremity after stroke is always challenging because of various factors. The purpose of this study was to find out the effect of tongue stimulation on upper extremity recovery in stroke patients. Fifty-four stroke patients with informed consent were screened and included in the study after they met the inclusion and exclusion criteria. They were randomly divided into experimental (N=26) and control group (N=28) using computerized randomization method followed by comprehensive assessment. Randomization was done by independent assessor. All patients were administered one hour of stroke rehabilitation program in both groups. In experimental group, periglossal electrical stimulation was done for 15 minutes along with upper limb retraining. Patients' functional scores were assessed in both groups at the time of enrolment into the study, which includes modified Rankin Scale and Barthel index, whereas the motor functions were assessed using Fugl-Meyer Assessment Scale. They were reassessed after 4 weeks and 8 weeks of the study. Data analysis was done using SAS software. Test of normality was done to find out the normality of the data. Within group analysis was done using paired t test or Wilcoxin Signed Rank test and between group analysis was done using independent t test or Mann-Whitney U test depending on the normality of the data. Twenty-five stroke patients in control group and twenty-three stroke patients in experimental group completed the study. There was significant improvement in

modified Rankin Scale, Barthel index and Fugl-Meyer Scale in both the groups ($P<0.05$). Between group analysis revealed that there is significant improvement in modified Rankin Scale, Barthel index, Fugl-Meyer upper extremity and lower extremity scale in experimental group compared to control group ($P<0.05$). Tongue stimulation was found to be effective in improving the upper limb functions in stroke patients. This is also cost effective and easy to administer for the benefit of the patients.

Keywords Tongue Stimulation, Upper Extremity Motor Functions, Neuroplasticity, Stroke

1. Introduction

Stroke is the second leading cause of morbidity and mortality in the world [1]. Incidence as well as prevalence of stroke has increased in low income and middle-income countries due to rapidly changing lifestyle [1]. Stroke rehabilitation is aimed at reducing the disability and returning the patient to functional status. It involves a team effort by neurologists, physical therapists, occupational therapist, speech therapist, vocational counsellor, psychologist as well as the patient's family members [2, 3].

Initial step in rehabilitation is assessment of recovery. Various assessment scales are used to assess the recovery of stroke patients [4]. An ideal assessment scale should be

simple, reliable, valid, sensitive to changes, should assess all aspects of stroke and can be easily used by the rehabilitation team [4]. One such assessment scale is Fugl-Meyer Assessment Scale for upper extremity and lower extremity, which is a more valid and widely used assessment scale in stroke rehabilitation [3, 4, 5]. Even modified Rankin Scale [6, 7] and Barthel functional index [8] are also more valid and reliable scales for evaluating recovery in stroke patients.

Various techniques have been used in the rehabilitation of upper extremity in stroke patients, which include but are not limited to bilateral arm training, biofeedback, brain stimulation using transcranial direct current stimulation, transcranial magnetic stimulation, constraint induced movement therapy, electrical stimulation, hands on therapy, mental practice, mirror therapy, music therapy, repetitive task training, robotics, sensory interventions, strength training, stretching and positioning, task specific training and virtual reality training [9].

Gentilucci et al (2008) stated that speech is accompanied by hand movements and from babbling stage onwards, manual action plays an important role in development of speech. Many studies have proved that Broca's area controls both speech and hand gestures [10]. The movements of tongue for producing vowel sounds and the movements of the hand share the action planning processes [11]. Similarly, movements of the tongue for producing consonants and precision and power grip share the action planning processes [11, 12].

Noninvasive electrical stimulation of tongue in addition to balance and mental activity training induces neuroplasticity and improves balance in patients with multiple sclerosis [13]. Tongue stimulation has been used to improve voice quality [14], improve swallowing [15] and improve balance in wide category of patients [16].

Tongue stimulation has been used in rehabilitation of stroke patients for improving balance and motor functions. [17, 18]. Tongue stimulation along with brain computer interface training has been used to improve upper extremity functions in stroke [17, 18, 19, 20, 21, 22, 23]. However, there is hardly any study done to find out the effect of tongue stimulation along with conventional rehabilitation techniques in improving upper limb functions in stroke patients. Thus, the main objective of this study is to find out the effect of periglossal electrical stimulation on upper limb motor functions in patients with cerebrovascular disease.

2. Methodology

2.1. Subjects

This was a randomized controlled trial with pre-post experimental design. This was approved by Institutional Ethics Committee of Narayana Superspecialty Hospital, Gurugram, Haryana and Amity University, Uttar Pradesh,

Noida (AUUP/IEC/2018-AUG/06) and registered in clinical trial registry of India (CTRI/2020/03/024353). Stroke patients admitted in Narayana Superspecialty Hospital and / or followed up in outpatient rehabilitation department were screened and explained about the purpose, benefits and methodology of the study. Written informed consent was obtained from patients and for patients whose dominant hand was involved, thumb impression was taken as well as consent taken from spouse or one of the parents. Patients who have suffered first time cerebrovascular accident, both genders, in the age group of 30 to 60 and also in Brunnstrom stage ≥ 2 were included in the study. Patients were in subacute stage when they were recruited in the study. Patients who were having unstable hemodynamics, uncontrolled arrhythmias, recent myocardial infarction, any musculoskeletal deformity of upper limb before stroke, sensory impairments of tongue, history of seizure and recurrent strokes, and patients who are uncooperative and unable to follow commands were excluded from the study. Recruited patients were randomly divided into experimental group and control group using computerized randomization method (Figure 1).

2.2. Intervention

All patients were comprehensively assessed as per institutional protocol and were evaluated using modified Rankin Scale, Barthel functional Index, Fugl-Meyer Assessment Scale for upper extremity and lower extremity. Patients in both the groups underwent one hour of rehabilitation which includes passive stretching, active assisted exercises and functional training using neurodevelopmental approach. It comprises of 10 minutes of bed mobility exercises, 10 minutes of upper limb cycling, 10 minutes of lower limb cycling using Thera-trainer, 15 minutes of upper limb retraining and 15 minutes of balance and gait training. Patients in experimental group were given tongue stimulation along with upper limb training using pen electrode. Assessment and therapeutic procedures were carried out by the principal investigator. Parameters of tongue stimulation include the frequency of 20 Hz, pulse width of 200 microseconds, intensity as minimal threshold experienced by the patient, 3 mA, intermittent stimulation with rest phase; stimulation phase of 10:10. Stimulation was given on periglossal region on three sides - right, left and centre for 15 minutes with one-minute break after every 5 minutes. Electrodes were sterilized with antiseptic solution before and after treating the patient. All patients' tongue were examined after the procedure for any redness, although it is unlikely because of the low intensity of stimulation. All patients and attendants were educated about the home exercise program.

Patients were re-assessed at the end of 4 weeks and 8 weeks of study with respect to modified Rankin Scale, Barthel functional index and Fugl-Meyer Assessment Scale.

Trial Registration Number: The Trial was registered under Clinical Trial Registration of India CTRI/2020/03/024353.

2.3. Outcome Measures

2.3.1. Primary Outcome Measure

Fugl-Meyer Assessment Scale (FMA): The Fugl-Meyer Assessment Scale is a more reliable and valid functional assessment scale for stroke patients. It has very high interrater and intra-rater reliability score ($r=0.98$) and has a very good criterion and construct validity. Fugl-Meyer scale has got excellent correlation with Barthel index and functional independence measure [5].

Scoring depends on the ability to perform an activity using a 3-point ordinal scale where 2 indicates activity is performed fully, 1 indicates activity is performed partially and 0 is scored when the patient cannot perform an activity. The total score is 226, out of which motor component score alone is 100 (Upper limb – 66, Lower Limb – 34) [14]. FMA motor scores have excellent floor effect and adequate ceiling effect. The minimal clinically important difference of the FMA scores was 12.4 (upper extremity), 5.6 (upper arm), and 4.9 (wrist/hand) [19, 20, 21, 22, 23, 24, 25].

2.3.2. Secondary Outcome Measures

Modified Rankin Scale: Modified Rankin Scale is a commonly used scale to assess the degree of disability in stroke patients or other neurological patients. It has very strong construct validity and good test-retest reliability [6, 7]. It is a 7-point ordinal scale where 0 indicates no signs and symptoms of disease, 1 indicates mild signs and symptoms of disease, 2 indicates mild disability, 3 indicates moderate disability, 4 indicates moderately severe disability, 5 indicates severe disability and 6 indicates that the patient is dead. Thus, 0 – 3 indicates mild to moderate disability and 4-5 indicates severe disability [26, 27].

Barthel Functional Index: Barthel index is used to assess functional independence of the stroke patients with respect to activities of daily living. It has very good concurrent and construct validity with respect to activities of daily living. Also, Barthel index has very good test-retest reliability. It is a 10-item scale which includes feeding, bathing, grooming, dressing, bladder and bowel control, toilet dependence, transfer dependence, mobility and ability to negotiate stairs. Scoring ranges between 0 to 100 [8, 18, 19, 28].

Figure 1. CONSORT Flow Diagram showing recruitment of subjects

2.4. Data Analysis

Data analysis was done using SAS software version 24. Test of normality was done to find out the normality of the data. If the data followed normal distribution, Independent 't' test was used to analyse the changes in dependent variables between the groups and paired 't' test was used to analyse the data within the group. If the data do not follow normal distribution, then Mann-Whitney U test was used to analyse the data between the group and Wilcoxin Signed Rank test was used to analyse the data within the group. Demographic data was presented by means of descriptive statistics. The level of significance was set at $P < 0.05$.

3. Results

A total of 54 stroke patients were enrolled for the study. Among them 48 patients completed the study, out of which, 23 patients were in experimental group and 25 patients were in control group. Demographics characteristics of the stroke patients and baseline characteristics of the patients were shown in Table 1 and Table 2. Within group analysis revealed significant changes in modified Rankin Scale, Barthel index, Fugl-Meyer upper extremity motor function and Fugl-Meyer lower extremity motor functions (Graph 1, Graph 2, Graph 3 and Graph 4). Between group analysis

also revealed that there are significant changes in modified Rankin Scale, Barthel index, Fugl Meyer Assessment Scale for upper extremity motor function and lower extremity motor function in experimental group compared to control group (Graph 1, Graph 2, Graph 3 and Graph 4).

Table 1. Demographic Characteristics of Stroke Patients (N=48)

Characteristics	Control Group (N=25)	Experimental Group (N=23)
Age (M $\pm$ SD)	53 $\pm$ 7	55 $\pm$ 10
Sex		
Male: Female	15:10	14:9

Table 2. Baseline Characteristics of the Stroke Patients

	Control Group (N=25)	Experimental Group (N=23)
Brunnstorm upper limb recovery stage	≥ 2	≥ 2
Modified Rankin Scale (Mean $\pm$ SD)	4.64 $\pm$ 0.49	4.22 $\pm$ 0.42
Barthel Functional Index (Mean $\pm$ SD)	9.60 $\pm$ 7.62	26.96 $\pm$ 18.99
Fugl-Meyer Assessment – Upper Extremity (Motor) (Mean $\pm$ SD)	5.28 $\pm$ 2.99	8.17 $\pm$ 5.63
Fugl-Meyer Assessment – Lower Extremity (Motor) (Mean $\pm$ SD)	6.04 $\pm$ 3.37	7.83 $\pm$ 4.86

* There is no significant difference between the groups at baseline

Graph 1. Disability status of the patients in both groups (Modified Rankin Scale Score)

* There is no significant difference between the groups at baseline

Non – parametric test was used since the data does not follow normal distribution

Graph 2. Functional Independence of the Patients in both groups (Barthel Functional Index Score)

* There is no significant difference between the groups at baseline

Non – parametric test was used since the data does not follow normal distribution

Graph 3. Upper Extremity Motor Functions of the patients in both groups (Fugl Meyer Assessment Scale - Upper Extremity)

* There is no significant difference between the groups at baseline

Graph 4. Lower Extremity Motor Functions of the patients in both groups (Fugl Meyer Assessment Scale – Lower Extremity)

4. Discussion

In this study, 48 stroke patients (25 - Control group, 23 - Experimental group) underwent 8 weeks of rehabilitation and their outcomes in terms of disability status, functional independence and motor functions of upper extremity and lower extremity were assessed after 4 weeks and 8 weeks of intervention.

The results of the study showed that there is significant improvement in disability status, functional independence, motor functions of the upper extremity and lower extremity in both groups over the period of 8 weeks ($P < 0.05$). Between group analysis also showed that there is significant improvement in above parameters in experimental group compared to control group ($P < 0.05$). There was clinically significant improvement in both groups.

4.1. Disability of the Stroke Patients

There is significant improvement in the disability status of the patients with respect to modified Rankin scale in both groups ($P < 0.05$). The recovery in stroke patients during the early period may be attributed to resolution of oedema and restoration of blood supply to ischemia penumbra [3]. Improvement during the subacute stage could be due to dendritic sprouting, synaptogenesis, restoration of axonal transport, unmasking of the alternate pathways facilitated by structured rehabilitation program [3]. The result of our study supports the findings of Lai (2001) [27] and Rangaraju (2017) [26] on the quality of life of stroke patients.

4.2. Functional Independence of the Patients

Functional independence of the patients was improved

significantly in both groups ($P < 0.05$). Improvement may be attributed to redevelopment of cortical inhibition, resolution of diaschisis, alteration in neurotransmitters and bilaterality of brain functions facilitated by functional training. The result of the study supports the study of Musa on functional independence [28]. The improvement in our experimental group is too supported by study findings of Lee [18] on functional independence using Barthel Index. In contrast to the study of Remsik, we found significant improvement on functional independence as it is showed in Barthel index [19].

4.3. Upper Extremity Motor Functions of the Stroke Patients

Upper extremity motor functions showed significant improvement in both groups over the period of 8 weeks. Between group analysis revealed significant improvement in experimental group compared to control group ($P < 0.05$). This may be due to tongue stimulation causing reorganization of the areas of the brain representing the tongue and hand, as tongue being represented bilaterally in brain and tongue stimulation might also cause increase in interhemispheric functional connectivity between homologous regions of the primary sensorimotor cortex, which is also one of the reasons for improvement in upper limb functions after stroke [19, 20, 21, 22, 23, 24]. Periglossal electrical stimulation along with upper limb retraining influences the areas in the brain responsible for motor control of the tongue and the upper limbs to reorganize and remap intra-cortical pathways, establishing a new sensorimotor pathway for the paralyzed upper limb [29]. This is in accordance with the study done by Young (2014), where increase in interhemispheric functional connectivity has been shown to correlate with improvement in Fugl-Meyer Score (motor recovery) in

stroke patients [20]. Minimum clinically important difference of Fugl Meyer Scale in subacute stroke patients is around 9 for upper extremity motor recovery [30].

4.4. Lower Extremity Motor Functions of the Stroke Patients

With respect to lower extremity motor functions of the stroke patients, there was significant improvement in motor functions in experimental group compared to control group ($P < 0.05$). Our study supports the findings of Cacho (2006) on the effects of rehabilitation on motor functions of lower extremity [31].

4.5. Tongue Stimulation in Stroke Rehabilitation

The improvement in motor functions in the experimental group could also be explained with respect to Hebbian theory of neuroplasticity. Based on Hebbian theory, the cells that fire together will wire together. Hebb also suggested that when one cell repeatedly assists in the firing of another cell, the axons of the first cell form synaptic knobs with the soma of the second cell. In case of damage to area controlling the movements, mirror neurons are activated. When a person does a particular action, he will see, hear and feel the performing of the action. These re-afferent sensory neurons will trigger activity in neurons responding to sight, sound and feel of the action [32]. Hebbian learning predicts that the synapses connecting neurons responding to the sound, sight, and feel of a movement and those of the neurons triggering the movement should be activated [33].

Reinforcement of motor behaviour is one of the key mechanisms responsible for training and use of therapy involving tongue stimulation. As the patients were given tongue stimulation and simultaneously made to do assisted or passive movements of the hand and upper limbs, there is visual, auditory cue given to the patients. Another probable mechanism is the simple Pavlovian mechanism, where learning a new behaviour in association with another stimulus and reinforcement leads to the development of new associations and pathways.

5. Conclusion

Tongue stimulation along with upper limb retraining has proved to be more beneficial in improving upper limb functions in stroke patients. This is one of the cost effective and easy to administer therapeutic procedures, which can be used for stroke rehabilitation.

6. Limitations and Recommendations

The study is limited to small sample size. Many parameters which could have influenced the outcome of

the studies are not controlled which includes but not limited to size of the infarct, area of the infarct and comorbidities. Further studies can be done on a larger sample size to find out the effect of tongue stimulation on upper limb functions in various types of stroke patients.

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