Original Research Paper

Physiology

Neuromuscular electrical stimulation for early recovery of motor control of ankle along with spasticity in stroke patients: A prospective randomized controlled study

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ABSTRACT

Background and objectives: Effect of neuromuscular electrical stimulation in acute stroke patients while stimulating only single muscle is not known. The purpose of the study is to find the influence of early neuromuscular electrical stimulation to the motor point of tibialis anterior muscle of the affected limb in achieving early motor control of the ankle with reduction in spasticity in post stroke patients.

Methods: One hundred and thirty-two subjects were selected between 45-65 years of age and within 2 weeks of the first attack of stroke. They were randomly divided into study and control groups comprising 66 subjects in each group. Study group received neuromuscular electrical stimulation to tibialis anterior muscle of the affected limb, 15 minutes twice daily, 5 days a week up to 3 weeks along with conventional exercise therapy whereas control group received only exercise therapy for that period. Outcome measures include Modified Ashworth Scale for spasticity of ankle plantarflexors, motor power of ankle dorsiflexors and plantarflexors, motor control of ankle joint. They were recorded before starting treatment, after 3 weeks and at 7 weeks following starting the treatment.

Results: Significant improvement of spasticity was noticed after 7 weeks follow up ($p<0.01$). Significant improvement also noticed in ankle dorsiflexor motor power ($p<0.001$), ankle motor control ($p<0.01$).

Conclusions: Neuromuscular electrical stimulation along with traditional exercise programme is superior to exercise alone for early recovery of ankle motor control, plantarflexor spasticity and ankle dorsiflexor motor strength.

KEYWORDS : Stroke, spasticity, motor control, neuromuscular electrical stimulation, tibialis anterior.

INTRODUCTION

Stroke is one of the most debilitating non-communicable diseases. World Health Organisation (WHO) defines stroke as "rapidly developed clinical signs of focal disturbance of cerebral function; lasting more than 24 hours or leading to death, with no apparent cause other than vascular origin".[1] The outcomes of stroke include coma, hemiplegia, hemianesthesia, hemianopia, dysphagia, aphasia, neglect syndrome, visuo-spatial deficit, monoplegia, nerve paresis, cognitive dysfunction, memory loss, bladder and bowel dysfunction etc. Of this hemiplegia contributes about 90% of patients.[1] Eighty percent of post stroke patients have some locomotor function but many have significant gait deficit.[4] Early stage training is more effective for motor recovery and functional recovery is inefficient if interventions start after 5 months of post stroke.[2,3]

Neuromuscular electrical stimulation is one of the frequently tested modalities in motor recovery of stroke patients. Lieberson and associates described the first single-channel surface peroneal nerve stimulator to provide ankle dorsiflexion during the swing phase of gait for stroke survivors. In the upper limb, its usefulness is well documented. However, we have come across only a few studies where functional electrical stimulation was used to influence early motor recovery of the lower limb.[4,5,6,7] Some studies reported that it has no advantage over conventional therapy.[8,9] Therefore, the role of neuromuscular electrical stimulation for early motor recovery and ambulation in post stroke patient is still a controversy.

After stroke extensor synergy dominates in the lower limb. This results in plantarflexion attitude of ankle, which in turn leads to compensatory circumduction gait, disturbance in balance during standing and walking. Therefore, improvement of ankle dorsiflexor motor control can influence this condition by reducing plantarflexor spasticity, increasing dorsiflexor strength and reducing plantarflexor attitude in both stance and swing phase of gait.[10]

Neuromuscular electrical stimulation can improve neuroplasticity by the following mechanism;

1. Increase of synaptic efficacy in existing neural circuits or form ation of new synapses. This can be explained by as follows;

   a. Electrical stimulation to muscles causes contraction of that particular muscle and leads to movement of joins and the limb. This sends proprioceptive inputs to brain and reinforce network connection patterns through formation of new synapses which ultimately induces cortical reorganization (studied in monkey).
   b. Electrical stimulation to skin expands cortical representation.[4]

2. Another mechanism that helps in early motor recovery is reduction of spasticity. The possible mechanisms are;

   a. Presynaptic inhibition of hyperactive stretch reflexes in spastic muscle

b. Direct inhibition of an abnormally excited nerve
c. Disinhibition of descending voluntary command to the motor neurons of the paretic muscles ultimately results in decrease in co-contraction of spastic antagonist.[6]

Most of the studies for lower limbs were on chronic stroke patients, some stimulated acupuncture points and most of the studies used Functional electrical stimulation (FES) not neuromuscular single muscle stimulation. Therefore the question arises, can an isolated neuromuscular electrical stimulation of the tibialis anterior muscle influences early recovery motor control of ankle in post stroke patients in terms of decrease in ankle plantarflexor spasticity and increased in dorsiflexors strength with a decreased in antagonistic co-contraction[4,6]

This study was contemplated to find the role of neuromuscular electrical stimulation of the lower limb muscles in early motor recovery in post stroke patients. In many rehabilitation centres, only exercises are advised to stroke patients till now. Electrical stimulation is a simple, affordable and easily available therapeutic modality for stroke recovery with minimum or no adverse effects. Use of neuromuscular electrical stimulation along with exercise therapy can speed up motor recovery in stroke patients. Thus, it improves quality of life of the patients, reduces burden of impairment and disability, and increases productivity.

MATERIALS AND METHODS

Study design, place of study and study period:

The study was a prospective, randomized controlled study, conducted in the Department of Physical Medicine and Rehabilitation, Regional Institute of Medical Sciences, Imphal, for the period of two years (October, 2012-September 2015). Ethical committee approval and informed consent from the patients were taken prior to the study. Post stroke patients within 2 weeks of the first acute stroke attack admitted in the Physical Medicine and Rehabilitation Ward for rehabilitation management were taken for the study (Schematic Diagram 1).

Sample Size:

A sample size of 59 in each group was calculated based on effect size of 20% with 10% early recovery in conventional exercise group at 5% significance level and 80% power. Adding 10% drop out; a final sample of 66 in each group had been considered.

Inclusion criteria:

Patients with cases of stroke confirmed by Computerized Tomography, independent in daily activities before stroke, having at least some visible voluntary movement in hip, knee and ankle (Medical Research Council Grade-1 and 2), age between 45 and 65years.

Exclusion criteria:

Exclusion criteria were medically unstable patient, repeated attacks of stroke (>1 attack), patient with flaccid lower limb, unable to walk before stroke due to some other causes, any neuromuscular disease present before stroke, brain stem or cerebellar lesion, patients with cardiac pacemaker, cognitive dysfunction (using mini mental state examination), all types of aphasias. All patients were taken from the medicine ward and because of that only CT scan was taken as the investigation to homogenize all the patients.

Method of recruitment:

After getting informed consent, patients were allocated into two groups by using a block randomization technique. Only the patients were blinded in the study. To minimize uneven distribution of the known variables, stratification of the variables were done.

Study Variables:

Age, Sex, aetiology of stroke - Ischaemic vs Haemorrhagic, paretic side - Right vs Left, site of lesion in the brain.

Outcome Variables:

1. Ankle Planter-flexor spasticity (measured by Modified Ashworth Scale)
2. Muscle strength of the muscle around the ankle specially dorsiflexors (measured manually by using Medical Research Council Scale)
3. Motor control of the lower limb specially ability to dorsiflex the ankle while lying and standing independently.

In our study, ankle motor control was classified into three groups. These are as follows:

- *Poor*- No voluntary ankle dorsiflexion, passive ankle dorsiflexion is full.
- *Fair*- Voluntary ankle dorsiflexion upto 50% of normal range, passive ankle dorsiflexion is full.
- *Good*- Full range of voluntary ankle dorsiflexion.

A conventional exercise includes neurodevelopmental training, stretching of spastic or tight muscles and maintaining range of motion of joints of the affected part.

Procedure:

The study population was selected after taking informed consent. The study population was divided into study and control groups. The study group received both conventional hemiplegic exercise programme and electrical stimulation to be affected lower limb and the control received only the conventional exercise programme. To the study group, surged Faradic current was delivered to the motor point of tibialis anterior muscle twice a day, 15 minutes each time for 5 days a week up to 3 weeks in resting position. The outcome variables were measured before starting the interventions and at 3 weeks and at 7 weeks of the initiation of the intervention for both the groups. Spasticity of the ankle plantiflexors was measured by using Modified Ashworth Scale. Strength of ankle dorsiflexors was measured by using manual muscle power grading of the Medical Research Council Scale. Motor control of the lower limb was measured by ability to voluntarily dorsiflex the ankle while lying and standing.

RESULTS AND ANALYSIS

There was no difference in baseline characteristics between the study and control group **(Table 1).**

Spasticity was compared between the groups before and after therapy using paired-t-test. There was no significant ($p>0.05$) difference at baseline values (Table 1) and no significant ($p>0.05$) difference was found at 3 weeks following therapy. But significant ($p<0.01$) improvement was noticed in the study population at 7 weeks **(Table 2).**

Ankle dorsiflexor motor power was improved in both the groups but more improvement was noticed in the study group compared to control group. At baseline, there was no significant ($p>0.05$) difference in between the groups ($p>0.05$) (Table 1). But after 3 weeks and 7 weeks follow-up there was significant ($p<0.001$) improvement in ankle dorsiflexion motor power in the study group **(Figure 1).**

For ankle plantarflexor motor power at baseline there was no significant ($p>0.05$) difference found in between the groups ($p>0.05$) (Table 1). This condition was improved significantly in both the groups following treatment in compare to control but there were no significant ($p>0.05$) difference in improvement between the groups at 3 and 7 weeks. Significant ($p<0.01$) improvement of ankle motor control was noticed in both study groups separately in compare to control group. When comparison was done between the groups, significant ($p<0.01$) improvement was noticed in the study groups after 3 weeks and 7 weeks **(Figure 2).**

DISCUSSION

This randomized controlled study was performed on 132 patients

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suffering from hemiplegia due to cerebrovascular accident within 2 weeks of attack. This study showed significant improvement of plantarflexor spasticity following Neuromuscular Electrical Stimulation (NMES) of tibialis anterior muscle of the affected limb in comparison to conventional therapy group. There was also significant improvement of ankle dorsiflexor motor power and ankle motor control in the study group. NMES was well tolerated in patients and there was not any report of any type of adverse effects. Clinical NMES systems stimulate either the nerve directly or the motor point of the nerve proximal to the neuromuscular junction. The threshold for eliciting a nerve fibre action potential is 100 to 1,000 times less than the threshold for muscle fibre stimulation. The nerve fibre recruitment pattern mediated by NMES follows the principle of "reverse recruitment order" wherein the nerve stimulus threshold is inversely proportional to the diameter of the neuron. It preferentially recruits type II muscle fibres. NMES is delivered as a waveform of electrical current characterized by stimulus frequency, amplitude and pulse width. Frequency range for NMES systems is 10–50 Hz. Ideal stimulation frequencies range from 12–16 Hz for upper-limb applications and 18–25 Hz for lower-limb applicat ions.[11]

Yan T and co-workers6 conducted a randomized placebo controlled trial in acute stroke patients to find out the effectiveness of functional electrical stimulation for early motor recovery and walking ability. They stimulated hamstring, quadriceps, tibialis anterior and medial gastrocnemius for 3 weeks. They found positive result in terms of improvement in composite spasticity score, maximum isometric voluntary contraction of ankle dorsiflexors and plantarflexors and walking ability. Our study was also done on acute stroke patients but we applied neuromuscular electrical stimulation only in tibialis anterior muscle to gain early motor recovery in ankle joint. We found it quiet impressive in terms of early recovery of ankle motor control in compared to traditional exercises alone.

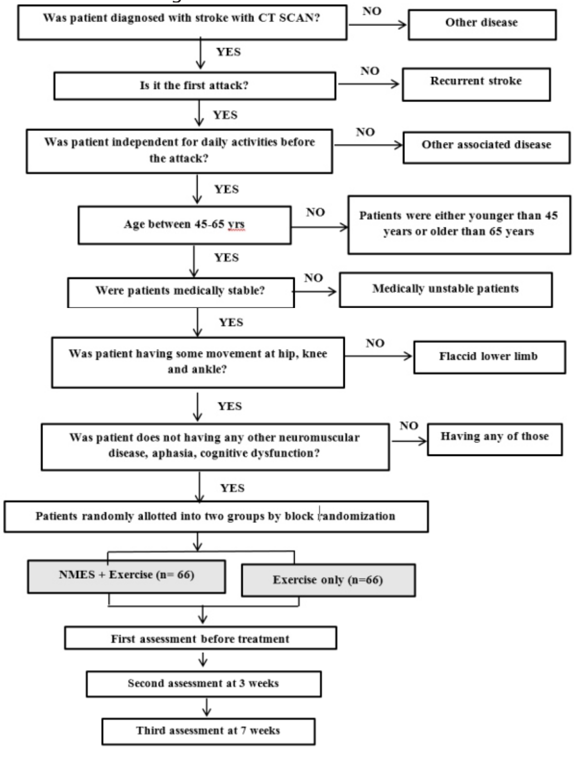
Mesci N and co-workers[12] did a similar study on chronic stroke patients and found neuromuscular electrical stimulation superior than conventional rehabilitation programme for the improvement of ankle dorsiflexor motor power and reducing plantarflexor spasticity. Our study shows similar findings in acute stroke patients.

Sabut Sk[13] concluded from their study that therapy combining FES and conventional rehabilitation programme was superior to a conventional rehabilitation program alone, in terms of reducing spasticity, improving dorsiflexor strength and lower extremity motor recovery in stroke patients. In the study they stimulated the tibialis anterior and peroneal nerve whereas, we stimulated the tibialis anterior muscle only to acute stroke patients to get early ankle motor control.

Yavuzer et al[8] did a randomized controlled, triple blinded trial with 25 post stroke patients with mean age 55 years and without volitional ankle dorsiflexion. Neuromuscular electrical stimulation was given to the study group 5 days a week for 4 weeks to tibialis anterior muscle of paretic limb. In this study, neuromuscular electrical stimulation was not found superior to conventional rehabilitation therapy. Brunnstrom stages improved significantly in both groups (p<0.05). In total, 58% of the NMES group and 61% of the control group gained voluntary ankle dorsiflexion. Between-group difference of percentage change was not significant (p<0.05). Gait kinematics was improved in both groups, but the difference between groups was not significant.

CONCLUSION

In our study, there was significant improvement in both the groups. This can be explained by case selection procedure. We selected cases with ankle dorsiflexor motor power of Grade 1 and 2 according to Medical Research Council scale within 2 weeks of stroke attack. Poor prognostic factors are usually not present in our study population resulting in good recovery. This study also shows that early rehabilitation has a great role in stroke recovery. Study limitations are small sample size, less duration of therapy, few assessment tools. Thus, future studies with bigger sample size, longer duration of therapy and with multiple standardized assessment tools to gain unbiased results are recommended.



Schematic Diagram 1: STUDY DESIGN FOR CONDUCTION OF EXPERIMENT

Table 1. COMPARISON OF BASELINE CHARACTERISTICS BETWEEN STUDY AND CONTROL GROUPS.

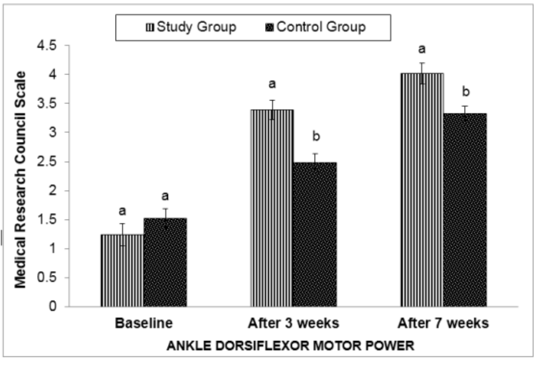
Groups Variables	Study (n= 66)		Control (n= 66)		p-value
Age (Years)	55.64±6.70		56.89±7.25		0.303
Sex	Male	42	Male	40	0.772
	Female	24	Female	26	
Type of stroke	Infarction	44	Infarction	50	0.100
	Haemorrhage	18	Haemorrhage	16	
	Both	4	Both	0	
Site of affection in brain	MCA	56	MCA	60	0.290
	Outside MCA	10	Outside MCA	6	
Baseline spasticity	Gr 0	14	Gr 0	12	0.346
	Gr 1	8	Gr 1	20	
	Gr 2	30	Gr 2	23	
	Gr 3	14	Gr 3	11	
Baseline ankle D/F motor power	Gr 1	41	Gr 1	32	0.117
	Gr 2	25	Gr 2	34	
Baseline ankle P/F motor power	Gr 1	6	Gr 1	7	0.240
	Gr 2	46	Gr 2	36	
	Gr 3	14	Gr 3	23	
Baseline ankle motor control	Poor	52	Poor	45	0.170
	Fair	14	Fair	21	

MCA: Middle cerebral artery, D/F: dorsiflexor, P/F: plantarflexor, p< 0.05: significant

Table 2: ASSESSMENT OF STATUS OF SPASTICITY

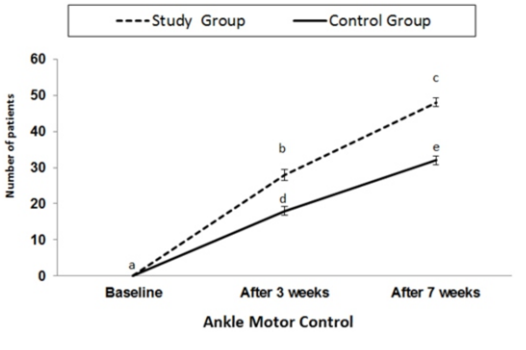
		Sum of Squares	Mean Square	Significance
Spasticity at baseline	Between Groups Within Groups Total	0.917 133.167 134.083	0.917 1.024	>0.05
Spasticity after 3 weeks	Between Groups Within Groups Total	0.371 113.348 113.720	0.371 0.872	>0.05
Spasticity after 7 weeks	Between Groups Within Groups Total	3.030 63.485 66.515	3.030 0.488	<0.01

Figure 1: BAR DIAGRAM COMPARING ANKLE DORSIFLEXOR MOTOR POWER



Bars with the same superscript (a) shows insignificant (p>0.05) difference in between groups whereas bars with the different superscripts (a, b) shows significant difference (p<0.01) in between groups.

Figure 2: LINE DIAGRAM SHOWING NUMBER OF PATIENTS WITH GOOD ANKLE MOTOR CONTROL.



Lines with the different superscripts (a, b, c, d, e) show significant difference (p<0.01) in between groups.

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