Long Term Effect of Contralaterally Controlled EMG-Modulated Electrical Stimulation Combined with Training and Botulinum Toxin A (BONT-A) Motor Point Block on Hand Function in Patients with Stroke

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Abstract: Objective: This study describes the long term effect of contralaterally controlled EMG modulated electrical stimulation combined with Botulinum Toxin A (BONT-A) motor point block and hand function training in stroke. Methods: Three stroke patients, onset ≥ 6 months, with paresis of wrist and fingers extensors (MRC 2/5), flexor spasticity ≥3 (MAS), were given BONT-A injections before training. The training consisted of 40 minutes electrical stimulation on the affected side, proportional to the EMG signal picked-up from the unaffected side, simultaneously doing hand function training, for 3-5 days/ week. Outcome measures were *Box and Block Test* (BBT) and *Nine Hole Peg Test* (NHPT) scored before, after training, and at follow-up of 4 and 9 months. After 18 sessions, grasp function (BBT) improved in 3 patients, pinch grip (NHPT) improved in 2 patients. One patient was lost to follow-up. At 4 and 9 months, BBT improved further in 1 patient, deteriorated in 1 patient, while NHPT deteriorated in both patients. Conclusion: Grasp function improved at long term follow-up in 1 chronic stroke patient who consistently used the affected dominant-hand. No improvement was seen in 1 patient affected at the non-dominant hand. Improvement in pinch grip was lost at long term follow-up.

1 INTRODUCTION

A stroke is often causing long term severe motor disability due to hemiplegia. In many patients the upper extremity does not recover to a functional level (Yavuzer et al, 2008). The synergy pattern that develops usually consist of flexion of the wrist & fingers, causing inability to open the fingers. Flexors muscle spasticity that occur after stroke can worsen the inability to extend the wrist and fingers. The effort to elicit active movement in the affected arm tend to increase spasticity, and is therefore less successful in producing an effective functional hand movement. The condition together has been shown to be one of the motor impairments responsible for disability (Hara, 2008). Botulinum Toxin A (BONT-A) motor point block injections showed efficacy to reduce spasticity and allow more voluntary grasping. Another study reported the efficacy of phenol motor point block to reduce spasticity in stroke patients (Hara et al, 2006).

Chronic stroke-related motor problems that begin in the first year after a stroke may lead to learned nonuse as individuals stop trying to move the affected upper extremity voluntarily (Inobe, 2013). Recent knowledge in the field of neuroplasticity and functional recovery in brain lesion has contributed in the development of several combinations of functional training with the application of physical modalities to enhance activity. Electromyography (EMG)-initiated electrical stimulation is one novel method of Functional Electrical Stimulation (FES). A surface electrode picks up the EMG signal and stimulates the target muscle in proportion to the integrated signal. This device induces greater muscle contraction because electrical stimulation is proportional to the EMG signal (Yamaguchi et al,

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2011). The efficacy of EMG-controlled electrical stimulation was reported by Hara et al in a study of combined Integrated Volitional Control Electrical Stimulation (IVES) on the affected extensor muscles, training, and motor point block using 5% phenol for antagonist muscles in patients with chronic stroke (Hara et al 2006).

Recently a device of EMG-modulated electrical stimulation enables to pick up EMG signal from active voluntary contraction of the contralateral non-affected arm, and send it as a trigger electrical stimuli to the muscle at the affected arm. The trigger delivered to the affected arm then should be followed by voluntary effort to increase the activity of the recipient muscle. This method requires active participation from patients to perform bilateral symmetrical movement on both arms or wrists. Several studies have reported the effectiveness of contralaterally controlled electrical stimulation alone in patients with early-phase stroke (< 15 days post stroke), subacute, and chronic stroke (> 6 months, but less than 2 years) (Zheng et al, 2019). None of these studies used combined electrical stimulation with motor point block injections. This study, therefore, aims to demonstrate the long term effect of contralaterally controlled EMG-modulated electrical stimulation combined with training, and Botulinum Toxin A (BONT-A) motor point block, to improve functional hand movement in stroke patients.

2 METHODS

The study participants were 3 patients with first episode unilateral stroke, onset ≥ 6 months. Two patients had chronic stroke (> 6 months), and one patient had a stroke 6 months before intervention. All 3 patients had hemiparesis of wrist and fingers, difficulty in extension movements (MRC scale 2/5), with flexor spasticity graded ≥ 3 (Modified Ashworth Scale). Patient 1 was a 40-year-old male with left hemiparesis after a hemorrhagic stroke 4 years ago. Patient 2 was a 50-year-old male with left hemiparesis after a thrombotic stroke 6 months ago. Patient 3 was 50-year-old female with right hemiparesis after a thrombotic stroke 3 years ago.

Botulinum toxin A (BONT-A) motor point block injections were given by an-experienced physiatrist to the flexor wrist and fingers muscles 7-10 days before start of training. All 3 patients received training that consisted of 40 minutes integrated volitional control electrical stimulation of extensor wrist and fingers on the affected side, in proportion to the voluntary EMG signal picked-up at the non-affected side, while doing therapist-supervised activities with the affected hand. Electrodes placement were on extensor carpi radialis longus and brevis, and extensor digitorum communis. The equipment Integrated Volitional Control Electrical Stimulation (IVES) GD-611 by OG Wellness Technologies Co, Ltd. was used in this study.

The combined contralaterally controlled EMG-modulated electrical stimulation with training is depicted in Figure 1. Treatment frequency was 3-5 days a week, up to 18 sessions. Subjects were dropped out from this study if they missed consecutively 2 therapy session in 1 week, or if they wished to stop the therapy.

The outcome measures were *Box and Block Test* (BBT) and *Nine Hole Peg Test* (NHPT) scored before training, after training, and at follow-up of 4 and 9 months. All patients were given detailed information about the procedure, and informed consent was obtained.

3 RESULTS

All 3 patients were successfully completed 18 sessions of training. Baseline scores of BBT were < 4, and NHPT were 0. All 3 patients showed improvement in grasp function starting from session 6 and achieved peak performance at session 12, as shown by the BBT results. Compared to session 12, session 18 did not show further improvement. Pinch performance as shown by the NHPT showed peak performance in session 18 in Patient 1 and Patient 3. Patient 2 was never able to perform the NHPT. Table 1 summarizes the changes in outcome measurement scores over the sessions, and at long term follow-up of 4 and 9 months.

Only Patient 1 and Patient 3 were assessed for long term follow-up at 4 and 9 months. Patient 2 was lost to follow-up because he worked in a different city. Hand function at follow-up of 4 and 9 months improved further as shown by the BBT score in Patient 3, while it deteriorated in Patient 1. The NHPT score deteriorated in both Patient 1 and Patient 3 at follow-up of 4 and 9 months. Figure 2 shows the progress in the NHPT and BBT scores of all 3 patients after 18 sessions, and at long-term follow-up of 4 and 9 months.

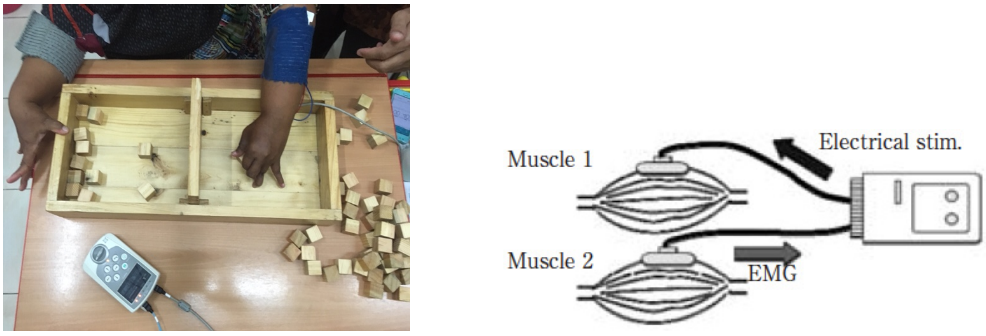

Figure 1: The EMG signal was picked up from active voluntary contraction of the contralateral non-affected arm (muscle 2) and delivered to the muscle in the affected arm (muscle 1). Integrated volitional control electrical stimulation on the affected side was in proportion to the voluntary EMG signal picked up on the non-affected side. The trigger delivered to the affected arm should then be followed by voluntary effort to increase the activity of the recipient muscle (Hara, 2008).

4 DISCUSSION

This study showed that after 18 sessions of combined contralaterally controlled EMG-modulated electrical stimulation, therapist-guided training, and Botulinum toxin A (BONT-A) motor point block, the grasp function represented by BBT score, optimally improved after 12 sessions in all 3 patients. No further improvement was seen after 12 sessions in Patient 1 and Patient 2, while Patient 3 showed further improvement at long-term follow up of 4 and 9 months. Improvement of the pinch started to emerge later than the grasp. Pinch grip performance, assessed by NHPT score, showed improvement after 18 sessions in two patients (Patient 1 and Patient 3), both who had chronic stroke (> 6 months). One patient who had stroke 6 months before intervention (Patient 2) did not show any improvement. These findings indicated that to improve the pinch grip more sessions are necessary compared to the grasp function. This can be explained because the pinch grip is a more selective and precise movement than the grasp. At long-term follow up of 4 and 9 months, the NHPT deteriorated in two patients, while one patient was lost to follow-up.

Patients who had chronic stroke still have a chance of recovery. A study by Hara et al in 16 chronic (more than 1 year) stroke patients showed improvement in motor performances of upper extremity with combined of power-assisted FES, training, and phenol motor point block injections (Hara et al, 2006). Lewinsky et al reported in a study of 9 chronic stroke patients, that BBT result at the time of inception (before training) has predictive value potential. There was no significant gain if the BBT score was below 4, even after 8 weeks of combined training and EMG-triggered electrical stimulation (Lewinsky et al, 2009).

Table 1: The *Nine Hole Peg Test* (NHPT) and the *Box and Block Test* (BBT) scored before treatment, after treatment, and at follow-up of 4 months and 9 months.

	Sessions											
	Baseline		6		12		18		4 months follow-up		9 months follow-up	
	NHPT	BBT	NHPT	BBT	NHPT	BBT	NHPT	BBT	NHPT	BBT	NHPT	BBT
Patient 1	0	1	0	1	0	10	3	10	0	0	0	0
Patient 2	0	0	0	0	0	3	0	2	-	-	-	-
Patient 3	0	2	0	5	4	6	5	5	2	10	0	16

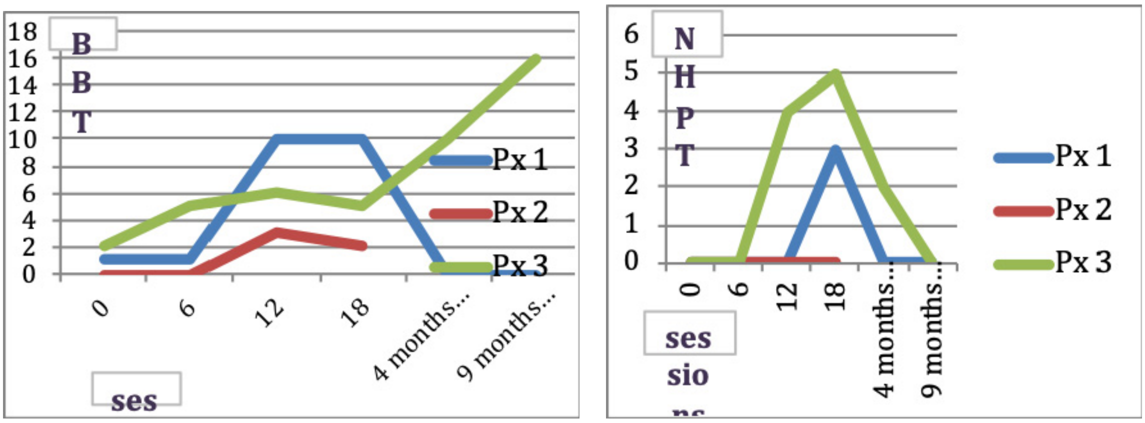

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Figure 2: (a) The *Nine Hole Peg Test* (NHPT) and (b) the *Box and Block Test* (BBT) scored before treatment, after treatment, and at follow-up of 4 and 9 months.

In this study, all 3 patients had BBT scores <4 at baseline measurement. Only one patient who had chronic stroke, with an initial BBT score 2, gained significant improvement (BBT score 16) after 18 sessions, and improved further at long term follow-up of 4 and 9 months. The other two patients, who had chronic stroke and stroke at 6 months before intervention, with initial BBT score 1 and 0, showed improvement (BBT score 10 and 2) after 18 sessions, and then deteriorated at long term follow-up of 4 and 9 months.

Stroke affecting dominant or non-dominant hand also plays a role in recovery. If the dominant hand is affected, the patient can be motivated to actively use the hand for daily activities. In this study, two patient (Patient 2 and Patient 3) were affected in the dominant hand. Patient 2, who had subacute stroke showed improvement in grasp function showed by BBT score, after 12 sessions of combined treatment. He consciously used his right (dominant) hand in activities of daily living, such as holding a cup and picking up objects. Patient 3, who had chronic stroke, showed further improvement in grasp function after 12 sessions and even at long-term follow-up of 4 and 9 months after BONT-A injections. This is because the patient actively used her right hand for daily household activities. She could use her right hand for cooking, such as cutting tofu and vegetables, holding saucepan and frying tofu. While Patient 1, who had chronic stroke, did not show improvement in grasp function. This can be explained because he did not actively use his left (non-dominant) hand for daily activities. He only used the left hand to open the door. This will worsen or deteriorate the learned nonuse as individuals stop trying to move the affected extremity voluntarily (Inobe, 2013).

The current study used contralaterally controlled (from the non-affected side) EMG-modulated electrical stimulation in chronic stroke patients. It is considered as novel method of FES, that requires active participation from patients to perform bilateral symmetrical movement, and not only electrical stimulation of the affected side (Zheng et al, 2019). Because this technique uses a control signal from the non-affected side, EMG signal will still be picked-up even when the target-affected muscles display no muscle contraction at all. With the non-contralaterally EMG-controlled electrical stimulation, the stimulator will not work when there was no contraction at all on the target-affected muscles (Chuang et al, 2017). The mechanism of contralaterally controlled EMG-modulated electrical stimulation on motor recovery after stroke remains unclear. The possible explanation may be that movement of the non-affected side can increase the corticospinal excitability of the stimulated muscles by interhemispheric disinhibition and intracortical facilitation (Zheng et al, 2019). Zhou et al reported that because patients could control the timing and degree of movements during training with EMG bridge detects surface electromyographic signals from the non paretic limb, may induce synaptic remodelling and cortical reorganization. In addition, because patients were more willing and more able to use their affected hand actively, it might enhance further the treatment effects (Zhou et al, 2017).

In stroke patients, good balance of movement between flexion and extension in the wrist and fingers should be obtained to achieve effective hand function. For patients who had stroke with significant flexor muscles spasticity in upper extremity, NMES or FES alone does not produce satisfactory improvement (Hara et al, 2006). Some authors have reported the efficacy of a phenol motor point block which is more cost-effective than Botulinum toxin A (BONT-A) (Hara et al 2006). We use motor point block with BONT-A to reduce spasticity in this study, because of technical constraints to obtain phenol for injection. Studies have shown the efficacy of BONT-A to reduce spasticity, thus allowing more voluntary grasping. For the long term follow-up assessment 4 and 9 months were the time points chosen because the average duration of the BONT-A effect is said to wear off within 3-6 months (Ambrose et al, 2018).

Longer duration of training seemed to have better results in chronic stroke. Hara et al evaluated the hand function after 4 months (2 times per week, total of 32 sessions) of combined treatment in chronic stroke. In this study, we have difficulty in maintaining patients' compliance for more than 18 sessions. The number of visits as well as frequency in an outpatient-based treatment plan is often limited by several technical factors, such as transportation and availability of family members to bring the patient to a rehabilitation facility. This condition is quite common in developing countries such as Indonesia.

5 STUDY LIMITATION

A limitation of this study is that we only had 3 patients as study participants, and the study was ended after 18 sessions.

6 CONCLUSIONS

Improved grasp function was seen as long-term effect of contralaterally controlled EMG-modulated electrical stimulation combined with training and Botulinum Toxin A (BONT-A) motor point block injections, in 1 chronic stroke patient who consistently use the affected dominant-hand. No improvement was seen in 1 chronic stroke patient affected at the non-dominant hand. Improvement in pinch grip performance was lost at long term follow-up.

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REFERENCES

Ambrose AF, Verghese T, Dohle C, Russo J. 2018. Muscle Overactivity in the Upper Motor Neuron Syndrome. Phys Med Rehabil Clin N Am. 29: 483-500

Hara Y. 2008. Neurorehabilitation with New Functional Electrical Stimulation for Hemiparetic Upper Extremity in Stroke. J Nippon Med Sch. 75: 4-14

Hara Y, Ogawa S, Muraoka Y. 2006. Hybrid Power-Assisted Functional Electrical Stimulation to Improve Hemiparetic Upper-Extremity Function: Am J Phys Med Rehabil. 85: 977–985.

Hara Y, Ogawa S, Tsujiuchi K, Muraoka Y. 2008. A Home-Based Rehabilitation Program for The Hemiplegic Upper Extremity by Power-Assisted Functional Electrical Stimulation: Disability and Rehabilitation. 30(4): 296-304

Inobe J, Kato T. 2013. Effectiveness of Finger-equipped Electrode (FEE)-triggered Electrical Stimulation Improving Chronic Stroke Patients with Severe Hemiplegia. Brain Injury. 27(1): 114-119

Lewinsky F, Hofer S, Kaus J, Merboldt KD, Rothkegel H, Schweizer R, et al. 2009. Efficacy of EMG-triggered Electrical Arm Stimulation in Chronic Hemiparetic Stroke Patients. Restorative Neurology and Neuroscience 27: 189-197

Shindo K, Fujiwara T, Hara J, et al. 2011. Effectiveness of Hybrid Assistive Neuromuscular Dynamic Stimulation Therapy in Patients with Subacute Stroke: A Randomized Controlled Pilot Trial. Neurorehabil Neural Repair. 20(10): 1-8

Yamaguchi T, Tanabe S, Yoshihiro M, et al. 2011. Effects of Integrated Volitional Control Electrial Stimulation (IVES) on Upper Extremity Function in Chronic Stroke: Keio J Med. 60(3): 90-95

Yavuzer G, Selles R, Sezer N, Sutbeyas S. 2008. Mirror Therapy Improves Hand Function in Subacute Stroke: A Randomized Controlled Trial. Archives of Physical Medicine and Rehabilitation.89:393-98

Zheng Y, Mao M, Cao Y, Lu X. 2019. Contralaterally Controlled Functional Electrical Stimulation Improves Wrist Dorsiflexion and Upper Limb Function in Patients with Early-Phase Stroke: A Randomized Controlled Trial. J Rehabil Med. 51: 103-108

Zhou YX, Xia Y, Huang J, Wang HP, Bao XL, Yang Z, et al. 2017. Electromyographic Bridge for Promoting the Recovery of Hand Movements in Subacute Stroke

Patients: A Randomized Controlled Trial. J Rehabil Med.49: 629-636