Effect of Functional Electrical Stimulation with Mirror Therapy on Upper Extremity Motor Function in Poststroke Patients

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Background: Motor recovery of the upper extremity in stroke patients is an important goal of rehabilitation. In particular, motor recovery can be accelerated when physical and cognitive interventions are combined. Thus, the aim of this study was to investigate the effects of functional electrical stimulation (FES) with mirror therapy (MT) on motor function of upper extremity in stroke patients. *Methods:* Twenty-seven stroke patients were recruited, and the 23 subjects who met the inclusion criteria were randomly allocated into 2 groups: the experimental group (n = 12) and the control group (n = 11). Both groups received conventional rehabilitation training for 60 minutes/day and 5 days/week for 4 weeks. In addition, members of the experimental group received FES with MT and members of the control group received FES without MT for 30 minutes/day and 5 days/week for 4 weeks. Immediately before and after intervention, motor recovery was measured using the Fugl-Meyer (FM) assessment, Brunnstrom's motor recovery stage (BMRS), the Manual Function Test (MFT), and the Box and Block Test (BBT). *Results:* Significant upper extremity motor improvements were observed in the experimental and control groups according to the FM, BMRS, MFT, and BBT ($P < .05$). In particular, FM subscores for wrist, hand, and co-ordination and MFT subscores for hand function were more significantly improved in the experimental group ($P < .05$). *Conclusions:* Motor functions of the upper extremity were improved by FES with MT versus controls. The study shows that FES with MT during poststroke rehabilitation may effectively improve motor functions of the upper extremity. **Key Words:** Stroke—mirror therapy—functional electrical stimulation—upper extremity—motor function.

Introduction

The impaired motor function commonly leads to functional limitations and disabilities in stroke patients,[1,2] and thus, the recovery of motor function is an important goal of stroke rehabilitation. In particular, recovery of upper extremity function is important for performing those activities required for independent daily life.[3,4]

Interventions used to improve upper extremity function include bilateral upper limb training,[5] constraint-induced movement therapy,[6] robot-assisted training,[7] and functional electrical stimulation (FES),[8] the latter of which is useful for activating paralyzed muscles. FES is conducted by directly stimulating the nerves or muscles of paralyzed limbs using a surface electrode connected to an electrical stimulator[9] and has been reported to increase wrist and finger movements.[10] However, the intervention is ineffective in patients with severe loss of motor function.[11] In 1 study, it was concluded that it is difficult to achieve motor function improvements by electrical stimulation alone in patients lacking active movement,[12] whereas in another study, it was found that although FES can increase range of motion, it does not improve purposeful movement or the ability to perform functional tasks.[13] Placing an emphasis on motor function might be

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Received March 12, 2013; revision received June 5, 2013; accepted June 7, 2013.

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1052-3057/$ - see front matter

http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2013.06.017

considered to result in inadequate consideration of cognitive aspects, but reorganization of the brain can be enhanced when cognitive aspects and physical functions are adequately addressed.[14]

Mirror therapy (MT) may provide a suitable intervention for addressing cognitive aspects; for example, it has been reported that movements of unaffected limbs visualized in a mirror provide improved movements of contralateral affected limbs by creating a visual illusion whereby unaffected limbs were replaced by affected limbs.[15] Furthermore, MT has been reported to promote motor recovery of the upper extremity in the subacute stroke patients,[1] and in 1 study, in which MT was applied to patients with acute stroke, it was suggested that MT might be effective at improving movements in distal affected upper extremities.[16] The facilitation of the damaged brain in poststroke patients is provided by sensory stimulation of the affected side and by cognitive intervention, such as visual stimulation, which can aid brain reorganization.[17,18] Therefore, it is generally believed that physical performance improves when physical and cognitive interventions are combined.[19,20] This explains why the combined use of FES and MT is more effective for the rehabilitation of stroke patients. Recently, Yun et al[21] applied FES with MT simultaneously in stroke patients and found that the technique elicited motor improvements in patients without sensory impairment.

Accordingly, it is important that we find a means of overcoming this limitation of simultaneous FES with MT in stroke patients with sensory impairments. Thus, in the present study, we sought to determine the effects of simultaneous FES with MT on upper extremity motor functions in poststroke patients by applying FES to nonparetic sides without sensory impairment.

Methods

Participants

Poststroke inpatients at a university hospital capable of participating in the rehabilitation program after stable medically were recruited. Participants were recruited by advertizing the study purpose and inclusion criteria in the hospital from July 1 to July 31, 2013. Thirty patients were initially recruited and screened using the following criteria: disease duration less than 6 months, a Mini-Mental State Examination score greater than 21, a Fugl-Meyer (FM) assessment score less than 44, a Brunnstrom motor recovery stage (BMRS) of 1-4, the absence of an orthopedic disease of the upper extremity, no visual perception disorder (such as, unilateral neglect, hemianopsia, or apraxia), no pace maker, not on anticonvulsant medication, and a medically stable condition. Twenty-seven participants who fulfilled the criteria participated in the study. All participants provided signed informed consent after receiving a detailed explanation of the study. The study was approved by the Sahmyook University Institutional Review Board. Table 1 summarizes the baseline information of the 27 patients.

Procedure

This study was conducted using a randomized controlled trial design. The 27 participants were randomly allocated to an experimental group (n = 14) or a control group (n = 13) using random allocation software.[22] Participants, investigators, and outcome assessors were unaware of group assignments. Before randomization, the 27 participants underwent FM and BMRS assessments and the Manual Function Test (MFT) and the Box and Block Test (BBT). Participants were then randomly allocated to the experimental group or the control group. The experimental group underwent FES with MT followed by conventional rehabilitation training. The FES with MT was conducted for 30 minutes/day and 5 times/week for 4 weeks. The control group underwent sham therapy using the back of the mirror to remove visual input during FES using otherwise the same protocol. In both groups, FES was followed by conventional rehabilitation training. In the experimental group, 2 subjects dropped out: 1 chose to drop out and the other dropped out because of discharge from the hospital. In the control group, 2 subjects dropped out because of discharge from the hospital. Overall, post-test data collection was conducted on 12 subjects in the experimental group and on 11 in the control group (Fig 1).

FES with MT

With the participant sitting on a stool was placed on a table in front of a square mirror with 30-cm sides.[21] The affected hand was placed behind the mirror so that it could not be seen, and the unaffected hand was placed in front of the mirror. A switch was placed for FES in front of the unaffected hand, and the participants were asked to extend the wrist and fingers to turn on the FES switch. At the same time, an attempt was made to extend the affected wrist and fingers while the participant looked at the movement of the unaffected side reflected in the mirror. Participants tried to attempt at the same movement with both hands simultaneously while looking at the mirror. Then, the FES switch was turned on by the movement of the unaffected hand, and extension of the affected wrist and fingers was induced by providing electrical stimulation to the affected side (Figs 2, 3).

Electrical stimulation was performed using FES (Microstim GmbH, Hamburg, Germany). The extensor muscles of digits, extensor carpi radialis longus, and extensor carpi radialis brevis stimulated, and a pair of disposable surface electrodes was attached to the proximal and distal end of each forearm. The frequency used was 20 Hz, the pulse rate was 300 μs, and the intensity was set to a level sufficient to allow muscular contraction that resulted in complete extension of the wrist and finger(s).[11] In this