The effects of EMG-triggered functional electrical stimulation on upper extremity function in stroke patients

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Objective: The aim of this review is to explore the latest intervention trends and effects of EMG-triggered functional electrical stimulation on the upper extremity functions in stroke patients.

Design: Systematic review on clinical trials.

Methods: A systematic literature search was performed to identify clinical trials evaluating the effects of EMG-triggered functional electrical stimulation (EMG-FES) and task-oriented EMG-triggered FES on the hand functions in stroke patients. Literature review was conducted with the following key words: hand function, functional electrical stimulation, task-oriented, stroke.

Results: Ten clinical trials were included; 8 of them were randomized controlled trial, 1 was block-randomized, and 1 was a pre-post comparison study. A positive effect of electrical stimulation was reported in the patient groups that were treated with functional electrical stimulation combined with specific tasks, and volitional muscle contraction-triggered stimulation that was synchronized with tasks. Motor capabilities of the hand and arm were improved after the rehabilitation.

Conclusions: EMG-triggered electrical stimulation may be more effective than non-triggered electrical stimulation in facilitating the hand functions in stroke patients in terms of muscle strength and voluntary muscle contraction of the paretic hand and arm. Triggered electrical stimulation can be even more effective when it is combined with specific tasks.

Key Words: Electrical stimulation, Hand, Stroke, Task

Introduction

Of all stroke-induced impairments, arm hemiparesis may be the most disabling, considering its impact on the ability to perform activities of daily living (ADL) [1]. Recovery of upper extremity function is most rapid during the first months after stroke, but only 20% of the stroke survivors who are 3 months post stroke have normal upper extremity function [2,3].

There is growing evidence that electrical stimulation (ES) has a positive effect on upper extremity motor recovery following stroke [4-6]. ES might be a useful therapy in the rehabilitation of patients with stroke, but research reports demonstrate a wide variety of stimulation paradigms in terms of stimulation parameters, method of stimulations, and duration of treatment. This raises the question of how ES should be applied in order to achieve the optimum outcome.

Various devices are available for the application of ES, and different adjustments of stimulation parameters including amplitude, pulse duration, and pulse frequency are provided. With regard to motor stimulation, several methods of application have been reported [6]. Cyclic neuromuscular electrical stimulation (NMES) or functional electrical stimulation (FES) is applied by a pre-programmed scheme, which causes repetitive muscle contraction without active participation of the patient [5]. This passive neuromuscular stimulation has been reported to produce increased muscle strength, but the evidence is less convincing for more com-
plicated hand manipulation tasks [7-9]. In contrast, electromyogram (EMG)-triggered functional electrical stimulation stimulation (EMG-FES) involves initiating a voluntary contraction for a specific movement until the muscle activity reaches a pre-set threshold level, and then an assisting electrical stimulus begins [7,10-12]. Compared to passive ES, voluntary initiating motor actions is known to be more effective in strengthening the muscles. Moreover, EMG-FES requires cognitive involvement by the motor cortex; improvement following EMG-FES was reported to be accompanied by changes in somatosensory cortex activation as measured by functional magnetic resonance imaging (fMRI) [13]. Other rehabilitative methods such as task-oriented training, bilateral movement training, and intensive tracking were associated with changes in size and location of motor output areas [10,14-17]. Therefore, task-oriented EMG-triggered FES can be a beneficial therapeutic intervention for hand function recovery in stroke patients.

The purpose of the present systematic review was to investigate the effects of task-oriented EMG-triggered FES on the arm/hand functions of stroke patients; mainly the wrist and finger extensors, which are known to be essential in regaining functional movement of the upper limb for ADL [18].

Methods

A computer-aided literature search up to March 2013 was performed in the following electronic databases: Pubmed (MEDLINE), Cochrane Central register of Controlled Trials, and CINAHL. The following medical subject headings and key words were used: stroke, hemiplegia, upper extremity, wrist extensors, hand function, task oriented, neuromuscular stimulation, EMG-triggered, and FES. References in relevant studies were examined, and the ones that were published after the year 2000 were included in this review.

Inclusion criteria for the present review were as follows. First, the studies involved patients diagnosed with a stroke. Second, the study investigated the effects of EMG-NMES or EMG-triggered FES by means of surface electrodes as the experimental intervention. Third, the EMG-NMES applied was targeted to activating the extensor muscles of the forearm. Fourth, the study was classified as a randomized controlled trial, involving at least one test treatment and one control treatment. Fifth, the application of EMG-NMES was the experimental treatment in the randomized controlled trial, not the control treatment. Sixth, the study analyzed the functional measures for the hemiparetic arm/hand functions. Case studies, animal studies, methodological, and theoretical discussions were exempted (Table 1).

Results

After searching the latest EMG-triggered NMES research studies, 10 clinical intervention studies were selected for review on the efficacy of the intervention. Clinical characteristics and results of the included studies are summarized in Table 2 and 3. Among the 10 studies, 8 of them were randomized controlled studies. One study was block-randomized [19], and one other study was a pre-post comparison study [20]. Except 2 studies [21], chronic stroke patients were recruited for the research.

For outcome measures, clinical tests, kinematic measures, and electromyographic measures were used. As a clinical test, Box and Block test was the most commonly used measure, and then the upper-extremity portion of the Fugl-Meyer assessment was the second most commonly used measure.

Four studies by Cauraugh and Kim [10,11] and Cauraugh et al. [22,23] were included in this study. The results of their studies showed significantly decreased motor dysfunction and improved motor capabilities of the wrist and finger extensors after intervention. When different durations of stimulation was applied, longer active stimulation decreased residual motor dysfunctions more than the shorter stimulation duration (10 s > 5 s > 0 s). Longer stimulation group (10 s) displayed improvements on all outcome measures compared to the control group. The two coupled motor recovery

### Table 1. List of inclusion and exclusion details

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