How will the FES function well? – Make the better use of Therapeutic Electrical Stimulation

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Abstract
In the past 40 years, from the aspect of its function, electrical stimulators have been improved greatly by the continuous efforts for research and development of scientists. In comparison with such improvement, except cardiac pacemakers, its effective application in clinics did not reach the anticipated level. To improve such limitations, first, the area that efforts have to be made continuously is the application of the-state-of-art technique to improve the development of more improved equipment. In addition to the development of the state-of-art technique, the area that research and developed should be performed is the addition of the efficacy and convenience to the already developed equipment with a low grade technology, and thus more patients could actually use them. In this presentation, the application of therapeutic electrical stimulation in clinics focused on the cases that the effect of the functional recovery was obtained by applying a basic neuromuscular electric stimulation together with tasks with a specific purpose for a certain period will be introduced.

1. INTRODUCTION
In the past 40 years, from the aspect of its function, electrical stimulators have been improved greatly by the continuous efforts for research and development of scientists. In comparison with such improvement, except cardiac pacemakers, its effective application in clinics did not reach the anticipated level.

The main cause is that as spinal cord injury, the number of patients is relatively small, or as the stroke cases, the number of patients is large, however, the problems requiring help is not fatal as cardiac arrest, and thus it is true that the demand is not high. Nonetheless, the fact that the development has been carried out focused on the developers rather than the users could not be denied. In other words, it was developed focused on the organ that its function had to be recovered and technical improvements were made primarily, on the other hand, the aspect of the characteristic of individual users or their convenience was not emphasized relatively. Thus many products have the state-of-art function but it was inconvenient to use them, and although it has many functions, the demand is not high, hence, the high cost of the products could not be avoided.

Particularly, recently, researches on new therapeutic methods using stem cells, etc. have been actively ongoing and the possibility of the regeneration therapy for central nerves system has been suggested, and thus the trend of patients to avoid invasive and irreversible therapies becomes evident. Thus the breakthrough research and the change of the direction of development are required.

To improve such limitations, first, the area that efforts have to be made continuously is the application of the-state-of-art technique to improve the development of more improved equipment. Particularly, it should be developed to have the-state-of-art function, as small as possible, and focused on the convenience of users and thus the users using the equipment as well as clinicians, therapist and other persons who apply the equipment to patients could handle them readily.

In addition to the development of the state-of-art technique, the area that research and developed should be performed is the addition of the efficacy and convenience to the already developed equipment with a low grade technology, and thus more patients could actually use them. In other words, while applying electric stimulation therapies to patients, not only adhere to typical methods, but also considering the recovery mechanism of each problem. Better functional recovery could be obtained by applying other modalities such as exercise, task, biofeedback, in addition to
electric stimulation. For this, more research and development for simple programs specific to each indication, electrodes and cables designed to be optimal patterns according to the application area, the design of the appearance of equipment suitable to the level of the major user group, should be conducted. In addition, the continuous education for the users who use the equipment, clinicians and therapist as well as the feedback from the users are necessary.

2. REVIEW OF CLINICAL TRIALS

FES-assisted task oriented training to improve hand function in subjects with stroke

This study examined whether functional electrical stimulation (FES)-assisted task-oriented training approach could improve hand function in two subjects with stroke. Test measurement included box and block test, detaching Velcro pegboard, moving the cone from one side to the other, and median frequency of finger extensor muscles during cones task – all as many as possible in 1 minute. Two pre-tests, one post-test measurements occurred. Training consisted of 20 sessions of cone transfer during the 30 minute with FES. A FES stimulator was used to assist hand opening. Data were analyzed by visual inspection and by statistical analysis that examined whether post-test measurements exceeded the pre-test mean by at least two standard deviations on at least two consecutive post-test measurements. Post-test results showed that the hand function improved statistically in box and block test, detaching Velcro pegboard task, and moving the cone task. Median frequency of finger extensor muscles showed increased statistically after training. We concluded that FES-assisted task-oriented training approach produced training effects in finger function and muscle recruitment.

EMG trigger EST; The effect and mechanism for recovery of hemiplegic arm function

This study was performed to identify the effect and mechanism of EMG-triggered electrical neuromuscular stimulation for recovery of hemiplegic arm function. EMG-triggered electrical stimulation was applied to the extensor digitorum communis(EDC) of chronic hemiplegics who showed no functional changes for more than 3 months. Stimulation was started when the amplitude of processed EMG signal from the same muscle exceeded the preset threshold. The effect was evaluated clinically. Quantitative EMG from EDC during volition was also evaluated before and after treatment. Subjects treated with EMG-triggered electrical stimulation showed significant gain in amplitude of quantitative EMG and excursion sum during maximal exertion comparing to those of pre-treatment. There was also a decrease of spasticity after treatment. But functional, perceptual and cognitive measurement was not changed significantly. These results suggest that EMG-triggered electrical stimulation of EDC improved the voluntary finger motion in chronic brain injury subjects. There was functional radiologic and physiologic evidence of central nervous system reorganization in one case who showed marked improvement in finger motion, which might explain the mechanism of effect as brain plasticity.

Direct Effect of Dermatomal Electrical Stimulation During Gait in Hemiplegic Spastic Drop Foot with Stroke

The purpose of this study was to examine the effect of the spasticity reduction in response to dermatomal electrical stimulation applied to the ankle plantar flexor on the spastic foot drop during gaits in hemiplegia patients. Sixteen patients with hemiplegic patients caused by stroke and traumatic brain injury. They walked for 5 times before electrical stimulation and during electrical stimulation. The surface electrode was attached to the S1 dermatome that was equivalent to the myotome of gastrocnemius, and in regard to the intensity of stimulation, it was in the range that was comfortable for patients without causing the non contraction of muscle. For the gait analysis, the data were collected by the 3-dimensional gait analysis system, Vicon 612 (VICON Motion Analysis System Ltd, UK). In the gait performed under dermatomal electrical stimulation, in the affected side, the ankle plantar flexion angle during the initial heel contact was significantly decreased and thus the dorsiflexion was increased significantly (p<0.05), and during the midstance, the maximal dorsiflexion angle of ankle joint was found to be significantly increased (p<0.05). The knee maximal extension angle during the stance phase was significantly decreased (p<0.05) and maximal flexion angle of knee during the swing phase was significantly increased (p<0.05). The single limb support time ratio of the affected side during gait cycle was significantly
decreased, \( p < 0.05 \). The experiment results show that in spastic foot drop patients caused by the spasticity of the ankle plantar flexor muscles, dermatomal electrical simulation increased the active range of motion of the affected ankle joint and asymmetry ratio the gait cycle.

**Effect of Gait training using electrical stimulation elicited flexion withdrawal reflex on gait pattern and endurance in Patients with incomplete Spinal Cord Injury**

The flexion reflex, also known as the flexion withdrawal reflex is a polysynaptic, multisegmental spinal in which a complex flexion synergy occurs in the stimulated limb. The result is a rapid withdrawal response, which occurs at the spinal cord to protect the limb from damage. The aim of this study was to examine changes in gait patterns in patients with spinal cord injury after gait training designed to elicit flexion reflex of the hip. The gait training was conducted for four weeks by stimulating the foot sole area with functional electrical stimulation (FES) regularly matching the patient’s normal walking pace. Gait patterns were analyzed before and after training using the VICON® motion analysis system, and walking distance, average heart rate were also measured. The knee moment and power significant increased during the loading response, compared with baseline measurements. At the same time, the maximum and minimum ROM of the knee shifted to normal values demonstrating the normal gait pattern.

**Dorsal Penile Nerve (DPN) stimulation to improve storage function of the bladder**

The aim of this study was to investigate the effect of semi-conditional DPN stimulation for complicated bladder in patient with spinal cord injury. DPN stimulation was applied to six male patients in semi-conditional pattern, which it is started as the subject sense the bladder contraction, and continued in cyclic manner by preset program, 1-3 times daily for two to four weeks. This method allows the bladder to distend, with low pressure. The infused volume of saline at the 1st reflex contraction, the maximal volume which could be attained by DPN stimulation and the clinical bladder capacity which measured as voiding volume by reflex voiding and/or CIC were significantly increased after treatment. The compliance of the bladder was also improved after treatment. Four cases of vesicoureteral reflux were disappeared, and degree of deformation of the bladder wall was improved after treatment. Electrical stimulation of afferent pathway to sacral cord has definite benefits for control in terms of timing. Adjuvant use of semi-conditional DPN stimulation with conventional treatment can avoid unnecessary emptying/leakage. This method allows the bladder to distend, with low pressure by the physiological filling of urine, and helps to improve compliance and capacity of the bladder.

**References**


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