Application of local EMG-Driven Electrical Stimulation to paretic shoulder muscle of the proximal dominant hemiplegics

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Abstract

We developed a local EMG-driven electrical stimulator (LEMDES) and tried applying it to the paretic shoulder muscle of the patients with proximal dominant hemiplegia as a substitution of active-assistive exercise. Two post-stroke patients with proximal dominant hemiplegia and motion pain in the paretic shoulder joint participated to the trial. Two weeks after the exercise with LEMDES their motion pain almost disappeared. One of the patients showed remarkable improvement of the paretic upper extremity function in 2 weeks while the other showed no change because spasticity disturbed elbow extension. Stabilization and electrical assist elicited by using LEMDES for the paretic shoulder allow painless movement of the shoulder joint. Training to the shoulder with LEMDES might realize quick improvement of the paretic upper extremity function in the hemiplegic patient without prominent spasticity.

1 Introduction

Many cases with post-stroke hemiplegia show distal dominant paralysis. Some patients especially with a thalamic lesion, however, suffer from proximal dominant hemiplegia, i.e., muscle weakness around the shoulder and hip joint. In the field of rehabilitation we sometimes experience the painful shoulder in the case with such hemiplegia. The patients with better recovery of paralysis in the distal part of the arm are often too eager to regain the total function of the upper extremity. In such cases, daily use or training of fingers and hand causes too much fatigue of the shoulder muscles because they work as a stabilizer for the distal joints in the arm. Active-assistive movement of the shoulder is a traditional way of exercise in physical and occupational therapy to avoid overuse and pain. However, assistive use of electrical stimulation for the shoulder might be more beneficial because it can achieve not only assist but also muscle reinforcement and, probably, functional facilitation.

Rule-based control is required to realize efficient assist by electrical stimulation for the patients with incomplete paralysis. There are many electrical stimulators with rule-based FES control proposed for the incomplete paralysis such as gait phase detection systems and/or devices installing some acceleration sensors. We developed a local EMG-driven electrical stimulator (LEMDES) and reported its application to incomplete hemiplegics to assist knee extension during walking. Use of EMG as a trigger signal for stimulation is practical and physiologically credible as feedback information of movement executed. The most beneficial and convenient characteristic of LEMDES is its mechanic feature realizing EMG detection from a muscle and stimulation to the same muscle simultaneously. It has only one output channel but this simplicity is sufficient to achieve functional assist for single joint.

We previously confirmed that LEMDES could be used as a neuroprosthesis for gait assist of hemiplegics in daily activity or training. In the present study we tried applying LEMDES to the paretic shoulder muscle of the patients with proximal dominant hemiplegia as a substitution of active-assistive exercise.

2 Methods

2.1 Basic design of LEMDES

To realize the surface FES and EMG detection to/from a same muscle or a muscle group, portable systems shown in Figure 1 were designed and used. The total system includes EMG electrodes, gated EMG amplifier, rectifying nonlinear circuit, smoothing circuit, surface stimulator and stimulating electrodes. The timing chart of the EMG-driven control is shown in Figure 2. Each amplitude of repetitive (25Hz) electrical stimulation of 5kHz-0.6ms burst was modulated by the smoothed power of voluntary EMG.
As shown in Figure 3, this EMG-driven FES is intended to reinforce the volitional motor commands on efferent nerves. However, there would also be some effects on central nervous system through afferent nerve stimulation.

2.2 Experiment protocol and subjects

EMG was detected from the deltoid muscle in the paretic side and electrical stimulation was performed on the same muscle. A pair of the electrodes for EMG detection was attached on the lateral part of the deltoid muscle. One of the stimulation electrodes was put on the skin above the shoulder joint and the other was attached below the EMG electrodes. First of all, the intensity of stimulation was gradually increased without EMG detection and held at the level inducing about 30 degrees of shoulder abduction without pain. Secondly, generation of assistive stimulation was confirmed when making voluntary effort of shoulder movement. Exercise with using LEMDES was performed 40 minutes a day in daily occupational therapy during 2 weeks. The chief task used for LEMDES training was peg-board. The subjects carried a peg with 3 cm in diameter and 10 cm in length to a hole as fast as possible. There were 20 holes on the board. Total number of pegs inserted and removed in 30 sec was counted everyday with and without LEMDES. At the beginning and the end of the exercise period, manual function score (MFS: 0~100%), grip strength and the angle of voluntary shoulder flexion were measured.

Two post-stroke patients with proximal dominant hemiplegia participated to the present trial. Both showed weakness of the shoulder muscles compared to the distal part in the arm. Basic personal data are as follows.

2.2.1 Case A

70 years, female, right hemiplegia caused by an onset of left thalamic hemorrhage. Intensive rehabilitation approach started 3 weeks after the onset. The level of hemiplegia evaluated with Brunnstrom’s test (BS) at start of rehabilitation was 3 in the arm, 5 in the fingers and 5 in the leg. Moderate sensory disturbance in the paretic upper and lower extremity was observed but muscle tone was kept at normal level. MFS, which shows the level of paretic upper extremity function, was 50% at start of rehabilitation and 59% at the time 8 weeks after rehabilitation approach. BS of the arm and fingers and grip strength showed no change during 8 weeks but motion pain of the shoulder gradually became clear.

2.2.2 Case B

49 years, male, right hemiplegia caused by an onset of hemorrhagic infarction in left thalamus and paraventricle. Intensive rehabilitation approach started 3 weeks after the onset as same as case A. Stage of BS at start of rehabilitation was 2 in the arm, 3 in the fingers and 4 in the leg. Hemi-sensory disturbance with dysesthesia was observed not only in the upper and lower extremity but also in the face. Though BS of the arm and fingers changed to 4 and 5 respectively and MFS also improved from 31% to 50% 12 weeks after start of rehabilitation, he became to complain of severe motion pain in the paretic shoulder joint. Furthermore he gradually showed spasticity in the paretic arm.

3 Results

3.1 Case A

Exercise with LEMDES began on the day 8 weeks after start of rehabilitation. Stimulation to the deltoid muscle was clearly confirmed when making voluntary shoulder movement and active angle of the shoulder expanded from 60 degrees to 80 degrees during stimulation. She also could move the paretic shoulder without pain during stimulation. Since one week after start of exercise she became able to complete the removal task of pegs in 30 sec during stimulation, we changed the peg-board from flat to tilting position. At the end of the exercise period MFS, grip strength and active angle of the shoulder flexion increased from 59% to 80%, from 6.8 kg to 8.9 kg and from 60 degrees to 180 degrees respectively. Motion pain of the shoulder decreased to the level at which practical use of the paretic upper extremity was not disturbed.

3.2 Case B

Exercise with LEMDES began on the day 12 weeks after start of rehabilitation. Painless movement of the shoulder and expansion of the shoulder abduction during stimulation was observed as same as case A. Though upper extremity function evaluated by BS showed no change, the number of peg he could insert and remove increased from 9 at start of exercise to 15 at 2 weeks after. Motion pain of the shoulder disappeared at the end of the exercise period but spasticity especially around the paretic elbow joint gradually increased.

4 Discussion

In the present trial, we could confirm that LEMDES assisted voluntary movement of the incomplete paretic shoulder. Contraction of the deltoid muscle elicited by EMG driven electrical stimulation was clearly detected and expansion of active range of motion about 20 ~ 30 degrees in the shoulder could be obtained without pain during stimulation. Furthermore, both patients acquired pain free voluntary movement of the paretic shoulder without stimulation at the end of the exercise period. One of the reasons causing mo-
tion pain in the paretic shoulder is subluxation of the shoulder joint. Forced use of the dislocating shoulder causes micro-injury of the soft tissues around shoulder joint and sympathetic hyperreflexia. The subjects participated to the present trial showed mild subluxation of the paretic shoulder joint. Electrical stimulation to the deltoid muscle probably made it possible to reposition the shoulder joint at least during voluntary movement. A pendulum device like balancer or manual assist is usually used for active-assistive training to the hemiplegics, however complete reposition of subluxation and sufficient assist for weak muscles are difficult. Electrical stimulation can realize “active” assist to the weak muscles and consequently brings painless movement of the paretic joint.

In case A, improvement of the paretic upper extremity function was rapidly attained during 2 weeks with LEMDES training, while the increment of MFS during 8 weeks from start of rehabilitation was only 9%. It takes more than a couple of months to achieve reinforcement of the weak muscles by electrical stimulation alone. Active and electrically assisted training has a possibility to provide rapid muscle reinforcement but such a quick improvement of function is chiefly based on other reasons like pain reduction and improvement of motor control. Since case A did not show prominent spasticity in the paretic upper extremity, stabilization of the shoulder provided by the electrical stimulation might permit efficient control of the elbow and wrist joint. Case B, on the contrary, showed no change of MFS during the exercise period with LEMDES though his motion pain in the paretic shoulder decreased. He showed spasticity in the paretic upper extremity, which appeared as flexion pattern of the elbow when making voluntary movement. In such a case functional control of paretic arm may not be realized by shoulder stabilization alone.

5 References