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MESH-GLOVE. 2. MODULATION OF RESIDUAL UPPER LIMB MOTOR CONTROL AFTER STROKE WITH WHOLE-HAND ELECTRIC STIMULATION

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ABSTRACT. The effects of whole-hand electrical stimulation via a wired mesh-glove upon the residual motor control of the upper extremity are described. Clinical observations were made in 2 patients with nonfunctional upper limbs, 4 and 2 years after stroke, who had been enrolled in the home mesh-glove program for 6 and 4 months, respectively. The stimulation paradigm is novel and the target of stimulation is the hand. Preliminary results indicate beneficial effects such as reduction in muscle hypertonia and facilitation of isolated hand movements.

Key words: hand, arm, electrical stimulation, stroke, rehabilitation.

INTRODUCTION

After stroke clinical recovery rapidly occurs in a first few weeks, being completed after six months in approximately 95% of the patients. (1, 7). Recovery of the hand functions can be arrested at any stage and patients may show nearly complete recovery but noticeable slowness of movements; partial recovery with lack of strength of the grip and of ability to perform fine movements; and poor hand recovery (useless hand) with loss of pinch between thumb and index finger (2). Loss of precise movements of the fingers represents a major functional impairment of the affected arm and is frequently seen in clinical practice. Development of new therapeutic interventions is needed with the emphasis on further recovery of the hand after plateau had been reached (5).

Newly devised method for the whole-hand electrical stimulation, via a mesh-glove was previously described (3). The hypothesis driving this approach is that externally controlled afferent stimulation of the whole hand is capable, in principle, to induce certain nervous system mediated effects on the residual motor control. In this report we present clinical observations in two stroke patients after spontaneous recovery had reached a plateau. Before mesh-glove stimulation was introduced, both patients underwent long-term physical therapy including functional electrical simulation in one case.

METHOD

Mesh-glove made of conductive wire was fitted on the patient's hand and connected to the anodal outputs of two-channel stimulator. A pair of surface electrodes (cathodes) were placed over the forearm approximately 2 cm above the wrist. Continuous synchronous stimulation of 50 Hz (pulse width 300 μs) below and at sensory threshold, followed by reciprocal stimulation that elicited finger extension/flexion movements was applied 15–20 min once or twice a day. Details of the method and stimulation protocols were previously described (3). Concurrent therapeutic interventions were not used.

CASE 1

This patient was a 51-year-old male who suffered a spontaneous intracerebral hemorrhage 4 years prior to admission to our program, which resulted in left hemiplegia. He was involved in regular physical therapy following medical stabilization. Most of the recovery occurred in the lower extremity and he regained functional ambulation. He received functional electrical stimulation for his paralyzed upper limb. No volitional movements were present in the affected upper limb. Attempts at maximal voluntary activation of the paralyzed hand produced a coarse synergistic movement involving both proximal and distal arm muscles, and trunk muscles occasionally. Flexor muscles of the affected upper limb exhibited severe increase in muscle tone and resting posture of the arm was characterized by the elbow flexion, forearm pronation and wrist and fingers flexion.

After admission, mesh-glove stimulation was applied to the affected left hand at sensory subthreshold level, for 30 minutes in the morning and 180 minutes in the afternoon. Subsequent clinical examination revealed diminished biceps spasticity with the increase in passive elbow extension for approximately 40°, until a significant resistance was noted. Moreover, the patient was able to demonstrate traces of isolated finger extension and flexion, in contrast to the previous synergistic movements only. Carry-over effect was noticeable for more than 12 hours. The protocol described above was repeated. He was then discharged and instructed to apply sensory subthreshold mesh-glove stimulation 15–20 minutes once a day, for 6 weeks. Since the patient was unable to return sooner, after 6 months of sensory subthreshold daily stimulation he reported increased awareness of the hand, further decrease of previously severe muscle hypertonia, reduced patterned arm movements and the presence of minute but steady volitional finger movements. Clinical examination confirmed the patient's report on alteration of muscle tone, passive and active movements.

Surface polyelectromyography of the affected upper limb muscles was obtained before and after 6 months of mesh-glove program. During the first recording, any attempt to isolate voluntary wrist movements of the affected upper limb was accompanied by a spread of EMG activity to the proximal muscles with repetitive bursts of clonogenic EMG activity recorded in wrist flexor and extensor muscle groups (Fig. 1A). Passive stretch of the wrist flexors evoked a sustained clonus of 8.9 s in duration. After 6 months of daily stimulation, a follow-up recording revealed the absence of clonogenic EMG activity during the volitional attempts and a slight increase of the motor unit output in the wrist extensor muscle (Fig. 1B). Duration of stretch-induced clonus was reduced to 3.7 s.

CASE 2

A 65-year-old female experienced left hemiplegia due to infarction in the middle cerebral artery area two years prior to admission. She was ambulatory with the assistance of an ankle-foot orthosis and a one-point cane. In the sitting position, the affected arm was presented with elbow flexed, forearm pronated and wrist and fingers in extreme flexion. Passive range of motion was reduced up to 50% in all joints due to severe hypertonia. The arm was nearly completely paralyzed. With great effort she was able to produce traces of finger flexion, traces of wrist dorsiflexion with forearm supination, slight elbow flexion and extension and slight shoulder abduction combined with scapular retraction. All movements were easily fatiguable.

Mesh-glove stimulation was started at sensory subthreshold level for 6 weeks, followed by 2 weeks of stimulation at sensory level, to be continued for the next 2 months at motor level.

On the follow-up visit, 6 months after the stimulation program was initiated, the patient reported relief of soreness in the left shoulder, increased passive range of motion in all upper limb joints and enhanced awareness of the hand. During sleep, her arm sustained a more relaxed position than before. Clinical examination revealed a suppression of muscle hypertonia in the shoulder, elbow, wrist and finger muscles. The previously reduced range of passive elbow extension and flexion returned to normal limits. Spasticity in finger flexors was markedly diminished and hand position was relaxed. Traces of volitional flexion and extension movements of the elbow and fingers were definitely present and sustained.

DISCUSSION

Following mesh-glove stimulation, in both cases we observed a decrease of spasticity and improvement in traces of voluntary motor activity in nonfunctional upper extremities. This is not an unexpected finding, since the effectiveness of functional electrical stimulation (FES) on the decrease of spasticity of the biceps and triceps brachii muscles and reduction of co-contraction was previously reported in stroke patients following spontaneous recovery (8, 6). Moreover, FES had long-lasting beneficial effect months after the stimulation program was completed (5). Although in two patients studied sensory functions were not quantified, their self-observations suggested improvement in the perception of touch and enhanced awareness of the affected hand. It appears that mesh-glove stimulation, in addition to its effect on motor functions, has a facilitatory influence on sensory functions. It has been reported that even years after

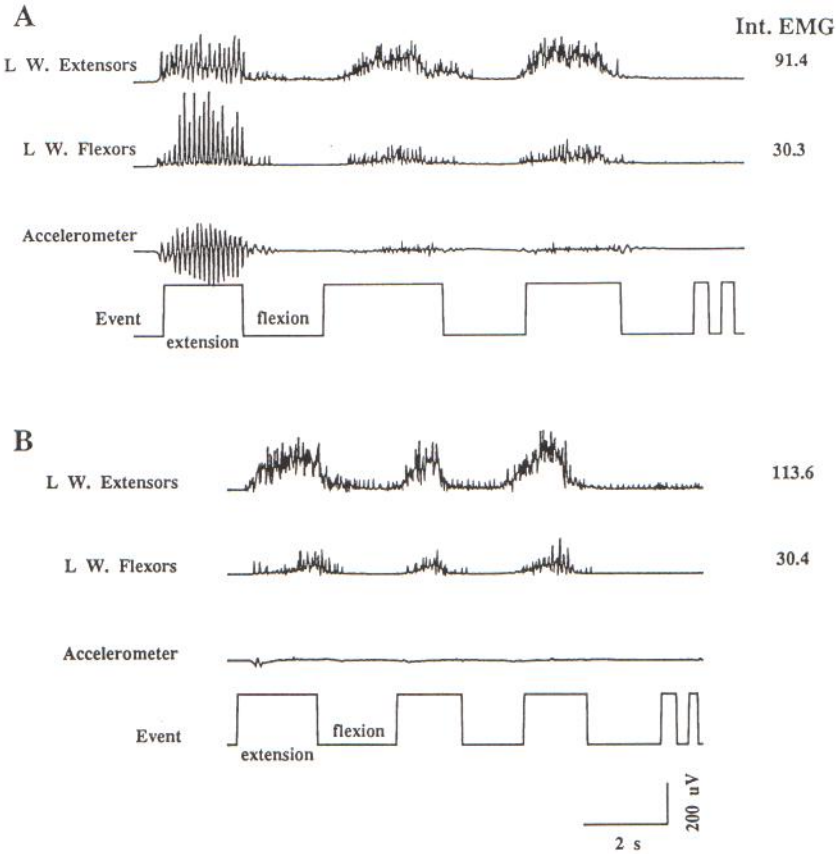

Fig. 1. PEMG recorded in wrist extensor and wrist flexor muscles of the paralyzed arm during attempts of volitional wrist extension and flexion, before (A) and after 6 months of the mesh-glove stimulation program (B). Numbers represent the averages of integrated EMG activity normalized for the duration of the extension phase in two respective muscles (units: μVs/s).

stroke, retraining of sensory functions of the hand can alleviate somatosensory deficit (9).

The presented clinical observations demonstrate that sensory subthreshold whole-hand stimulation resulted in the suppression of spasticity, and the subtle augmentation of volitional motor activity in the previously paralyzed upper extremity. Future studies will be needed to define a spectrum of effects and the possible underlying mechanisms.

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