EVALUATION OF USE OF FUNCTIONAL ELECTRONIC PERONEAL BRACE IN HEMIPARETIC PATIENTS

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In this report, an attempt to evaluate prolonged application of functional electrical stimulation in hemiparetic patients will be presented.

Functional electrical stimulation is, by our definition, electrical stimulation of muscles (both smooth and striated ones), deprived of nervous control, with the purpose to evoke muscle contraction (also, sometimes, muscle relaxation), yielding functional, useful movement.

This kind of stimulation was applied instead of classical braces and splints for the purpose of rehabilitation of patients with hemiparesis or hemiplegia, i.e., partial or complete paralysis of the muscles of one side of the body. This condition follows destruction of a definite structure in the CNS, i.e., the upper motor neurons, and may be due to a variety of causes, such as cerebral stroke, injury, inflammation, or tumor, the most frequent being cerebral stroke. The condition is characterized by spastic palsy of various muscles. During the first period following a cerebral stroke, the condition of paralyzed muscles gradually improves as a rule, so that their number and degree of weakness decrease. Very frequently, however, involvement of certain muscle groups is definite and irreversible. Damage to the peroneal muscle group with the consequent drop foot (Fig. 1) appears to be by far most common. Among 23 patients with hemiplegia or hemiparesis whose condition was stationary, 18 were found to have peroneal palsy, i.e., drop foot, which was in five of them the only permanent defect (Fig. 2). This, however, represents a major trouble in walking, which is characteristically changed: it is marked by slowiness during the swing phase of gait, by loss of suppression of normal synergistic reflexes and by circumduction in the hip joint.

The classical rehabilitation helped these patients with the aid of various mechanical splints and braces, which have certain disadvantages; above all, they usually impose a strain on other paretic and normal muscles.

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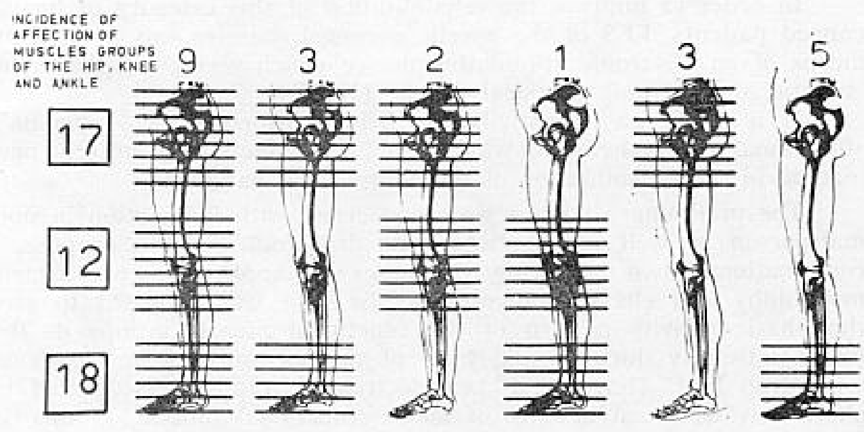

Figure 1. Distribution of weakness among different muscle groups among 23 hemiparetic patients with drop foot due to cerebral stroke

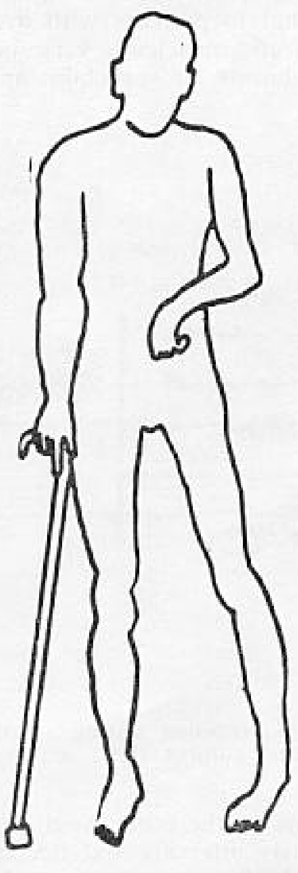

Figure 2. The characteristic gait of hemiparetic patient

In order to improve the rehabilitation of this category of handicapped patients, FES of the paretic peroneal muscles was applied by means of an electronic stimulating device which was given the name »functional electronic peroneal brace« (FEPB).

It is based on essentially the same principles as Liberson's »functional electrotherapy«, which can be considered an entirely new method in the rehabilitation of the neurological patients.

The preliminary studies were concerned with locomotion in normal persons as well as in patients with drop foot. For this purpose, a combination of two measuring techniques was applied, i.e., polyelectromyography and electrogoniography[2]. The first was expected to give the phasic activity pattern of the functional muscle groups of the lower extremity during walk, both of normal subjects and patients with drop foot. The second, i.e., electrogoniography, was applied to show how electrical activity of single functional muscle groups is related to phases of the walking cycle, as well as to demonstrate the mechanical changes in locomotion.

This method showed significant and characteristic differences between the electromyographic and electrogoniographic gait pattern in normal subjects and that in patients with drop foot. In the latter, electrical activity of paretic muscles is very inconstant: it may be continuous with irregular bursts, or very faint and incontinuous (Fig. 3).

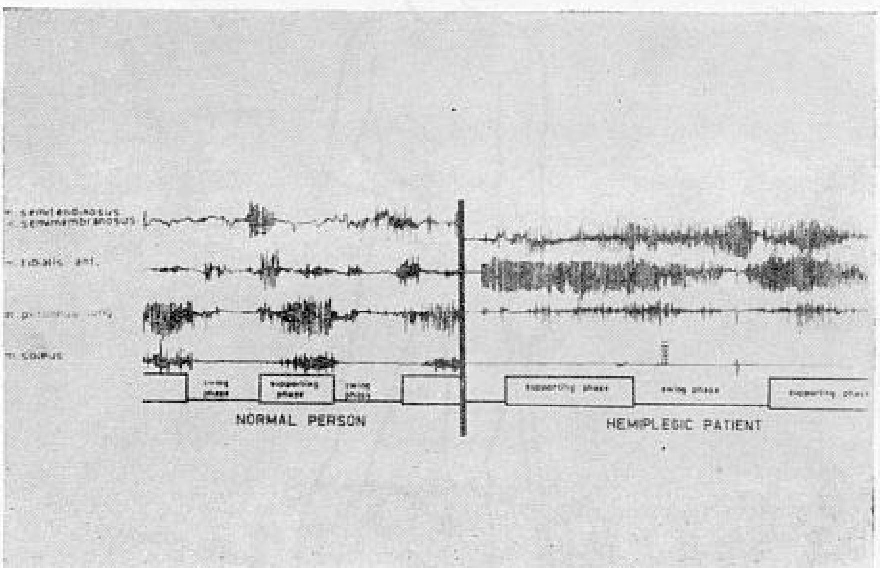

Figure 3. Electromyogram recorded during swing and supporting phases of the walk in the normal subject (left) and hemiparetic patient (right)

Electrogoniography, on the other hand, reveals that angle speed is increased in some phasis intervals and decreased in others, as compared to normal walk. It demonstrates also plantar flexion of the foot at the beginning of the supporting phase, which is considerably increased during the swing phase (Fig. 4). These are the factors which account for the mechanical changes in locomotion, and their study was of considerable help in the choice of the parameters of stimuli.

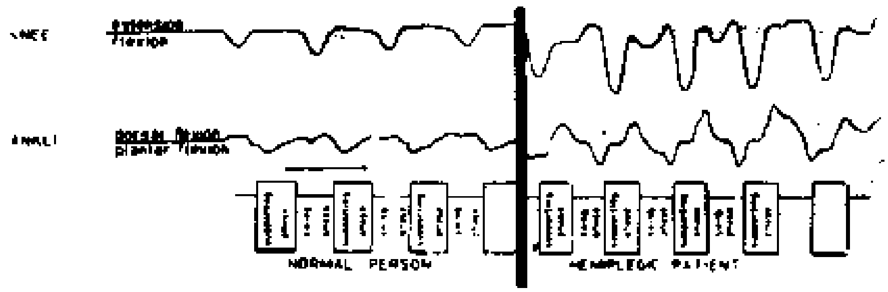

Figure 4. Electrogoniometry of knee and ankle joints in the normal and hemiparetic subject

Our FEPB consists of a miniaturized stimulator, stimulating electrodes and a heel-switch. The stimulator, which has adjustable frequency, duration and intensity of stimuli, is triggered by the heel-switch in the second half of the supporting phase of the walking cycle (Fig. 5).

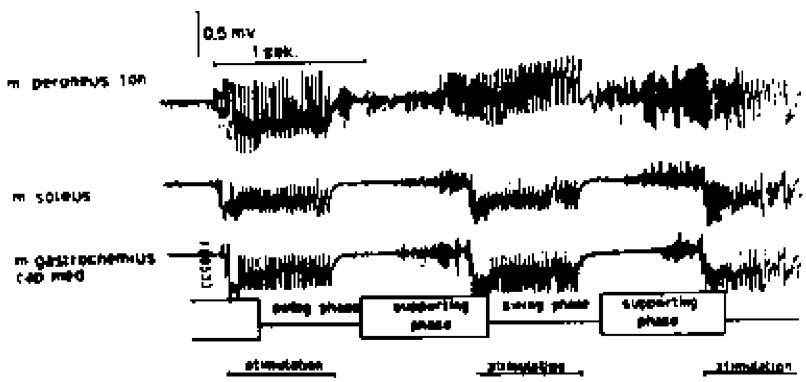

Figure 5. Electromyogram of a hemiparetic patient, recorded during walk aided by electrical stimulation

The main problems encountered were, apart from miniaturization of the stimulator, the choice of parameters of the stimuli, which must be painless and as little irritant as possible; further, duration of the tetanizing, choice of electrodes, which should be fixed so as to permit easy mounting, choice of the site of stimulation and mode of control of stimulation. The most convenient stimulus was found to be a rectangular one, with the following parameters: duration 0.1 msec; amplitude, 30—40 V; and frequency, 30—40 c/sec., the last varying individually within the indicated range. Duration of train is 0.8 sec. for a speed of walk at which 1 cycle is completed in 1.5 to 1.8 sec. In order to obtain a smooth and plastic movement, a gradual increase of amplitude at the onset as well as a gradual decrease at the end of the tetanizing is needed. The site of stimulation was chosen over the common peroneal nerve, on the skin behind the capitulum of the fibula, and some centimetres proximal (in the direction of the popliteal fossa).

The electrodes are square in shape, 2 × 2.5 cm., covered by plastic material to prevent drying, and, on the other hand, to prevent absorption of moisture. They are fixed permanently to the inner side of an elastic, knee-supporting bandage which provides a good contact with the skin, as well as easy placing. First applications of the FEPB and measurements were performed in eight patients whose only or most striking permanent defect was impairment of walk due to drop foot.

After the optimal conditions of FES had been established, the FEPB was applied for a longer period of time in order to observe its effects on walking mechanisms as well as the possible undesirable consequences.

With the described stimulation technique an optimal motor response, i.e., eversion of the foot, without uncomfortable sensations can be obtained. Besides, the size and strength of eversion can be controlled and adjusted according to need.

According to first experiences, locomotion of all our patients is greatly improved by the use of the FEPB. They are enthusiastic about the brace, which enables them to walk for long periods of time, and which is effortless and safe even in crowded streets at rush hours. They adopted the FEPB very quickly and developed various maneuvers with the heel-switch to make the movements smooth and fluid while standing and walking. Mounting of the complete stimulating device doesn't take more than 2—5 minutes and is performed every morning. Two of the patients have already left our Rehabilitation Centre with the FEPBs and are now using them in everyday activity for 4 — 8 hours daily. Best results were, of course, obtained in the group with »pure« drop foot, whereas in others with involvement of several muscle groups, the results were less favorable. However they performed better than they did, with classical braces. We observed, similarly to Liberson, that walk is somewhat improved and safer even a few hours after the application of the FEPB. We noted also that a short time after the first application of the FEPB the parameters of stimuli need to be changed, while the movements elicited by stimulation gradually become a more and more functional part of the mechanics of walking. An interesting observation is that in some patients spontaneous movements occur identical with those obtained by electrical stimulation. This happens a few hours after use of the FEPB, usually before sleep.

In repeated polymyographic recordings we could observe gradual restoration of the cyclical activation and inhibition of the stimulated muscles in harmony with the walking cycle, even in the absence of stimulation. It is clearly visible in Figure 6, the left side of which demonstrates polymyographic recording before the application of the FEPB, while the right side represents the recording of the same muscles taken after one and a half month's training with the FEPB.

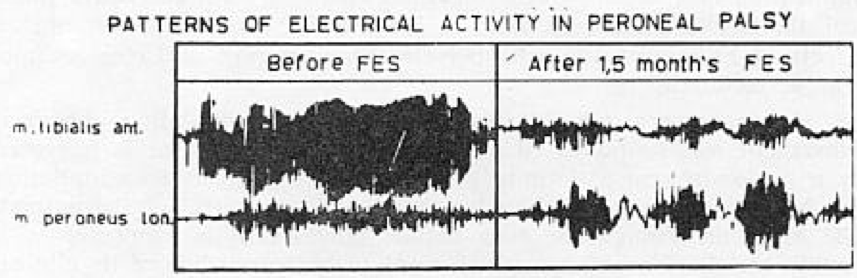

Figure 6. Electromyogram of a patient with hemiparesis, recorded before and after 1½ month training with functional electronic peroneal brace

These observations suggest that FES does not represent a mere production of orthodromic impulses, which are conducted from the sites of stimulation to the muscle, evoking its contraction. Apart from this, an additional ortho- and antidromic afferent conduction of impulses is involved, the former including those from proprioceptive and exteroceptive receptors. It is evident that important mechanisms, which

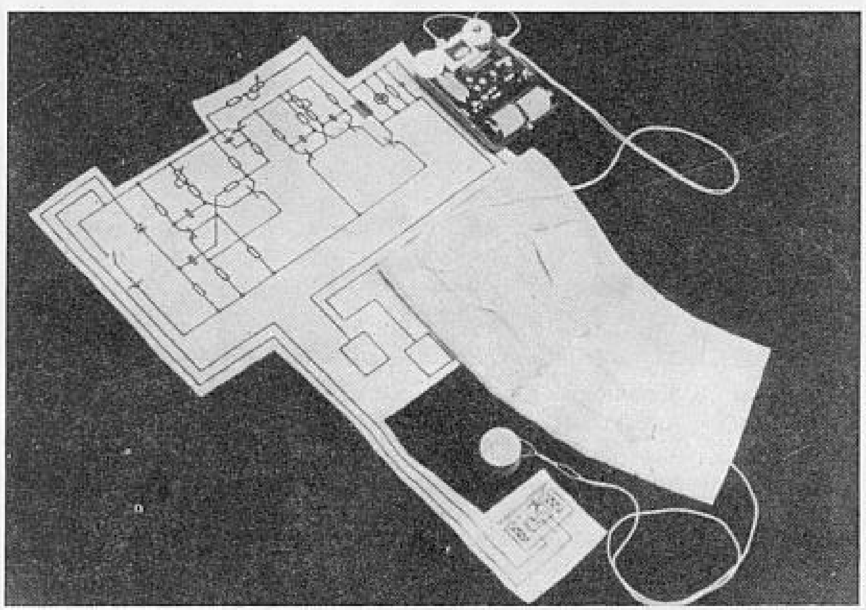

Figure 7. Functional electronic peroneal brace — opened stimulator and circuit diagram

affect the motility in locomotion, are activated at the spinal level; these were discussed in another report to this Symposium.[5]

Our first experiences and evaluation have shown that the FEPB could improve the walk of our patients more successfully than the application of classical braces together with long-term corrective physical therapy. A useful method of observation and evaluation of the effects of FES is provided by polyelectromyographic and electrogoniographic technique.

Among several possible ways of control of stimulation, the most convenient was found to be one by which the stimulator is triggered by a heel-switch in a definite phase of walking cycle: so stimulation can be both automatic and under the conscious control of the patient. The myocontrol might be even better; however, it is connected with certain technical problems, which need to be solved before its clinical application and evaluation.

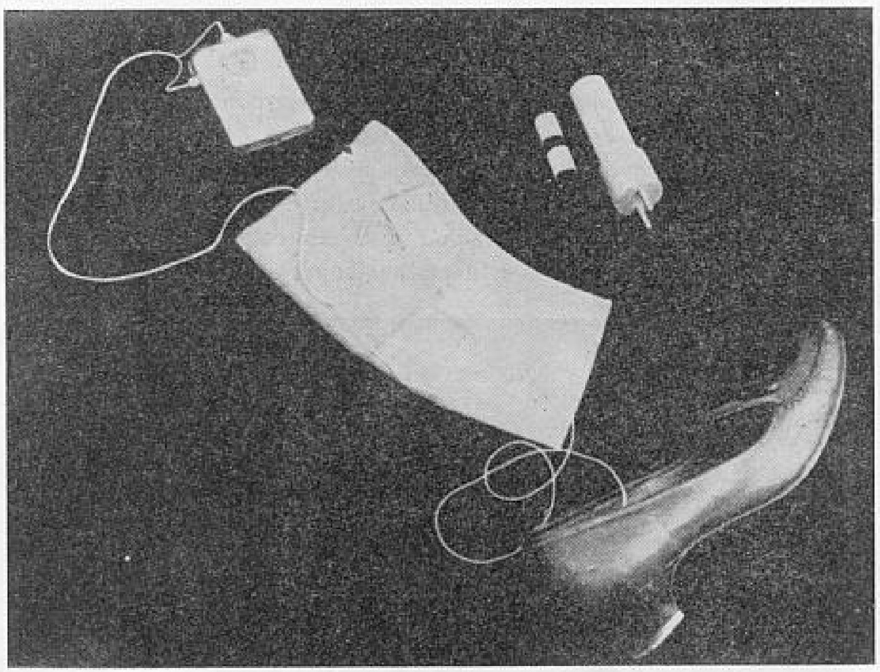

Figure 8. Functional electronic peroneal brace and battery with charging unit

It must be realized that there exist certain limitations for the application of the FEPB. The patients must be cooperative and without behavior disturbances and intellectual impairment, since they are expected to take care of the devices and their adjustments.

Further progres in FES of the paralyzed lower limbs is expected; it will demand, however, advanced theoretical knowledge about neurophysiological mechanisms of gait.

Summary. Functional electrical stimulation of the peroneal nerve was applied by means of an electronic device (»functional electronic peroneal brace«) for the purpose of rehabilitation of the patients with drop foot due to upper motor neuron involvement. Several problems had to be solved, e.g., that of prolonged electrical stimulation, which must not be uncomfortable or injurious. Apart from clinical observations, polyelectromyographic and electrogoniographic techniques were used in evaluation of the efficiency of functional electrical stimulation. It can be concluded that our FEPB represents an effective system capable of improving the walk of our patients with drop foot more successfully than braces together with long-term corrective physical therapy.

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