Functional Electrostimulation: Some Clinical Uses of the Electronic Peroneal Brace

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SUMMARY

The mechanism of operation of a commercially available electronic peroneal orthotic brace is described. The application of the device to several patients is discussed. Observations are recorded on some patients with apparently permanent paralysis and others in the process of recovery from spinal injury. Comments are made regarding functional electrostimulation and improvements to equipment.


Electrostimulation has long been used by physiotherapists in the treatment of paralysis. Until recently, such electrostimulation had always been employed in a non-functional way, that is with the patient lying or sitting, with surface electrodes attached to a muscle or near to the nerve supplying the muscle to be exercised. Often a heavy and bulky mains-operated electrical stimulator supplies the required pulses to produce the desired contractions. With great strides made in recent years in the construction of light and compact battery-operated electronic devices, attention has been directed towards providing functional electrostimulation, that is in providing electrostimulation of the paralysed muscle at an appropriate intensity level, and with the correct timing to allow it to play its proper part in the co-ordinated movement of the limb it serves. The condition most amenable to the application of functional electrostimulation is foot drop, where the dorsiflexing and everting action of the foot is absent or is deficient, as a result of an upper motor neurone lesion. This condition is sufficiently disruptive to the patient's gait to make it a well worthwhile aim of treatment, while at the same time not requiring a very fine degree of control. What is required is that the foot mainly dorsiflex and evert to some degree as the affected leg starts to swing forward, thus preventing it from scraping along the ground during the swing phase, and that the aforementioned actions cease as the heel again makes contact with the ground. The exact degree of movement required is not critical, provided it is more than a certain minimum, and there is no thrusting, weight-bearing or balancing action to be considered.

Two groups in particular have developed commercially available functional electrostimulation devices to overcome this condition. Van Leeuwen and Vredenbregt developed the Philips peroneal brace, and Gracanin and Grobelnik were involved in the development and evaluation of the Ljubljana functional electronic peroneal brace. The use of the Philips peroneal brace, several of which were acquired by the Department of Bio-Engineering and Medical Physics at Groote Schuur Hospital, is discussed here and some observations are recorded on some patients with apparent permanent paralysis and others in the process of recovery from spinal injury. Finally, some comments are made regarding improvements to equipment and further possible applications of functional electrostimulation.

THE PERONEAL BRACE

The peroneal brace, intended for patients with drop foot on one side only is shown in Fig. 1.

In the upper left-hand corner is a rubber air cushion which is worn inside the shoe on the unaffected side. A flexible rubber tube leads from the air cushion to the stimulus generator on the right-hand side, and usually the generator is supported by a belt around the waist. When weight comes on to the unaffected foot, the pressure in the air cushion increases. The pressure increase is transmitted via the rubber tube to a pneuo-
matic switch in the stimulus generator and switches the stimulator on, just as the affected side enters the swing phase. The stimulator operates on a single 22V-volt battery, and produces a 50 Hz square wave current output, each pulse being about 0.5m/sec duration with a maximum current of 10 mA, and maximum voltage of 100 volts. The stimulating current passes via a twisted pair of leads to the bipolar electrode which is seen at centre bottom of Fig. 1. This consists of a central metal pin, which constitutes the cathode, or active electrode. There is a circular recess round the pin, into which is inserted a small piece of sponge, moistened beforehand with tap water, which serves to provide good electrical contact. Outside this is a ring of insulating plastic, and then a conducting rubber pad which forms the anode. The electrode pad is attached just behind or to the side of the knee, over the lateral popliteal nerve. The current flows from the conducting pad, through the patient's leg to the metal pin. The stimulus level is set by the patient by adjusting the control visible on the front of the stimulus generator, between '+' and '-' signs, these being the directions of rotation for increased or decreased stimulation respectively. Fig. 2 shows a patient wearing the device.

RESULTS OBTAINED WITH THE PERONEAL BRACE

An evaluation of the brace was attempted on two categories of patients: (i) those in whom permanent paralysis was apparent; and (ii) those still in the process of recovery from spinal injury.

Category 1

A 57-year-old female had had a left-sided stroke 9 years before, and since then had been wearing a mechanical brace to correct foot drop. Her physiotherapist had been applying regular electrostimulation, so that her tibialis anterior had been maintained in a relatively good condition. A peroneal brace was fitted on her in January 1972 and operated so successfully, that the patient has since purchased her own brace. Apart from overcoming drop foot the device has had a valuable secondary effect in relieving the patient of the considerable discomfort caused to her by a continual flexion of the big toe. While wearing the brace this flexion is eliminated. Because of paralysis of one hand, someone has to fit the device for her each morning. She observes that a rather higher stimulating current is needed earlier in the day than later on. There has been no improvement in voluntary muscle function when the brace is taken off.

A 34-year-old male had suffered from left-sided foot drop for several years, due to TB meningitis. The patient was fitted with a peroneal brace in January 1972, and it has been working well since then, providing adequate simultaneous dorsiflexion and eversion. There have been a few breaks in its application, due to skin sensitivity and a rash developing under the electrode pad, but this clears up quickly after a few days without wearing the device. It is interesting to note that the patient's functionality without the device has improved over the several months of use. He has indicated that shoes which previously lasted 2 months before requiring repairs to the undersole, now last 4 months. Before using the brace he usually had an ache in his leg by 1600 h, and this has now disappeared.

So far these are the only 2 patients who have been wearing the brace for extended periods. Two patients who at first seemed well suited for the brace, afterwards rejected it.

A 13-year-old boy, with right-sided paralysis arising from a brain tumour which had been removed 4 years previously, walked well with the brace on, but its use was discontinued after 6 weeks because he was too embarrassed to wear the device when playing with friends while wearing shorts. Also when barefoot the device is not usable.
A 9-year-old girl, who suffered a brain haemorrhage at 4 years of age, presented with a flaccid equinus of the left foot and was fitted with a peroneal brace. Excellent movement was obtained. Initially the patient got on well, but rejected the device after a few weeks, saying that the stimulation was too uncomfortable.

Category 2

Physiotherapists at Conradie Hospital have been fitting the peroneal brace to suitable spinal injury cases, i.e. those who have recovered sufficiently to be able to walk with the aid of sticks or crutches, but who are hampered by foot drop. In a series of 8 patients 6 have walked well with the brace. Being relieved of the need to struggle to overcome foot drop, they were enabled to walk both more easily and faster. Balance was considerably improved and it was often possible for a patient to discard one of the two walking sticks. Bearing in mind that this is a small number of cases from which to judge, the impression is that recovery has been speeded up. Table I summarizes their progress, the power scale being given according to the standard Oxford rating.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Period over which stimulator worn (weeks)</th>
<th>Power of tibialis anterior Initially</th>
<th>Power of tibialis anterior Finally</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>3 (continuous)</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4 wearing</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>2 and</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>1 walking</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>2½</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

The patients all discarded the device once their muscle power had returned to a certain level, presumably when the inconvenience of wearing the device could be equated with that due to their muscular weakness. Three of these patients were able to fit the device independently after a brief period of instruction. This enabled them to persist with the device over weekends and other occasions, when physiotherapy is not normally available. In the remaining 2 patients, one demonstrated an unsatisfactory response to stimulation; the other yielded good muscular contractions unfortunately accompanied by hypersensitivity, due to the spinal cord injury.

Mechanical and Electronic Faults

A number of breakdowns of the peroneal brace have occurred, the most common fault being a break in the connecting wire between the stimulus generator and the electrode pad, or breakages in the connecting plugs at the ends of these wires. A defective pressure switch was responsible for one breakdown, and a loose piece of solder shorting across components in the electronics pack for another. The plastic clip which is used to fasten the stimulator pad round the leg, tends to break easily. Potential purchasers of the device should ensure that service facilities and spare parts are readily available to them.

DISCUSSION

In properly selected cases, the peroneal brace is capable of rendering patients with foot drop virtually normal function. In recovering cases of spinal injury, it is apparent that the recovery process is facilitated and may even be accelerated.

It should be borne in mind that not only is a muscle stimulated, but also portions of a partially intact nervous system. This fact is emphasized by the observation in the 34-year-old male patient, where functionality without the brace has improved with the passage of time. Aleyev and Bunimovitch allude to this point, and are optimistic about the possibilities of reprogramming the damaged neuromuscular system with the aid of programmed regimens of electrostimulation. Improvements to the peroneal brace are possible. Among them is a radio frequency switch mounted in the shoe, so as to avoid wires or the pressure tubing leading from the shoe to the stimulator. Jeglic et al. have developed a suitable switch-transmitter and switch-receiver system, to achieve this end. Another possibility is the use of suitable myo-electric signals to trigger the brace. Jeglic et al. have been experimenting with implanted electrodes, where the electrode is actually implanted round the nerve in question. This gives great selectivity of muscle function, overcomes pain because of the lower stimulation levels required, and avoids the need for recurrent positioning of electrodes on the patient. This together with an implanted switch-transmitter, would resolve the cosmetic problems such as those which led to rejection of the brace by the 13-year-old boy.

Given that the technical problems of implanted electrodes may be satisfactorily solved, there remains one major obstacle which must be overcome before electrostimulation can be practically used for the functional stimulation of two or more different muscle groups. This is how to provide the electrical stimulus at the correct time, and with the correct intensity. As mentioned earlier, the tibialis anterior is relatively non-critical as to the fineness of degree of control needed. It is a relatively simple matter to build a stimulator to play a fixed 'programme' of stimulation to say 3 groups of muscles, e.g. tibialis anterior, gastrocnemius, quadriceps, in one leg, such that the patient might walk at a steady pace on a smooth flat surface. Some preliminary work along these lines has been reported by Milner and Quanbury. Kralj et al. have developed a 3-channel programmable functional electrostimulation system for hemiplegics, the programme being remotely triggered by a heel-switch transmitter. Effort such as this, concentrated on hemiplegics, where one sound leg is available to provide balance and general stability, promises to be fruitful.

The major problem is to build into the system the flexibility of movements so vital in everyday life, (for example, to enable a patient to negotiate a small object such as a pavement curb, and to deal with changes in terrain). In a normal person, the eyes, among other sensory inputs, would provide advance warning that a
step was coming and the necessary adjustments made automatically by the brain. To achieve such control without highly complex and expensive electronic systems, investigations to determine the utilization of suitable control signals, which could be provided by the patient, are called for.

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**History of Medicine:**

**Jewish Ethics in Relation to Medicine**

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**SUMMARY**

Irrespective of individual beliefs and practices, Judaism presents itself as encompassing all of life from conception to death. Accordingly medicine is but a semi-autonomous branch of the larger whole, and the physician-prophet, physician-priest and physician-rabbi have characterized Jewish life until very recent times. Religious insights still illumine medical dilemmas today, though these dilemmas are far from solved; new problems require rethinking of old answers. Jewish medical attitudes have been pragmatic and experiential rather than arbitrary and of 'natural law' character, and are chiefly concerned with the need to preserve life. There is an unbroken tradition of devotion to hygiene and medical practice dating from Moses, the first practitioner of preventive medicine.


... and live by them ... Leviticus 18:5,
... not die by them. Talmud, Yoma 85b

For a people given to invoking 'Thus saith the Lord . . . ' there is a curiously paradoxical attitude to the instructions of the Lord. They are ignored, they are contested, and they are debated, from the days of Abraham to this very day. This critical attitude colours everything relating to the life of Jews, including the practice of medicine. Jews could never find a reason for forbidding blood transfusions on the basis of 'Thus saith the Lord . . . ' or for having doubts about priorities, where one must choose between the life of a mother or her unborn child. If God's commandments be dubious or unacceptable, Jews easily find a way to circumvent them. This may seem a strange, even blasphemous, attitude to Moslems (the word Islam means submission to God's will), for whom the will of Allah is supreme, never to be contested, or for Christians, for whom 'thy will be done' (Matthew 6:10) is the end of the matter.

Jews argue with their God, Who has ample reason to call them a defiant and obdurate people, but Who also had the good grace, and the humour, when worsted in a proxy debate with the 1st-century Rabbi Joshua, to admit defeat and chuckle with divine joy that one of His creatures had defeated Him. (Gloss on Talmud, Baba Metzia 59b.)

Does this sound like religious lunacy? Not at all. God is not absolute for Jews, only a senior partner to a contract, a covenant. Jews share a particularly warm and intimate relationship with the God Who chose them to be His peculiar people. This people Israel is likened to a child, God's son (Exodus 4:22, Deuteronomy 14:1, Isaiah...