A preliminary non-randomised study to evaluate the safety and performance of the ActiGait implanted drop-foot stimulator in established hemiplegia

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Abstract

Correction of drop-foot using surface functional electrical stimulation has been shown to be clinically effective, but patients have reported problems with electrode positioning, skin irritation and the inconvenience of external leads and electrodes. Implanted systems have until now been unable to control inversion and eversion, as components of normal ankle lift during walking. The ActiGait implanted drop-foot stimulator uses a cuff around the common peroneal nerve (just proximal to the bifurcation into deep and superficial branches) within which are four sets of electrodes that, by activating different nerve fascicles may allow individual control over inversion and eversion as well as dorsiflexion. The data presented here were collected as part of a non-randomised trial with 15 subjects to evaluate safety and performance of the device in preparation for CE marking. The study has shown that the system is well accepted by users, no incidence of changes in nerve conduction velocity and statistically significant improvement in a range of walking parameters.

1 Introduction

Stroke is the third leading cause of death in the United States and other developed countries and a major source of disability [1][2]. According to Duncan [3] 350K Americans survive a stroke each year, and nearly 3M have some degree of stroke-related disability. In the UK stroke consumes 4% of the NHS budget. The problem of drop-foot has been the focus of treatment with FES for many years and surface systems are now becoming clinically accepted. A study to evaluate the ODFS from the patient’s perspective identified that problems with the system were concerned with donning and doffing - particularly accurate positioning of electrodes and irritation of the skin following prolonged use. Both these issues can be overcome by an implanted system, yet such systems have as yet failed to achieve clinical acceptance. One important reason may be that they have not allowed sufficient control over which nerve pathways are stimulated to achieve a balanced normal dorsiflexion.

2 Method

The ActiGait is an implantable drop-foot stimulator comprising an implant, control unit, heel switch and clinical station (Figure 1). The design of the system allows independent adjustment of output from four channels of stimulation via one nerve cuff. The implant cuff is placed around the common peroneal nerve just proximal to its bifurcation into deep and superficial branches to the anterior tibial and peroneal muscles. At this point the nerve fascicles have become spatially organized within the nerve so that each set of electrodes within the cuff is adjacent to fascicles travelling to different motor points or muscles, thus potentially activating slightly different movements. A cable from the nerve cuff travels subcutaneously to the receiver, implanted on the lateral aspect of the upper thigh. An antenna is positioned on the skin over the receiver and is hard wired externally to the control box worn on the belt. The user is able to switch stimulation on and off and make small adjustments to levels via the controller. Stimulation is activated by a RF footswitch
worn in the shoe. This design avoids many of the inconvenient aspects of external systems. The only external wire is between the control box and the antenna. Because the receiver is positioned on the upper thigh positioning the antenna over it does not involve bending or awkward turning. Stimulation parameters are set up within the control unit via the clinical station - a standard computer (PC) and graphical software program. The clinician can control frequency, pulse duration, ramping, amplitude and timing of each channel and can test the effect of individual and combined channels of stimulation.

2.1 Study design
A consecutive sample of subjects, recruited from three stroke rehabilitation centres in Denmark, acted as their own controls. The effect of stimulation was measured by comparison with pre-implantation values (two sets of baseline measurements were taken to avoid bias related to unfamiliarity with the assessment procedure) with measurement taken 90 days later. The effect of stimulation was measured by comparisons between baseline 2 values and measurements made with stimulation at 90 days and the orthotic effect by comparison with and without stimulation at the 90 day follow-up assessment. As this was a pre-CE marked study, safety issues were addressed and all device related, and non-device related adverse and serious adverse events were documented. Patient’s acceptance of the device was assessed by an independently administered questionnaire.

2.2 Subject selection criteria
All subjects gave informed consent and were over the age of 18. Subjects had a drop-foot following a stroke at least six months prior to recruitment. Drop-foot was defined as: lacking ability to obtain normal heel contact during gait. All subjects had at least 30 degrees passive ankle movement and were able to stand upright with heels touching the floor when the hip and knee were in a neutral position. Subjects had a positive response to surface stimulation – muscle contraction resulting in ankle dorsiflexion and improved gait. Subjects who were unable to walk 100 m without stopping prior to their stroke and who either walked faster than 1.2ms or were unable to stand without an AFO at the time of screening were excluded. Further exclusion criteria were applied for safety reasons, such as a history of falls or uncontrolled epilepsy and the presence of other implanted devices such as a cardiac pacemaker. The study was approved by the Local Ethical Committees.

2.3 Procedure
This was a prospective multi-centre study using repeated measures over a period of 90 days taken with and without stimulation. Outcome measures were applied prior to implantation on two occasions, one week apart, to ensure that patients were familiar with the procedure and to detect any statistically significant changes during this non-intervention period. Data from the second visit was used in the analysis to compare changes over time.

2.4 Outcome measures
The primary safety outcome was the incidence of device related Adverse Events. Nerve conduction velocity of peroneus profundus (supplying the extensor digitorum brevis and tibialis anterior muscles) and peroneus superficialis (supplying the peronei muscles) were measured prior to implantation and >90days post surgery. The performance outcomes reported here, were distance walked in four minutes around a 20m figure of eight walkway and walking speed. Both were recorded with and without stimulation. Order of the tests was randomised and subjects were allowed to rest between tests. The patients’ perception of the ActiGait system was evaluated subjectively via an independently administered questionnaire based on one used with a surface system [4].

2.5 Statistical analysis
Mean (95%CI) are presented for changes in each variable. Changes in walking variables with respect to time and use of stimulation have been analysed using paired t-tests.
3 Results

Fifteen subjects were recruited from three stroke rehabilitation centres. Two subjects were withdrawn from the study due to device related problems. In both cases this was found to be due to the cuff being too large; both have now been re-implanted with a smaller one. There were no reports of changes in nerve conductance velocity as a consequence of constriction by the cuff-electrode or the surgical procedure. Distance and speed data recorded during walking are presented for 13 subjects. For each variable the effect of stimulation is presented as a) the effect of stimulation (changes from baseline at 90 days measured with stimulation) and b) orthotic effect (differences with and without stimulation) measured at the 90 day follow-up assessment. Results from the questionnaire (n=12) identified that 91% of subjects used the stimulator everyday and 82% for over 9 hours each day. 82% could don the stimulator without help, 63% in less than three minutes and the remainder in less than six. As with Taylor et al’s study the most ‘popular’ reason for using the stimulator reported was to make walking less effort. 90% of subjects also reported that with it they were less likely to trip or fall.

a) Effect of stimulation over time (n=13)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Means</th>
<th>Baseline 2 vs 90 days</th>
<th></th>
<th>P Value</th>
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<tbody>
<tr>
<td></td>
<td>B2</td>
<td>90 days</td>
<td>Mean difference (95% CI)</td>
<td></td>
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<tr>
<td>Distance walked in 4 mins (m)</td>
<td>115.7</td>
<td>124.9</td>
<td>9.2 (-19.13, 0.067)</td>
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</tr>
<tr>
<td>Walking speed (m/s)</td>
<td>0.48</td>
<td>0.53</td>
<td>0.05 (-0.089, 0.001)</td>
<td>0.054</td>
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b) Orthotic effect of stimulation (n=13)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Means at 90 days</th>
<th>Mean difference (95% CI)</th>
<th>P Value</th>
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<tr>
<td>Distance walked in 4 mins (m)</td>
<td>115.4</td>
<td>124.9</td>
<td>9.5 (-16.55, -2.53)</td>
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<tr>
<td>Walking speed (m/s)</td>
<td>0.49</td>
<td>0.53</td>
<td>0.04 (-0.063, -0.004)</td>
</tr>
</tbody>
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(Figures in bold indicate p<0.05)

4 Discussion and Conclusions

Our results show a similar orthotic improvement in walking speed as a previous study of surface stimulation [5]. In this study the stimulator was set-up and evaluated by expert users of the device whereas in our study testing was performed by therapists working in a clinical environment. Patient satisfaction was high, no nerve damage has been shown relating to the cuff or surgery and both cases of malfunction seem at this stage to have been rectified by using a smaller cuff. Measuring performance of the stimulator as subjects walk on an even surface may not be the most sensitive or realistic way to evaluate it and in future studies we are considering asking subjects to walk over an uneven surface, including ‘natural’ distractions such as background noise and require the subject to look ahead while walking rather than at their feet or the floor.

References


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