Recent Developments in Implantable and Surface Based Dropped Foot Functional Electrical Stimulators

L. Kenney¹, P. Taylor², G. Mann², G. Bultstra³, H. Buschman⁴, H. Hermens⁴, P. Slycke⁶, J. Hobby², N. van der Aa⁵, B. Heller⁷, A. Barker⁷, D. Howard¹, N. Sha¹

¹University of Salford, UK; ²Salisbury District Hospital, UK; ³University of Twente, the Netherlands; ⁴RRD bv, the Netherlands; ⁵TWiN, the Netherlands; ⁶Xsens Motion Technologies bv, the Netherlands; ⁷University of Sheffield/Sheffield Teaching Hospitals Trust, UK.
l.p.j.kenney@salford.ac.uk

Abstract

One approach to improving the gait of patients with foot drop is the use of functional electrical stimulation (FES) as a neural prosthesis. However, there remain limitations with the current clinically used technology and the paper describes some recent developments addressing some of these problems. The paper describes initial work on an alternative surface-based solution and recent developments of an implantable two channel stimulator.

Keywords: Functional electrical stimulation, drop foot.

1 Introduction

Drop foot is a condition found in significant numbers amongst stroke, cerebral palsy, partial spinal cord injury, multiple sclerosis and other populations. The condition comes about through a loss of central control over movement of the foot and is characterized by weakness in the muscles that dorsiflex (lift) the foot, and/or spasticity in the plantarflexors (muscles that act to lower the foot). This results in reduced dorsiflexion during the swing phase of gait and an inability to achieve heel strike at the beginning of stance phase. Typically at the end of swing phase in drop foot gait the foot lands plantarflexed and sometimes inverted, whereas in healthy gait the foot lands dorsiflexed and slightly everted. Compensatory strategies are required to clear the ground during the swing phase of gait and the net re-
The result of these impairments and compensatory mechanisms is gait that is tiring, unsteady and slow.

There are a number of treatment options for drop foot patients, including physiotherapy, use of an ankle foot orthosis (AFO) and Botulinum Toxin (BoTox). The evidence base for the long-term effectiveness of any of these treatments is variable in both quantity and quality and in certain cases, rather poor. An alternative approach, first demonstrated in the early 1960s, is the use of artificially generated electrical pulses to stimulate activity in peripheral muscles, in this case muscles that control the ankle [1].

Functional electrical stimulation is the electrical stimulation of a peripheral nerve to generate nerve impulses (or action potentials) sufficient to produce functional activity in a muscle [2]. The effect of FES using conventional surface mounted electrodes is complex. Stimulation acts not only on the muscles directly supplied by the stimulated nerve, but also, via reflex action, to inhibit or stimulate other muscles. Secondly, when stimulation is delivered via a pair of conventional surface electrodes, the effective stimulation field, the volume within which stimulation levels are sufficient to generate action potentials, is difficult to control in a systematic way by adjusting electrode placement on the skin. This results in difficulties with only recruiting the targeted muscle groups. This problem is termed selectivity and is a well established limitation with surface stimulation.

There are a number of clinical FES systems currently available for patients with drop foot. The vast majority of these are based on the principle originally described by Liberson in 1961. In order to understand the principles of drop foot FES, it is useful to consider the relevant anatomy.

Fig. 1. The common peroneal nerve, showing its major branches and the muscles supplied

The common peroneal nerve divides at the head of the fibula into the deep and the superficial peroneal nerves. These supply both the musc