Development of Gait Assist Device for Foot Drop Patients

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Abstract

Some of foot drop patients can generate voluntary electromyogram, which is not sufficient to dorsiflex an ankle joint. We developed a gait assist device that employs an electrical stimulation for these patients. When surface EMG of tibialis anterior muscle is observed, an electrical stimulation is applied to the same electrodes. The stimulation is repeated 15 times per second with bipolar pulses with the duration of 0.1 to 0.5 ms. The pulse duration is changed according to the amplitude of the voluntary EMG. The duration is calculated with a microcomputer. The device is worked with a 006P-type dry battery (9 V), and is mounted on a knee supporter for sport players. The electrodes are also mounted on the inner side of the supporter for easy don and doff. Patients improved the foot drop and inversion of their ankle joints.

Introduction

Drop foot is one of the sequelae of stroke. For those patients an ankle-foot orthoses (AFO) is widely used.

Some of these patients can generate voluntary electromyogram, but it is not sufficient to dorsiflex the ankle joint. If we can detect the EMG and give electrical stimulation to the same muscle, the patients can walk without the AFO.

We developed a gait assist device that employs an electrical stimulation for these patients.

The studies on electrical stimulation that restore standing and walking after spinal cord injury or stroke are being done by the group of University of Alberta (Canada), the group of University of Ljubljana (Slovenia), and the other. [1]-[3] Several types of devices that assist walking have been developed by now. One type of the devices is equipped with a force sensor mounted under the heel of the healthy leg for triggering the stimulation, e.g. SAMMS (BEAC Biomedical, Italy). Another type is triggered by EMG with a special optional sensor. Or tilt sensors are being applied to the detection of gait phase.[2] The other type of the devices controls the parameter of electrical stimulation by the amplitude of EMG, as our developing device does. [4] But in the conventional device, two sets of electrodes for stimulation and measuring electrodes are needed.

We intended to develop a more miniaturized and simpler device for daily use.

Design and Development of the Device

Our device stimulates common peroneal nerve that governs dorsiflex muscle group, i.e. tibialis anterior m. (TA), extensor digitorum longus m., fibularis longus m. (FL), fibularis brevis m. (FB). The latter three muscles also work to everse a foot. The block diagram of the device is shown in Fig.1. One of the electrodes is mounted on TA belly and the other is on its origin where the common peroneal nurve runs. When the electrodes detect voluntary EMG, it is amplified and transferred to a microcomputer (PIC16C711; Microchip, USA), which A/D converts the EMG and calculates the stimulation pulse duration, according to the EMG amplitude.(Shown in Fig. 2) The pulse repetition is pre-determined as 15 Hz. The microcomputer generates a proper pulse train and it is transferred to a stimulation circuit. The stimulation circuit is connected to the same electrodes that detect voluntary EMG. Since the stimulation voltage is thousands times larger than voluntary EMG, the microcomputer switches off the EMG from the stimulation circuit in order not to be interfered from the stimulation artifact.

The device is worked with a 006P-type dry battery (9 V), and mounted on a knee supporter for sport players. The electrodes are also mounted on the inner side of the supporter, for the easy don and doff.

It is one of the features of our device that it conducts both of output of stimulation and detection of the EMG by one set of electrodes. It made easy to attach the device and electrodes.

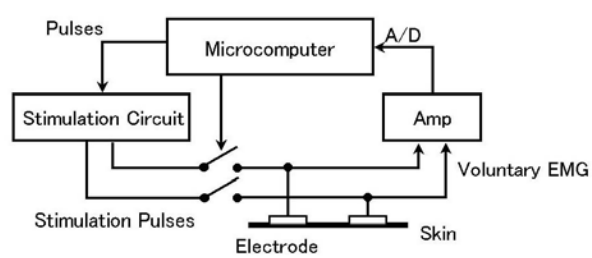

Fig. 1 The block diagram of the device

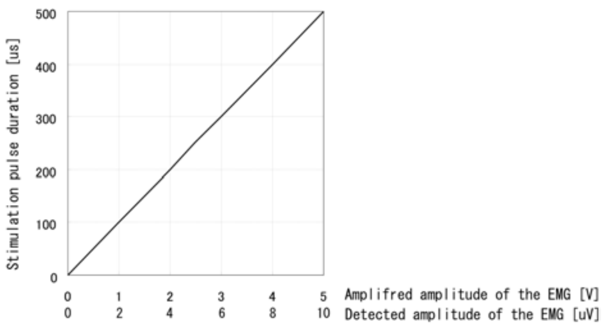

Fig.2 Control of the stimulation pulse duration according to the EMG amplitude

Results and Discussion

The device was used for two stroke patients (57 y/o male, and 55 y/o female), after informed consent. They have drop-foot and spasticity of gastrocnemius m. and hamstrings m. They daily walk with an ankle-foot orthoses and a T-cane.

They could walk with our device and a T-cane. Stimulator was on, at the start of swing phase and stance phase, when dorsiflex muscle group contracted and the EMG of these muscles were detected. (Shown in Fig. 3) Their inversions were found to be improved by a video picture analysis. (Shown in Fig. 4) Thus, the splasticity seemed to be decreased. It should be proved by the decrease of the EMG of gastrocnemius m. and hamstrings m.

Since they could smoothly swing affected leg, by using our device, their gait speed became faster than the speed without stimulation.

Since after stop using the device they returned to the previous gait posture, the device seems not to give plastic effects to the spasticity.

The device was so compact that a patient could easily put on and take off.

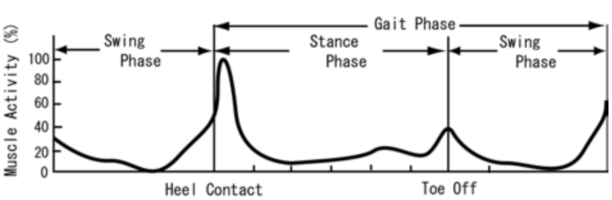

Fig. 3 The period of activity of tibialis anterior m. in gait [5]

(a) (b)

Fig. 4 Appearance of gait with stimulation (a), and without stimulation (b). Inversion is disappeared in (a).

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