

# Enhancement of Gait Retraining by Electrical Stimulation of Flexor Reflex Afferents in Acute Stroke Patients: A Randomized, Controlled Clinical Study

**Quintern J<sup>1</sup>, Krewer C<sup>1</sup>, Bisle G<sup>1</sup>, Husemann B<sup>1</sup>, Heller S<sup>1</sup>**

<sup>1</sup> Neurological Hospital Bad Aibling, Kolbermoorer Strasse 72, D-83043 Bad Aibling, Germany

Email: jquintern@schoen-kliniken.de

Website: www.schoen-kliniken.de

## Abstract

*A randomized, controlled clinical study of gait retraining with and without electrical stimulation of flexor reflex afferents synchronized with the gait cycle was conducted in severely affected hemiparetic patients after acute stroke (n = 38).*

*After 4 weeks of gait therapy there were significant and long lasting improvements of walking speed in the group receiving afferent functional electrical stimulation (FES group) compared to the control group. Also, gait symmetry had improved more in the FES group than in the control group. Also, more patients in the FES group achieved independent and functional walking than in the control group.*

*It can be concluded that electrical stimulation of flexor reflex afferents during gait retraining improves the rehabilitation of gait in non ambulatory hemiparetic patients after acute stroke and that this new kind of therapy may be an alternative to treadmill training or mechanical gait trainers .*

## 1 Introduction

Already at the beginning of the 20<sup>th</sup> century C.S. Sherrington [1] and other scientists discovered the relevance of the spinal neural networks for the control of locomotion. Within the last few decades these rhythm and pattern generating networks have been widely identified in several species, e.g. the lamprey [2]. Although there is no definite proof of the existence of a human spinal pattern generator yet, studies in paraplegic patients have shown that the transected human spinal cord is also able to produce locomotor-like muscle activation patterns during imposed stepping movements on a treadmill [3].

There is increasing evidence in the literature that the spinal neural network transmitting long latency flexion reflexes in vertebrates [4] and humans [5] is closely linked to the spinal networks generating rhythmic activity for locomotion. Our own study of the input-output relationship of the human flexion reflex network in patients with complete spinal cord injury revealed that the human flexion reflex network itself supports the generation of rhythmic alternating movements [6]. The functional model of the flexion reflex network which is based on the results of our study resembles in wide parts to models of the central pattern generator (CPG) for locomotion in vertebrates [2]. Therefore, it is very likely that electrical stimulation of flexor reflex afferents (FRA) gives access to the spinal networks for locomotion. This access may be used therapeutically.

The aim of this study was to test if FRA stimulation during gait training enhances the recovery of locomotor functions in patients with hemiparesis after stroke.

## 2 Methods

### 2.1 Study design and trial intervention

The present study is a two-arm randomized controlled clinical trial in severely affected hemiparetic patients after acute stroke. Both groups received four weeks of intensive gait retraining (5 x 30 min / week gait training, additionally 3 x 30 min / week conventional physiotherapy). The control group received gait training without electrical stimulation. The treatment group (FES group) received gait training with afferent electrical stimulation in order to elicit flexion reflexes during the swing phase of the gait cycle. Stimulation site: sole of the foot, dorsum of the foot, or lateral to medial aspect of the knee joint. Stimulation parameters: frequency: 40 Hz, pulse width 320

μs, current amplitude adjusted to release a visible flexion reflex below the pain threshold (20-80 mA). After the end of the 4 week treatment period all patients received conventional physiotherapy.

The following methods against bias were applied. Block randomisation with different randomisation layers for patients with ischemic brain infarctions and patients with spontaneous intracerebral bleedings (ICB) was used. The randomisation lists were hidden to the person who recruited the patients (concealment). There were always different persons responsible for recruitment, treatment and evaluation of the patients. The data analysis was done by intention to treat.

The study was conducted in a neurological rehabilitation hospital and was approved by the ethics committee of the University of Munich.

## 2.2 Patients

38 patients with hemiparesis after acute stroke were enrolled into the study. 9 Patients had an spontaneous intracerebral bleeding (ICB), 29 patients an ischemic brain infarction, mostly in the territory of the middle cerebral artery. All patients gave their informed consent.

Inclusion criteria were: age between 18 and 80 and hemiparesis after unilateral acute stroke. Time between lesion and enrollment into the study: 3 weeks – 6 months. Functional state: able to stand without the help of a therapist, but not able to walk more than 10 m without therapist or holding at a railing. Only patients who had a positive flexion reflex response on electrical stimulation below the pain threshold were enrolled into the study; this was true for about 70% of the tested patients.

Exclusion criteria were: prior stroke or other neurological disorders, severely restricted joint range of motion, severe cardiac insufficiency, neoplasms, active implants (like cardiac pacemakers), severe aphasia or dementia (not able to understand the informed consent).

Two of the 38 patients (1 in the FES group, 1 in the control group) were excluded later because the time between the lesion and enrollment into the study was more than 6 month. 2 patients in the control group dropped out of the study after the baseline measurement due to severe intercurrent diseases not related to the study. One patient in the FES group developed strong spasticity during the treatment period,

otherwise no trial-related complications were noted.

## 2.3 Baseline and Outcome Measurements

The patients were evaluated before (week 0) and immediately after the end of the 4 week treatment period (week 4), 2 weeks and 3 month after the end of the specific treatment period (week 6, week 17). In most patients, the last one or two evaluations were done as an outpatient. The main outcome variable was the walking speed as measured by the 10 m walking test. If a patient was not able to walk 10 m without the help of a therapist, the walking speed was assumed to be zero. In the FES group the walking test was done twice, with and without electrical stimulation. However, only the results without electrical stimulation have been used for further data analysis. The evaluation also included the measurement of gait parameters with pressure insoles, a standardized neurological examination, an assessment of spasticity with the Ashworth Scale. As functional scales the Rivermead Motor Assessment (RMA) and the Barthel Index were used. As the study has just been finished, not all data have been analysed yet.

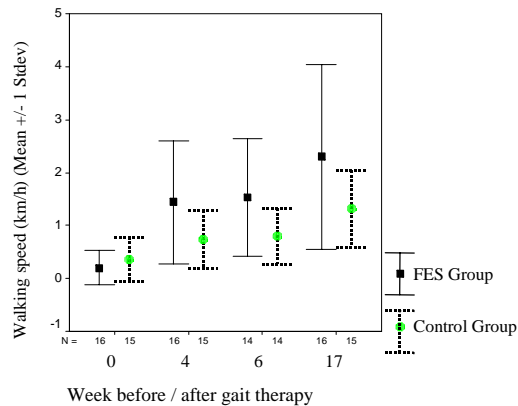
## 3 Results

The main result of the study was that the walking speed significantly improved in both groups, however it improved significantly more in the FES group ( $p = 0.02$ ) than in the control group (figure 1). The difference between the groups was still significant in favour of the FES group 3 months (week 17) after the end of the treatment period ( $p = 0.03$ ). At the end of the treatment period (week 4) 6 out of 17 patients in the FES group but only 1 out of 16 patients in the control group achieved functional walking as defined by a 40 m walking test (item 10 of the general part of the RMA).

The data from the pressure insoles have not been evaluated yet for all patients. However in the intermediate analysis of the first 24 patients there was a significant increase of gait symmetry as defined by the ratio of stance phase duration between the paretic leg and the non-affected leg in the FES group, but not in the control group.

The spasticity slightly increased during the therapy period and dropped back to initial

values at week 17 in both groups. There was no significant difference in the Ashworth scores between the control group and the FES group. Due to the relatively small number of patients no significant differences of the RMA and Barthel Indices between the groups have been found.



**Figure 1:** Walking speed (km/h) before (week 0), immediately after the end of the treatment period (week 4), 2 weeks after treatment (week 6) and 3 months after treatment (week 17). Squares: mean values of FES group, circles: mean values of control group. The bars represent +/- 1 standard deviation.

#### 4 Discussion and Conclusions

From this study it can be concluded that functional electrical stimulation of the flexor reflex afferents (FRA) enhances the recovery of gait function in patients with hemiparesis after acute stroke. The hardware requirements are very low when compared to other devices used for gait rehabilitation such as treadmills, orthoses or electromechanical gait trainers.

Although flexion reflexes triggered by electrical stimuli are a standard method to initiate a swing phase of gait during ambulation with neural prostheses in patients with paraplegia [7], flexion reflexes were never used in the rehabilitation of gait in hemiparetic patients. A related application of FES is the stimulation of the peroneal nerve in patients with hemiparesis and drop-foot [8]. In a pilot study, we also could elicit flexion reflexes by stimulation of the common peroneal nerve. It therefore may be suspected if some of the positive effects of common peroneal nerve stimulation on the gait of hemiparetic patients are also due to effects on the flexion reflex network in the spinal cord.

Because of the above mentioned advantages, stimulation of flexor reflex afferents has the potential for a widespread clinical use in neurological rehabilitation. However, not all patients may be suitable for this kind of therapy. Although facilitation of voluntary leg flexion by subthreshold FRA stimulation has been shown in a pilot study, it is not yet clear if patients who have no visible flexion reflex below the pain threshold may profit from this kind of therapy. Larger numbers of patients and subgroup analyses are needed to define the candidates who may profit most from this novel and very promising kind of therapy.

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