Spastic Tone Increase Reduced Using Repetitive Peripheral Magnetic Stimulation: Pilot Study

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***Abstract*—Spastic tone increase is a frequent phenomenon after lesions on central nervous system. There are numerous and various physiotherapeutic and pharmacological options available and all of this are not enough to control the negative effects of muscle stiffness. We investigated the possible effects of repetitive magnetic stimulation on spastic tone increase of the lower limbs by applying the stimulation paravertebrally at the lumbar level in order to stimulate spinal nerve roots innervating the targeted muscles, the quadriceps muscle of the thigh.**

***Index Terms*—Muscle stiffness, peripheral repetitive magnetic stimulation, stroke rehabilitation.**

I. Introduction

The increase of the elder population is a general phenomenon for European countries [1]. Once with the age, the chronic diseases, especially stroke, frequently encountered in elderly patients, contribute to functional disability. In Europe, the annual incidence for stroke is 113 per 100,000 per year [2].

All the stroke survivors require rehabilitation in order to help them to become as independent as possible and to attain the best possible quality of life. After damage to central motor pathways, there is initial paralysis followed by adaptive changes, in the brain and spinal cord that develop over time, which result in a complex set of motor behaviors [3]–[7]. Paresis, soft tissue contracture, and muscle overactivity are the 3 major mechanisms of motor impairment [8].

Three months after stroke for instance, 25% of the surviving patients present an upper limb and 15 % of them - lower limb stiffness [8], [9] an important cause of disability. Increased tone or spasticity is a term often used as an umbrella term, but is important to understand that it is just one component of the muscle overactivity. Extensive work was done in order to develop improved treatments for muscle overactivity and to improve the outcome in patients with upper neuron motor lesion, even though the treatment remains a big challenge for neurological rehabilitation.

Usually the patient seeking treatment is looking for increased function, a decrease in their pain, improve posture or easing of their caregiver's burden. In order to design the treatment plans and goals that fits each patient the clinicians need to consider some factors: the patient [10]; the support system [11], financial resources [12], the skills of the treatment team and the availability of different treatment modalities [13].

Nowadays, beside the conventional treatment of muscle overactivity which includes: oral medication, physical and occupational therapy, chemoneurolysis with Phenol and Alcohol, Botulinum toxin injections (BTX), intrathecal treatment and surgery, the painless and non-invasive repetitive peripheral magnetic stimulation of nerves, muscles or spinal roots can be an alternative. Magnetically stimulation of excitable tissue has been studied for more than a century [10-16]. More than this repetitive peripheral magnetic stimulation has been used in studies on people for two decades and became more attention in clinical neurorehabilitation research. It is mainly proposed that peripheral recruitment of sensory afferents generates cortical somesthesic reactivation that may improve sensorial and motoric integration in patient with stroke [17], [18]. A literature review showed few studies which provides results regarding the influence of rPMS over nerve, muscle and spinal roots in healthy individuals and in people with stroke, e.g. decreasing of spasticity and improvement in motoric function as well as activation of fronto-parietal loops.

II. Objective of the Study

This study's objective was to test whether rPMS paravertebrally lumbar and accompanied by a routine rehabilitation could lead to a reduction of quadriceps muscle stiffness on patients with stroke.

III. Method

A. Subjects

A total of 12 patients (range: 62-78) with spastic tone increase of the lower limbs due to stroke lesions were investigated in this study.

Patient's characteristics:

- The target joints of the upper and/or lower limb did not reach the neutral position when passively moved, even when applying a strong force. The corresponding value on the Modified Ashworth Scale (0-5) was 3 or 4, i.e. the joint could be moved minimally, but was not fixed.
- A conventional X-ray excluded an osseous joint contracture and/or a myositis ossificans.
- A preceding Botulinum A toxin injection with a dosage according to national guidelines had not resulted in a relevant stiffness reduction. The time interval since the last injection was at least four months.

Manuscript received May 29, 2016; revised July 23, 2016.

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doi: 10.18178/ijssh.2017.7.1.795

- Any metal implants, deep vein thrombosis, open wounds and relevant edema in the extremities under investigation as well as pacemaker excluded the patient.
- Patient understood and signed the written informed consent of the study, which was approved by the local ethical committee.

IV. Experimental Design

Initially the patients participated in a familiarization session in order to be introduced with the study algorithm, the measurement protocol and the mechanism of the rPMS.

The magnetic stimulation was done using a Magstim Rapid stimulator with two circular coils (diameter 9cm). The coil was placed 2cm paravertebrally, at the level of vertebra L3 and L4 and it was oriented with the A-side vertical on the spinal cord. The coils where changed during the stimulation when it became too warm in order to apply the complete amount of magnetic stimuli in all patients. The patients received 10 sessions 1 time per day, ten days consecutive.

The patients were randomly allocated in 2 groups, I and II. Group I received verum and group II sham stimulation.

The stimulation parameters were:

- Group I: 20Hz, suprathreshold intensity, 10s trains of stimulation and 40s pause, a total of 2000 magnetic stimuli. The intensity was above the motor threshold. These stimulation parameters have been used in previous studies [19].
- Group II: the same parameter just intensity was 1%.

V. Outcome Measures

A blinded investigator assessed the patient while lying supine; the joint under investigation was positioned on a supportive pillow, after the patient had been instructed to extend the joint to their individual maximum. Given the poor interpretation reliability of the goniometer measurements, the same investigator made all the measurements all along the study.

Dependent variable were the relative active flexion deficit and Modified Ashworth Scale of the muscles, assessed at baseline, daily at a fixed time before and after stimulation, and 10 days later (T10).

All outcome measures were assessed 13 times: pre-intervention baseline assessments were repeated 5 days apart (T-10, T-5, T0), T1 – direct after the 1st session, T2 – 24 hours after the 1st session, T3 – direct after 2nd session, T4, T5 – before and after 5th session, T6,T7 – before and after 9th session, T8, T9 – before and after 10th session.

At each measurement point, the investigator assessed the flexion deficit active and passive, with the help of a goniometer, at rest. Every assessment was followed by the joint repositioning on the supportive pillow, with no intervention.

VI. Statistics

As a first step, the flexion deficit of each joint related to the maximum anatomical joint flexion was calculated. The corresponding degrees of the knee joint were 140°. The relative flexion deficit and the Modified Ashworth Scale were calculated with the help of a computerized statistical program (SPSS 17.0). Statistical differences between the pre and post measurements and between patients and controls were tested by Wilcoxon's tests for paired samples and with the Bonferroni correction for multiple comparisons.

VII. Results

All the patients completed the study with no adverse events from either aspect of intervention. During the baseline (time period T-10 to T0) the active and the passive flexion knee deficit did not decrease significantly (only with 2.14 %) in both groups. In sham group, within the study interval, as we expected, the Modified Ashworth Scale and the flexion deficit of knee joint didn't change.

Immediately following the first verum stimulation, the mean knee flexion deficit decreased significantly (passive with 20.97 % and active with 13.95%). The overall positive effects following verum stimulation were fully sustained 2 hours later, at 24 hours the effects had decreased but not yet reached the baseline values. A significantly larger decrease from baseline to T9 (of 59.60% respective 41.64%) was observed.

Fig. 1a and Fig. 1b Graphical representation of progress of the flexion deficit for knee joint during intervention period in both groups of patients:

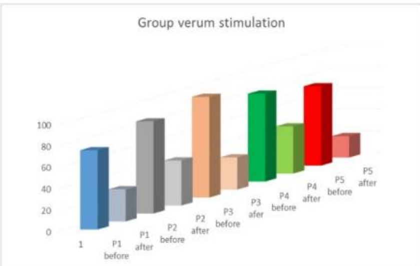

Fig. 1a. Group of patients that received verum repetitive peripheral magnetic stimulation.

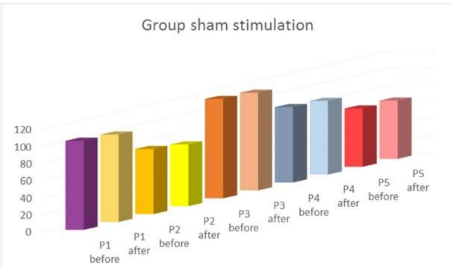

Fig. 1b. Group of patients that received sham repetitive peripheral magnetic stimulation.

The mean Modified Ashworth Scale showed a similar behavior, i.e. no significant change during the baseline in both groups, followed by a significant reduction after the verum stimulation and no change in sham group. Muscle tone was reduced in group II within 10 days of stimulation with 1 points on the Modified Ashworth Scale.

VIII. Discussion

It is already known that the repetitive peripheral magnetic stimulation had positive effects on increased muscle tone due to an inhibition of the signal flow and thus modulate spastic tone on the spinal and that the excitability of spinal motor neurons in patient with spastic tone increased is typically increased [20]-[21]. Krauss et al. used a 20Hz rPMS and the motor threshold was significantly higher in patients than in controls and he obtained a significant decrease in spastic tone [19]. In another study it was shown that repeated sessions of 1Hz rpms applied over the nerve roots in the paravertebral region can decrease spasticity and spasm frequency [24].

Grozoiu *et al*. stimulate the muscle corresponding to the target join with 5Hz rPMS while stretching and the extension deficit at rest deceased significantly [26]. As we observed different frequents of stimulation as well as the place of stimulation have showed positive results. We published until now preliminary results from our study that it is still going on and whose purpose it is to find the parameters of rPMS that bring the best improvement for the patient with residual spasticity after stroke. All the patients enrolled in our study respect the same criteria only the parameter and the place of stimulation it is changed.

We performed this study for the patients group that received verum stimulation, using 20Hz rPMS and the intensities of the motor threshold were higher than expected and there was an increase of intensity of the motor threshold for the stimulation series by around 15%.

A single session of verum rPMS paravertebrally lumbar was able to reduce significantly the knee flexion deficit and the positive effects after one single session of rPMS that were maintained after 24 hour, diminished but not reached the baseline values.

Similar effects of repetitive peripheral magnetic simulation were observed in early publications, where the authors concrete that the spastic tone decreased immediately after stimulation and was followed by a reduction in spastic tone lasting up to 24h [18], [22]-[24].

More than that after every session the positive effect sum, so at the end of the 10 consecutives workdays sessions it was a significant decrease of muscle stiffness but we were not able to follow how long the positive effects would have last.

IX. Conclusion

The decrease in spastic tone after repetitive magnetic stimulation applied to lumbar nerve root, for patients with residual lower limb spasticity after stroke can have potential in future as well as rPMS applied over the muscle while stretching [26]. The positive effects appears to be only for short time and it is obvious that after every stimulation the effect are summated. Nevertheless further studies are required in order to elucidate complete the mechanism of repetitive peripheral magnetic stimulation and to develop the best strategy to improve on a long term the negative effect of spastic tone increase.

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