Deep Brain Stimulation of STN in patients with Parkinson’s Disease: effects on EMG signals of leg muscles during walking

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Abstract

Goal of the present study was to quantitatively evaluate the effects of unilateral and bilateral subthalamic nucleus stimulation on walking features of patients with Parkinson’s disease. In particular, the EMG activation pattern of proximal and distal muscles of lower limbs are here reported. Results showed that, bilateral STN stimulation is able to increase EMG bursts with the physiologic timing in the gait cycle. Unilateral STN stimulation is less effective, but do not induce asymmetric EMG activation pattern between right and left side.

1 Introduction

Parkinson’s Disease (PD) is a neurodegenerative disorders of unknown cause due to the progressive loss of dopaminergic neurons in a cerebral region of Basal Ganglia. Rigidity, akinesia, tremor and postural instability represent the main motor symptoms of PD. Moreover, gait disorders play a key role in the generation of patient’s motor disability. In the advanced phase of PD it is often impossible to obtain a good improvement of the motor symptoms despite the best pharmacological treatment; therefore, recently the surgical approach in this advanced phase has shown an increasing interest. It has been demonstrated that the bilateral High Frequency Stimulation (HFS) of the Subthalaric Nucleus (STN) is capable to significantly improve most of PD symptoms, through a functional reversible inhibition of the hyperactive targets [1]. In this procedure an electrode is implanted in the brain target and connected to a subcutaneous electrical pacemaker. Improvements on gait kinematics and kinetics provided by STN stimulation have been already quantified through 3D gait analysis techniques [2]. In the present study we analysed the changes induced by bilateral and unilateral HFS of the STN on the EMG activity of the main lower limb muscles during gait, in comparison with the effects of pharmacological treatment (L-dopa).

2 Methods

A group of ten idiopathic PD patients (age: 52-68 yrs, H&Y: 2.5-4.5, PD duration: 8-26 yrs, postsurgery: 3-28 months) implanted bilaterally with a STN stimulation system and ten age-matched controls were studied with a 3D gait analysis procedure described in [3] and an 8-channel surface EMG system (TELEMG, BTS, Italy). In particular, EMG signals were detected through bipolar surface Ag/AgCl pre-gelled electrodes, and then band pass filtered (10-200Hz) and A/D converted (sampling rate 500Hz, resolution 12 bit). The patients have been analysed, after 12 hours of drug wash out, with (S+) and without (S-) bilateral STN stimulation and with (M+) and without (M-) pharmacological treatment (L-dopa); thus in the following four conditions: S-M- (basal), S+M-, S-M+, S+M+. Moreover, unilateral STN stimulation of both sides have been analysed without L-dopa (rightS+M- and leftS+M-). A clinical evaluation according to UPDRS motor scores, has been performed in each of the above conditions. The stimulation parameters used during the test were the same of the chronic use (monopolar chatodic stimulation; mean amplitude 3.1±0.4 V, mean rate 144.4±18.0 Hz, pulse width 60 or 90 μs). EMG post-processing procedure consisted of signal rectification and 7.5 Hz low pass filtering, for envelope detection, time normalization within each gait cycle and averaging on the available gait cycles for each considered condition. Then, RMS have been computed within six intervals of the gait cycle, to quantify EMG activity in specific stride phases (first double stance, early and late single stance, second double stance, early and late swing). Non parametric statistical analysis (ANOVA Friedman and Wilcoxon paired test) has finally been used to compare conditions and evidence significant differences.
3 Results

Kinematics data confirmed that bilateral stimulation alone (S+M-) and L-dopa alone (S-M+) both significantly improved stride length and gait speed, with an additional effect when the treatments were applied simultaneously (S+M+). Concerning the effects of unilateral STN stimulation, UPDRS motor scores showed that, in average, it presented significant improvement respect the basal condition, although less effective than bilateral stimulation. Moreover, in each patient it was possible to identify a more effective side of stimulation (right or left). Therefore, the results of unilateral STN stimulation were averaged among patients considering both the better stimulation side (uni-b) and the worse one (uni-w). In fig. 1 the stride lengths found with bilateral and unilateral stimulation are compared with the basal condition (S-M-), showing a pattern similar to that of UPDRS scores. Median, 25-percentile and 75-percentile are reported; upper lines indicate statistically significant differences (p<0.05).

![Figure 1: Comparison of stride length among basal condition (S-M-), bilat STN stim (S+M-), and unilat STN stim considering the better stimulation side (uni-b) and the worse one (uni-w)](image)

As regard muscular activity, in basal condition PD patients presented a reduction of EMG bursts in specific gait phases respect normal patterns. Bilateral STN stimulation was found to induce an increase on EMG bursts in those gait phases. In figure 2 an example of comparison between S-M- condition and bilateral STN stimulation is showed for Tibialis Anterior (TA), Gastrocnemious Medialis (GM), Rectus Femoris (RF) and Semi Membranosus (SM) muscles. In particular a recovery of physiologic burst of EMG activity at heel strike (HS) was found in TA, RF and SM, at push off (PO) in GM and at initial swing (IS) in TA.

Another interesting aspect was the comparison between the effects of unilateral STN stimulation both on the contralateral and on the ipsilateral side. UPDRS motor scores showed a clear higher efficacy of unilateral stimulation on the contralateral than on the ipsilateral side, in particular for tremor, akinesia and rigidity indexes. On the contrary, the analysis of EMG burst during gait, showed, in general, a smaller effect of unilateral than bilateral stimulation, but not a significant asymmetry between ipsilateral or contralateral side (see figure 3).

4 Discussion and Conclusions

High Frequency Electrical Stimulation of the Sub-Thalamic Nucleus provides significant improvements in walking pattern of patients with idiopathic Parkinson’s Disease. Bilateral stimulation of STN showed to be the most effective condition: it increases gait speed, stride length and the Range of Motion of all lower limb joints. Moreover, it improves EMG activation profiles of leg muscles toward the physiological patterns. In accordance with previous studies [4], we found that distal muscles (TA and GM) are more easily
modulated by therapy in PD patients than the proximal ones (see figure 3).

Unilateral stimulation (stimulation of only one subthalamic nucleus) is, in general, less effective than bilateral STN stimulation, for both the clinical symptoms, as measured by UPDRS motor scores, and the gait features (velocity, kinematic and kinetic patterns).

As reported by other authors [5], the effects on the main clinical symptoms (rigidity, tremor and akinesia) is mainly contralateral, i.e. on the side of the body opposite to the stimulated STN. However, the EMG activation patterns of leg muscles during walking with unilateral STN stimulation do not present significant differences between sides.

Bastian et al. [6] showed that, while arm reaching is improved by unilateral STN stimulation alone with no additive effect of bilateral stimulation, walking speed and stride length are more improved by bilateral stimulation. The findings of the present study confirm that these result depend directly on the muscle activation patterns, which are not asymmetric.

According to previous studies [5][6], it can be concluded that basal ganglia in each hemisphere can influence both lower limbs during bilateral motor tasks like walking, presumably through bilateral brainstem and/or cortical projections.

References


Acknowledgements

This work was partially supported by the Italian Ministry of Health (Fondi Ricerca Finalizzata IRCCS).