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CONTRIBUTION OF LOCAL FIELD POTENTIAL TO SUBTHALAMIC NUCLEUS DEEP BRAIN STIMULATION IN PARKINSON’S DISEASE

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INTRODUCTION

The subthalamic nucleus (STN) is the main target for deep brain stimulation (DBS) in Parkinson’s disease. We analysed the relationships between magnetic resonance imaging (MRI) anatomy and electrophysiology done during surgery. In addition to extracellular recording of spontaneous neuronal activity (carried out conventionally in our Hospital), we performed simultaneous recordings of local field potential (LFP), i.e. deep EEG activity. We hypothesized that the contribution of LFP to neuronal firing rate with detailed MRI anatomy should allow to explore finely anatomo-electrophysiological relationships and also to determine precisely functional surgical targets.

PATIENTS, MATERIAL AND METHODS

Patients
10 patients with Parkinson’s disease (9F – 1M; mean 62±4 years old; 11±3 years disease duration) underwent bilateral STN DBS surgical procedure.

Surgical technique

Stereotactic MRI. On the first day, the stereotactic Leksell G frame (Elekta, Sweden) was placed with its repositioning kit (Leksell repositioning kit, Elekta, Sweden) under local anesthesia. A stereotactic MRI was performed (1.5 Tesla, Siemens, Germany) with notably a White matter Artifact Reduction Inversion Recovery (WARR) sequence on the coronal plane: T1 = 650 ms; T1 = 15 ms; T1 = 100 ms; 8 = 13 images (2 mm in slices thickness). The frame was removed.

Stereotactic surgery. The following day, the stereotactic frame was repositioned. Under local anesthesia after repositioning of the repositioning kit, we identified all the nuclei of the subthalamic region. With the help of probes we reconstructed, we determined a trajectory, with a double obliquity, avoiding the main vessels, going straight through the parenchyma and with an end point located in the STN. We planned two parallel tracks, a central one centered on the best anatomical target, a 2mm-distant one.

Implantation surgery. The following day, the stereotactic frame was repositioned. Under local anesthesia after repositioning of the repositioning kit, LFP and DBS an acute stimulation (continuous, voltage/current, frequency: 130 Hz, pulse width: 0.0–0.5 ms) was performed using unshielded tungsten microelectrodes (Dreis子弟 E; length: 1.5 mm, diameter 100 µm) MRI and a MondoGuide Pro system (Alpha Omega, Israel). We explored the clinical effects every 0.5 mm (run-up to 3 mm) along the 10 mm of the parallel tracks. Then, a quadrupolar electrode (DBS 3387, Medtronic, USA) was placed on the selected track with one of two contacts in the clinically most efficient area. Perioperative X-rays, and postoperative CT scanner acquisitions were performed to control the electrode positioning. Postoperative clinical assessments (2 months) showed a mean improvement of 43.8% (H|4.0), ranging from 30.0 to 75.5 (4 median control (part of UPDRS).

Electrophysiology

1. 715 unidary electrophysiological recordings of spontaneous extracellular neuronal activity (calculating the mean frequency of neuronal activity, and the occurrence of burst activity)

2. DBS LFP recordings. Power spectral density (3–1000 Hz; 100 ms) frequency bands. Brain stimulation was used to stimulate the DBS (130 Hz, 130 µA;150 Hz, 250 µA) and DBS (50 Hz, 250 µA) frequencies.

3. In MRI outlined anatomical structures (Thalamus (Thal), Zona Incerta (ZI), Forel Field (Forel) and STN) were analyzed.

RESULTS

Electrophysiological recordings of spontaneous unitary extracellular neuronal activity

1. In this study, the mean frequency failed to discriminate between the structures of the region of interest (non-parametric Kruskal-Wallis ANOVA; p = 0.13).

2. The frequency of burstic activity was significantly different between structures (K-W; p = 0.01). Burst activity in thalamus was statistically higher than in the STN (pairwise comparisons: p = 0.002).

Local field potential power spectral density analysis

3. Delta band power spectral density (PSD) of LFP was significantly different between structures (K-W: p = 0.0003). Post hoc tests showed differences between Thalamus and Forel Field (p = 0.0001), between Forel Field and STN (p = 0.003) and between Thalamus and Zona Incerta (p = 0.008).

4. Theta band PSD was significantly different between structures (K-W: p = 0.02). Thalamus had higher theta band activity than Forel Field (p = 0.001). Alpha and 100-Hz bands showed the same statistically different pattern between Thalamus and Forel Field. Beta band PSD failed to discriminate between the structures of the subthalamic region (K-W: p = 0.2; data not shown).

5. Gamma band activity was significantly different between structures (K-W: p = 0.0003). Thalamus γ activity differed from all other structures (Thalamus-ZI: p = 0.0004; Thalamus-STN: p = 0.001; Thalamus-Forel: p = 0.002).

CONCLUSION

1. This study suggests the interest of LFP, which is at least as effective as extracellular neuronal activity (Coste et al., 2009), to discriminate between structures in the subthalamic region using exploration electrode with patient at rest during DBS surgery. Contrary to previous studies reporting an increase in θ band when entering the STN (Chen et al., Exp Neurol, 2006), no significant difference was shown between structures concerning the θ band.

2. Another part of this study will consist in correlating extracellular neuronal activity and LFP, and analyzing modulations on LFP during voluntary movements of the patients.

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