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Contribution of local field potential to subthalamic nucleus deep brain stimulation in Parkinson's disease

J Coste^(1,2); P Derost⁽³⁾; A Mulliez⁽⁴⁾; J Gabrillargues^(1,5); B Pereira^(1,4); JJ Lemaire^(1,2)

(1) Image-Guided Clinical Neurosciences and Connectomics, IGCNC, EA 7282, Université d'Auvergne, Clermont-Ferrand, France

(2) Service de Neurochirurgie A, CHU de Clermont Ferrand, Clermont-Ferrand, France

(3) Service de Neurologie, CHU de Clermont Ferrand, Clermont-Ferrand, France

(4) Direction de la Recherche Clinique, CHU de Clermont Ferrand, Clermont-Ferrand, France

(5) Service de Radiologie A, Unité de Neuroradiologie, CHU de Clermont Ferrand, Clermont-Ferrand, France

INTRODUCTION

The subthalamic nucleus (STN) is the main target for deep brain stimulation (DBS) in Parkinson's disease. We analyzed the relationships between magnetic resonance imaging (MRI) anatomy and electrophysiology (local field potential, LFP) done during electrodes implantation surgery.

OBJECTIVES

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 Ten patients with Parkinson's disease (5F – 5M; mean 62±4 years old; 11±3 years disease duration) underwent bilateral STN DBS surgical procedure.

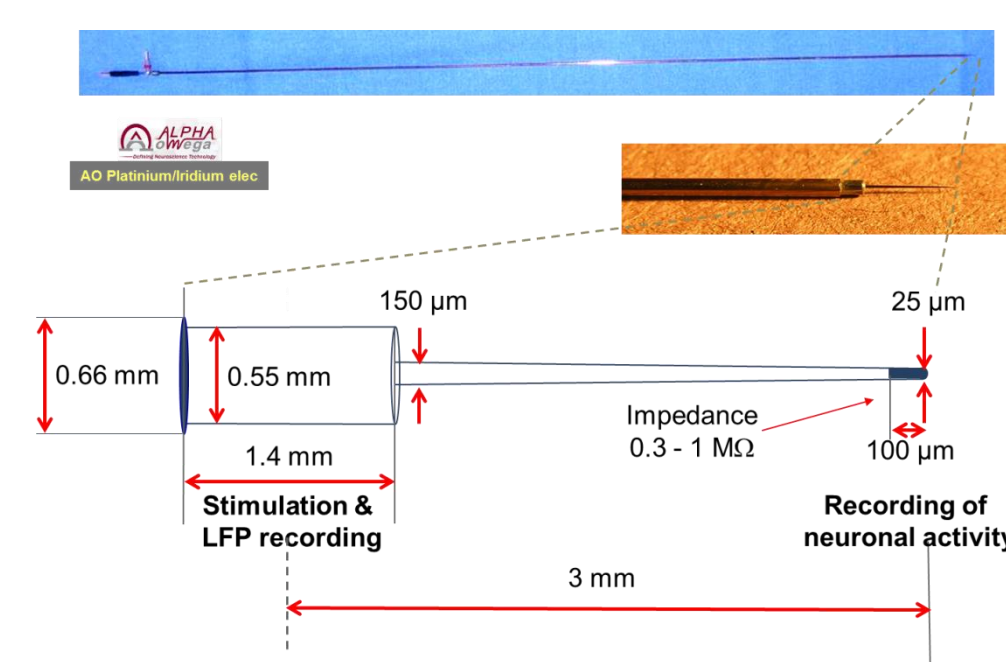
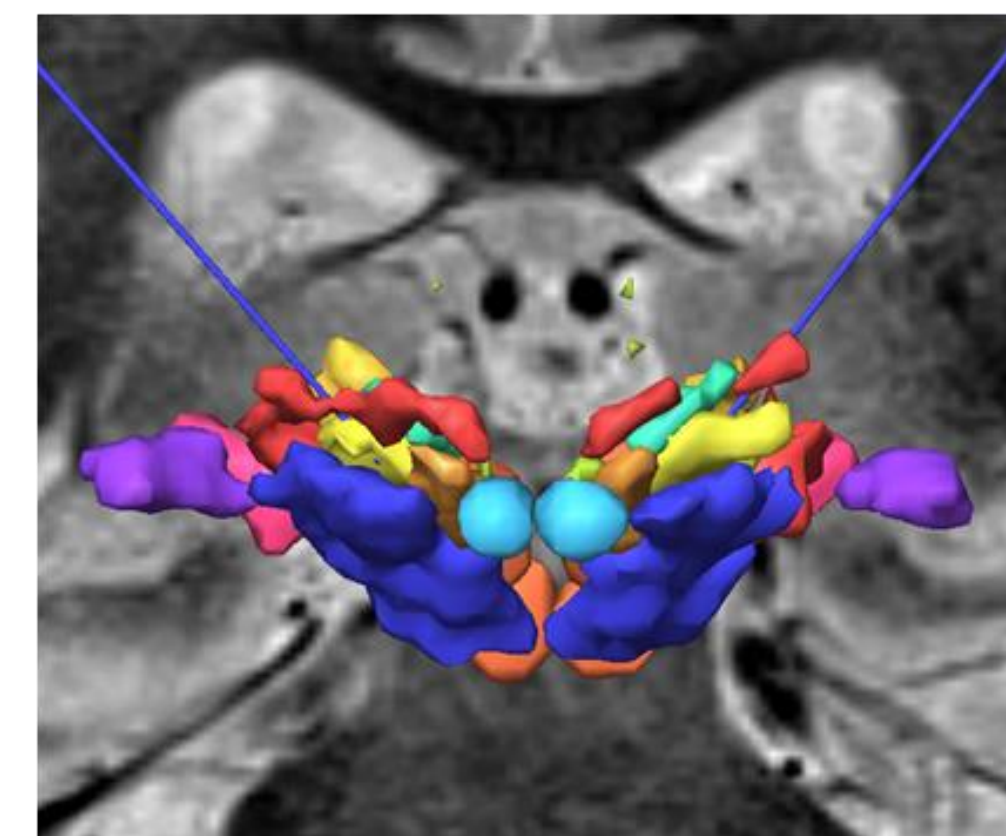
Surgical technique Stereotactic MRI: On the first day, the stereotactic Leksell G frame (Elekta, Sweden) was placed with its repositioning kit (Leksell repositioning kit, Elekta, Sweden) under local anesthesia. A stereotactic MRI was performed (1.5 Tesla, Siemens, Germany) with notably a White matter Attenuated Inversion Recovery (WAIR) sequence on the coronal plane. The frame was then removed.

Planning: Direct targeting of STN region was performed using a stereotactic software (*Iplan, BrainLab, Germany*). We identified all the nuclei of the subthalamic region. We determined a trajectory, with a double obliquity, avoiding the main vessels, going strictly through the parenchyma and with an endpoint located in the STN. We planned two parallel tracts, 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 recording of neuronal activity and LFP, an acute stimulation (monophasic, negative current, frequency: 130 Hz, pulse width: 0.06 msec) was performed using unshielded tungsten microelectrodes (stimulation tip: length 1.2 mm, diameter 550 µm) with a MicroGuide Pro system (*Alpha Omega, Israel*). We explored the clinical effects every 0.5 mm (current up to 3 mA) along the distal 10 mm on the 2 parallel tracts.

Then a quadripolar electrode (*DBS 3387, Medtronic, USA*) was placed on the selected tract with one or two contacts in the clinically most efficient area. Peroperative tele radiographic X-rays controls and postoperative CT scanner acquisitions were performed to control the electrode positioning. Postoperative clinical assessments (6 months) showed a mean improvement of 63.6% (±14.9; ranging from 30.0 to 75.5) of motor control (part III of UPDRS).

Electrophysiology 693 LFP recordings in MRI-outlined anatomical structures (Thalamus [Thal], Zona Incerta [ZI], Forel Field [Forel] and STN) were analyzed: Power spectral densities (PSD) from 0 to 100Hz; 1024 frequency values; Normalization: percent of total PSD; Calculation for delta (0-4 Hz), theta (4-7 Hz), alpha (7-13 Hz), beta (13-30 Hz), gamma (30-50 Hz, 50-100 Hz) frequency range. Non-parametric Kruskal-Wallis ANOVA tests were performed followed by pairwise comparisons with adjusted p-value.



RESULTS

The most frequently encountered structures were STN (n=192), thalamus (n=178), ZI (n=139) and Forel (n=132).

Delta band power spectral density (PSD) of LFP was significantly different between structures (K-W: $p = 0.0002$). Post hoc tests (pairwise comparisons: adjusted p-value = 0.004) showed differences between thalamus and ZI ($p = 0.003$), between Forel and thalamus ($p = 0.00005$) and between STN and Forel ($p = 0.0004$).

Alpha band PSD was significantly different between structures (K-W: $p = 0.04$). STN had higher α band activity than Forel ($p = 0.003$).

Gamma band PSD was significantly different between structures (K-W: $p = 0.0001$). Thalamus γ activity differed from all other structures (thalamus-ZI: $p = 0.00001$; thalamus-STN: $p = 0.0005$; thalamus- Forel: $p = 0.0005$) with higher γ activity in thalamus than in others structures.

50-100Hz band power spectral density (PSD) of LFP was significantly different between structures (K-W: $p = 0.02$). 50-100Hz band activity in Forel was statistically lower than in the thalamus ($p = 0.002$).

Theta and Beta bands PSD failed to discriminate between the structures of the subthalamic region (K-W: $p = 0.09$ and $p = 0.08$ respectively; data not shown).

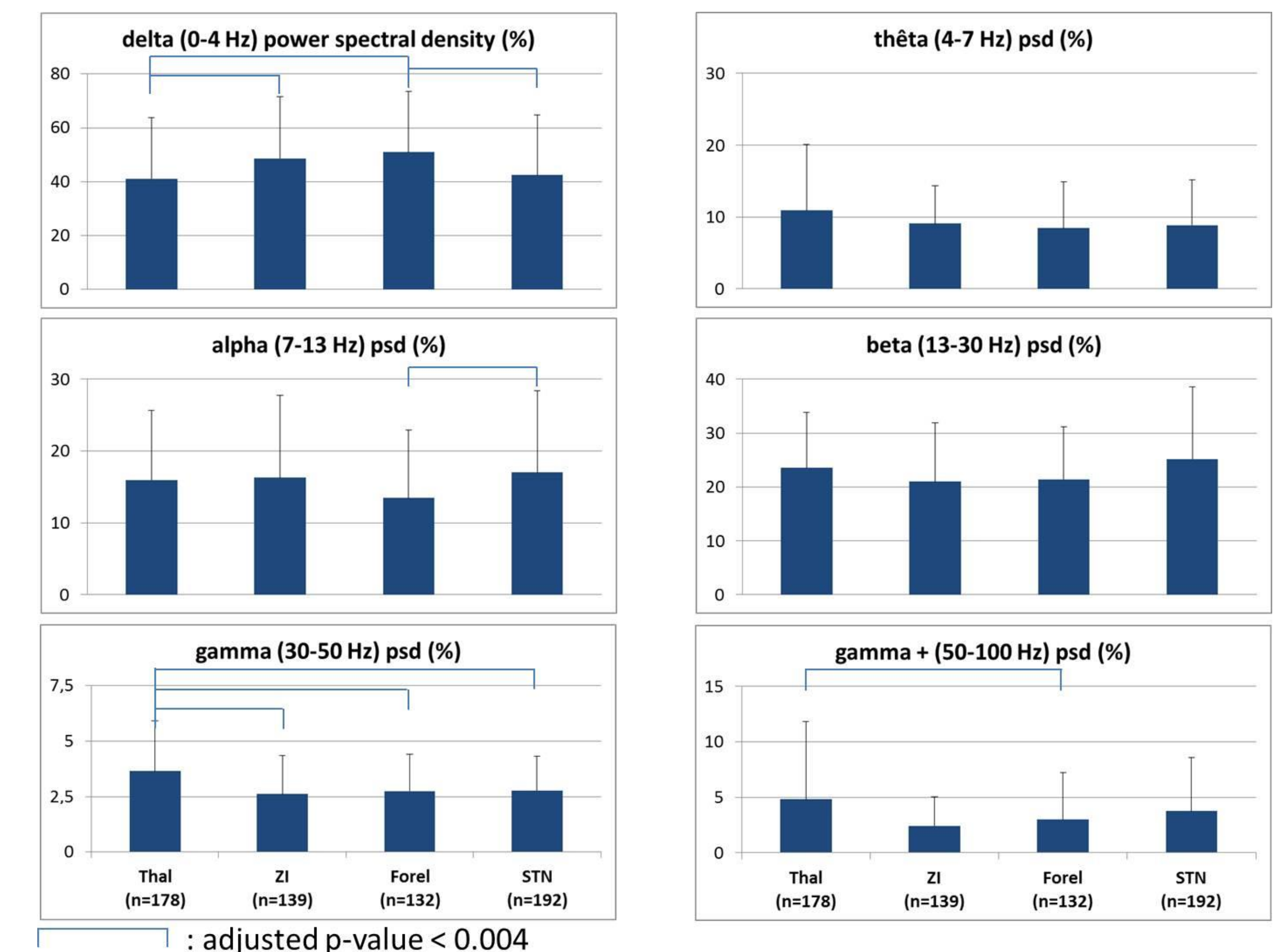


Figure: Local field potential power spectral density analysis

CONCLUSION

This study suggests the interest of LFP, which is at least as effective as extracellular neuronal activity (Coste et al., EJN, 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 β band when entering the STN (Chen et al., Exp Neurol, 2006), no significant difference was shown between structures concerning the β band.

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.