The Effects of Microelectrode Penetration of the Subthalamic Nucleus on Intraoperative Electrophysiologic Recordings

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Introduction

Background

Characterization of electrophysiological recordings during deep brain stimulation (DBS) surgery is critical for anatomical targeting and is extensively utilized to investigate physiologic markers of Parkinson's Disease (PD).[1,2] Transient improvement in clinical symptoms has been reported after microelectrode penetration, but the mechanism(s) underlying this improvement are not well understood.[3] Thus, we sought to determine the electrophysiologic effects of microelectrode penetration in the Subthalamic Nucleus (STN).

Methods

Patient

A 57 year-old left hand dominant woman with a 20+ year history of advanced PD underwent surgical implantation of bilateral DBS electrodes in the STN.

Microelectrode Recordings

LFP recordings were collected beginning at the entrance of the dorsal border of the STN as determined by electrophysiological criteria.[4,5] These recordings were 8 seconds in duration and were obtained at 0.3mm steps until the ventral border was reached (Figure 1). The microelectrode was then extracted in a step-wise fashion using 0.3mm-step increments to ensure repeat 8-second recordings obtained from the same anatomic positions.

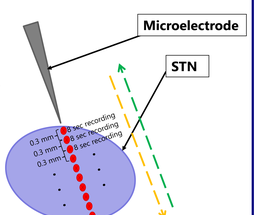

Figure 1 - Path of recordings (orange line representing direction of insertion; green line representing direction of extraction; red targets indicating recording locations; not to scale).

Data Pre-processing and Analysis

Data was processed and analyzed in MATLAB 2020a using custom scripts and the Fieldtrip toolbox. Significance was determined using Mann-Whitney nonparametric tests. A p-value of <0.05 was deemed statistically significant.

Hypothesis: Microelectrode penetration will cause decreased power on local field potentials (LFP).

Results

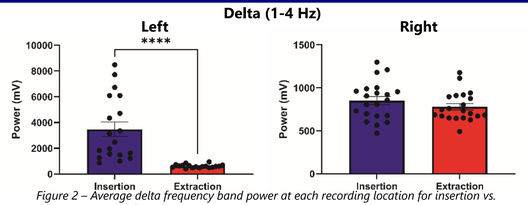

Figure 2 – Average delta frequency band power at each recording location for insertion vs. extraction in the left and right hemisphere.

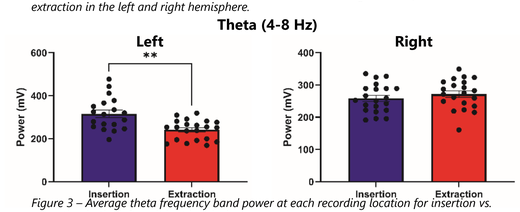

Figure 3 – Average theta frequency band power at each recording location for insertion vs. extraction in the left and right hemisphere.

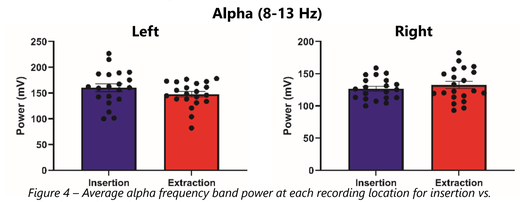

Figure 4 – Average alpha frequency band power at each recording location for insertion vs. extraction in the left and right hemisphere.

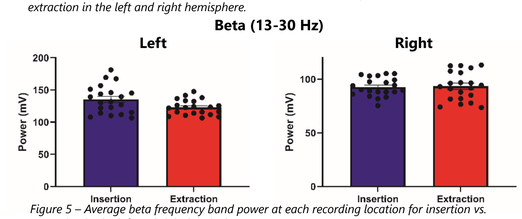

Figure 5 – Average beta frequency band power at each recording location for insertion vs. extraction in the left and right hemisphere.

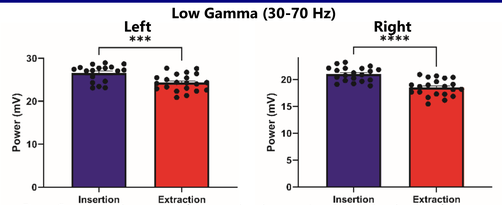

Figure 6 – Average low gamma frequency band power at each recording location for insertion vs. extraction in the left and right hemisphere.

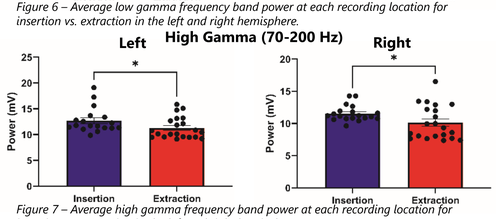

Figure 7 – Average high gamma frequency band power at each recording location for insertion vs. extraction in the left and right hemisphere.

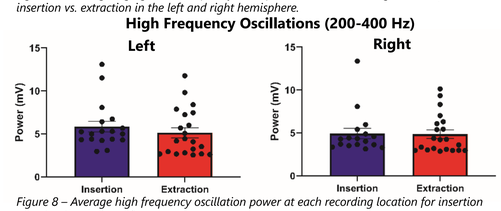

Figure 8 – Average high frequency oscillation power at each recording location for insertion vs. extraction in the left and right hemisphere.

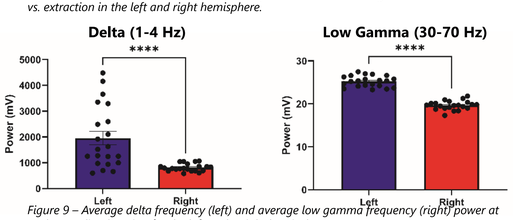

Figure 9 – Average delta frequency (left) and average low gamma frequency (right) power at each recording location for the left vs the right hemisphere.

Summary of Results

Insertion vs Extraction

- Significantly higher average power for insertion recordings vs extraction recordings
  - Left Hemisphere: delta, theta, low gamma, and high gamma
  - Right Hemisphere: low gamma, and high gamma

Left Hemisphere vs Right Hemisphere

- Significantly higher average power in the left hemisphere recordings for delta and low gamma vs the right hemisphere recordings

Conclusions & Future Directions

Conclusions

- There is an effect of microelectrode penetration on electrophysiologic recordings in the STN:
  - Could represent an electrophysiologic effect produced by the lesion from penetration
- Difference in left vs right hemisphere recordings
  - This may be the result of handed-ness or perhaps related to severity of PD symptoms

Future Studies

- Larger sample size to verify results
- More brain locations to expand generalizability
- Correlate with clinical outcomes for potential predictive modeling

References

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4. Wang J, Hirschmann J, Elben S, Hartmann CJ, Vesper J, Wojtecki L, et al. High-frequency oscillations in Parkinson's disease: spatial distribution and clinical relevance. Mov Disord. 2014;29(10):1265-72.
5. Yang AI, Vanegas N, Lungu C, Zaghloul KA. Beta-coupled high-frequency activity and beta-locked neuronal spiking in the subthalamic nucleus of Parkinson's disease. J Neurosci. 2014;34(38):12816-27.