Electrical Biomarker Predicts Optimal Targeting in Subthalamic Deep Brain Stimulation for Parkinson's Disease

Akshay T Rao, Charles W Lu, Asra Askari, Karlo A Malaga, Kelvin L Chou, Parag G Patil*

Introduction

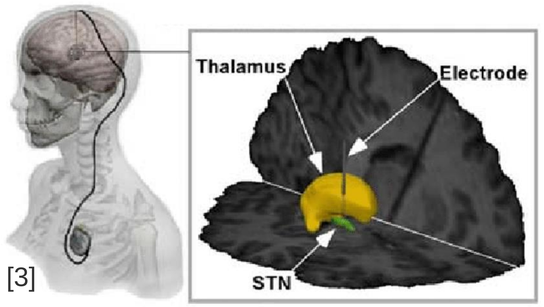
- **Subthalamic deep brain stimulation (STN DBS)** is a well-established surgical therapy to treat the motor symptoms of **Parkinson's disease (PD).**
- Selecting the optimal trajectory and stimulation zone for an individual patient during STN DBS surgery is a significant challenge. Various stimulation parameters and locations are tested through trial-and-error until an ideal **volume of tissue activation (VTA)** is produced that leads to the greatest clinical effect [1]. Exhaustive parameter search is not possible in a clinical setting, which may lead to electrode misplacement.
- A **data-driven approach** to electrode localization based on microelectrode recordings (MER) may lead to more efficient and effective DBS surgery [2].

Objective

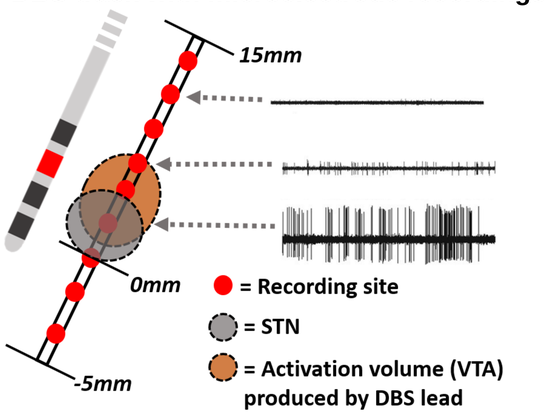
To define a data-driven electrophysiological biomarker that selects (1) the optimal track, (2) location of stimulation along the track, and (3) span of stimulation volume in STN DBS.

Methods

Anatomical model of STN DBS



DBS track with microelectrode recordings

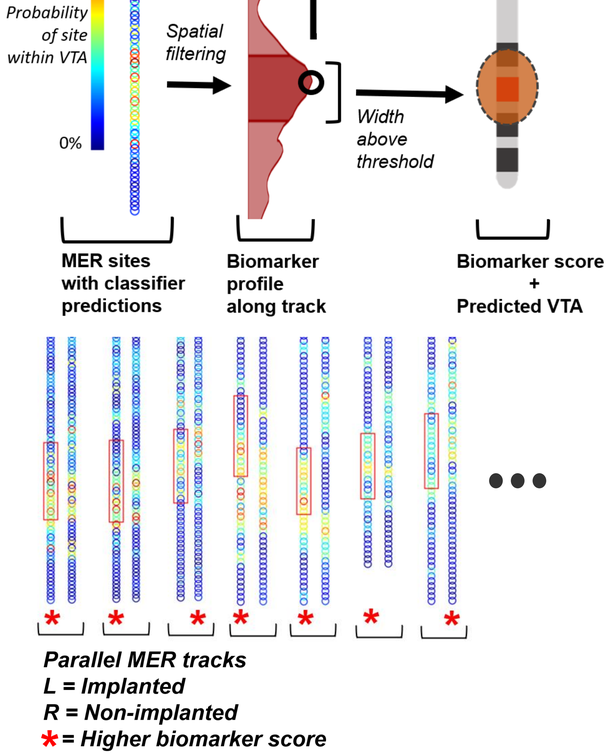


- **Random forest (RF) feature selection** and classification was used to identify electrophysiological features that predict clinically programmed VTA regions (1046 microelectrode recordings, 13 patients)
- Probabilistic predictions were spatially smoothed to produce a **biomarker score** that measures the probability of localization within an optimized VTA.

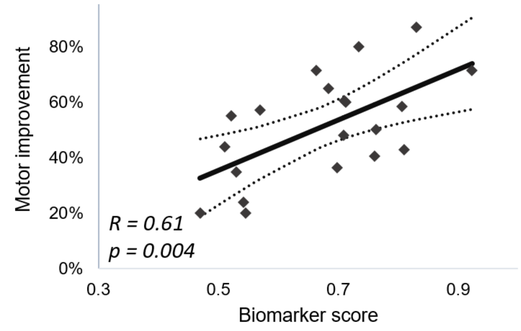
Results

- Predicted VTA span was correlated to true VTA span (R=0.58, p=0.008).
- Biomarker scores were correlated to postop motor symptom improvement based on UPDRS-III (R=0.61, p=0.004).
- Notably, the length of STN, a common criterion for trajectory selection, did not show similar correlation (R=-0.31, p=0.18).
- The retrospectively calculated score was *lower* in the clinically selected tracks in 5/15 cases, indicating potentially sub-optimal DBS electrode localization for these patients

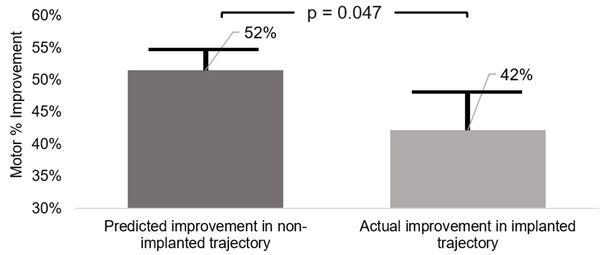
Visualization of site prediction algorithm



Biomarker score is correlated to motor symptom improvement



Biomarker-based targeting may enhance improvement in motor symptoms



Conclusion

An electrophysiological biomarker predicts the clinically determined VTA and correlates well with motor outcomes in STN DBS for PD. The ability of this biomarker to guide trajectory and stimulation site selection should be validated in a prospective study.

References

[1] E. C. Conrad, J. M. Mossner, K. L. Chou, and P. G. Patil, "Atlas-Independent, Electrophysiological Mapping of the Optimal Locus of Subthalamic Deep Brain Stimulation for the Motor Symptoms of Parkinson Disease.," *Stereotact. Funct. Neurosurg.*, vol. 96, no. 2, pp. 91–99, 2018

[2] C. W. Lu, K. L. Chou, and P. G. Patil, "Correspondence of optimal stimulation and beta power varies regionally in STN DBS for Parkinson disease," *Park. Relat. Disord.*, vol. 78, no. July, pp. 124–128, 2020

[3] C. Butson, C. SE, and M. CC, "Deep Brain Stimulation of the Subthalamic Nucleus: Patient-Specific Analysis of the Volume of Tissue Activated," Jan. 2005.