BMT 2025 Basel, CH (2025 09 09 – 11) | Poster session 11 (2025-09-10)

Identifying Key Predictors of Deep Brain Stimulation Outcomes: a Feature Importance Analysis

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Introduction

Data-driven prediction of Deep Brain Stimulation (DBS) effects represents the foundation for algorithms automating DBS programming. Several models aiming at predicting symptom improvement in correspondence with specific stimulation parameters have been presented in literature. They exploit features ranging from patients' clinical characteristics, to measures extracted from fMRI scans or probabilistic mapping. However, the relationships between predictive features and clinical improvement are often underexplored. Therefore, this study aims to conduct a feature importance analysis to identify the most influential predictors of DBS outcomes.

Methods

2112 intra-operative stimulation tests of 65 patients were used to simulate the Volumes of Tissue Activated (VTAs) and to compute probabilistic volumes of therapeutic (Probabilistic Sweet Spots, PSS) and side effects (SE). Clinical, morphological, stimulation and probabilistic mapping-related features were calculated and DBS effects were categorized in 3 classes (side effects, low and high improvement). Feature importance was assessed with: univariate feature selection with ANOVA F-value, permutation importance and SHAP values.

Results

Despite being based on different principles, all three approaches consistently identified the same top three most influential predictors. These were: "VTA volume" (F=269.5), "PSS-VTA centroid distance" (F=123.3) and "VTA-SE volume overlap" (F=115.9). SHAP analysis revealed that high values of these features drive the prediction towards side effects class, whereas low values shift it towards high improvement class. Low improvement is associated with high VTA volumes and distances to PSS, coupled with low overlap with SE.

Conclusion

The findings highlight the predictive value of features derived from probabilistic mapping results in determining DBS outcomes. Clinical and anatomical features demonstrated limited predictive power. The high importance of the "VTA volume" may be attributed to the characteristics of the collected data: tests at the minimum amplitude yielding a therapeutic effect and maximum amplitude before onset of adverse effects.
This work was financed by the Swiss National Science Foundation (205320_207491).