Assessing Basal Ganglia Circuitry Function in Parkinson's Disease: Phenotypic and Movement-Dependent Periodic and Aperiodic Activity in Human STN-LFP Recordings

WSSFN 2025 Interim Meeting. Abstract 0047

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Abstract

Introduction: Parkinson's disease (PD) presents distinct motor phenotypes—tremor-dominant (TD) and postural instability/gait disorder (PIGD)—which differ in prognosis and response to deep brain stimulation (DBS)[1]. Identifying electrophysiological markers reflecting these phenotypes and motor states is essential for optimizing adaptive DBS.[2] Traditional analyses of subthalamic nucleus local field potentials (STN-LFPs) often conflate oscillatory (periodic) and broadband (aperiodic) activity, potentially masking key neural dynamics.[3] This study investigates whether parameterizing STN-LFPs into periodic and aperiodic components enhances detection of phenotype- and movement-specific features in PD.

Method: STN-LFPs were recorded intraoperatively from 35 hemispheres in 22 PD patients (15 TD, 20 PIGD) during rest and voluntary upper-limb movement. Power spectral density was used to isolate periodic (alpha, low beta, high beta) and aperiodic (offset, decay exponent, knee frequency) components (Fig. 1). Periodic power was analyzed with and without aperiodic adjustment to improve oscillatory signal precision. Mixed-design ANOVA assessed effects of phenotype and motor state. Logistic regression tested phenotype classification using spectral features. Correlations with UPDRS-III subscores were explored.

Result: TD patients showed movement-related suppression in adjusted low beta power ($p = 0.003$), while PIGD showed elevated high beta power at rest ($p = 0.056$). Aperiodic parameters significantly differentiated TD and PIGD during movement. In PIGD, aperiodic features also separated rest from movement. Rigidity was correlated with periodic and aperiodic features (e.g., high beta, $þ = 0.601$). A logistic model combining adjusted low and high beta with exponent decay achieved strong phenotype classification (AUC = 0.83) (red area in Fig. 2).

Discussion: Decomposing STN-LFPs into periodic and aperiodic components revealed phenotype-and movement-specific patterns in PD. Adjusting for aperiodic activity enhanced interpretation of canonical power bands, revealing phenotype–condition interactions, particularly in low beta. The spectral exponent and knee frequency showed distinct responses to movement: flatter exponents (greater excitation) in TD and steeper ones (enhanced inhibition) in PIGD. Combined periodic and aperiodic metrics outperformed periodic-only models in phenotype and movement condition classification, underscoring the clinical value of aperiodic features.

Conclusions: Spectral decomposition of STN-LFPs improves detection of phenotype- and movement-specific neural dynamics in PD. These findings support incorporating spectral parameterization into adaptive DBS strategies.

References

1. Jankovic J. Parkinson's disease: clinical features and diagnosis. Journal of Neurology, Neurosurgery & Psychiatry. 2008;79(4):368-376. doi:10.1136/jnnp.2007.131045
2. Neumann W, Gilron R, Little S, Tinkhauser G. Adaptive Deep Brain Stimulation: From Experimental Evidence Toward Practical Implementation. Movement Disorders. 2023;38(6):937-948. doi:10.1002/mds.29415
3. Little S, Brown P. What brain signals are suitable for feedback control of deep brain stimulation in Parkinson's disease? Annals of the New York Academy of Sciences. 2012;1265(1):9-24. doi:10.1111/j.1749-6632.2012.06650.x

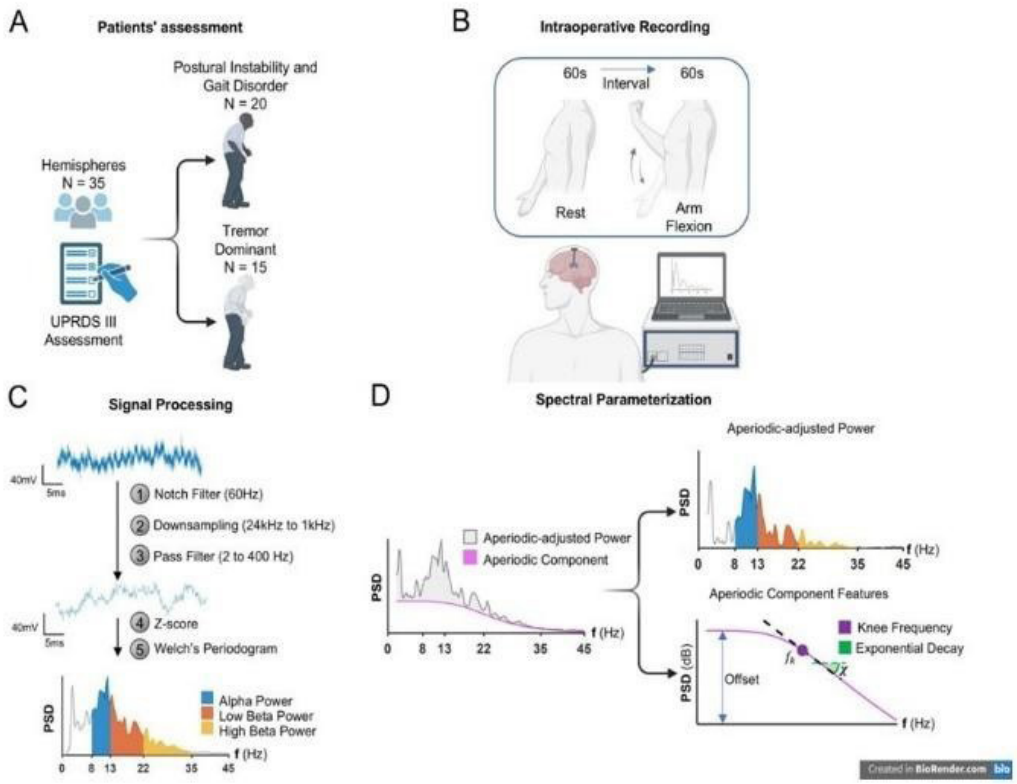

Figura 1. STN-LFPs were recorded intraoperatively from 35 hemispheres in 22 PD patients (15 TD, 20 PIGD) during rest and voluntary upper-limb movement. Power spectral density was used to isolate periodic (alpha, low beta, high beta) and aperiodic (offset, decay exponent, knee frequency) components.

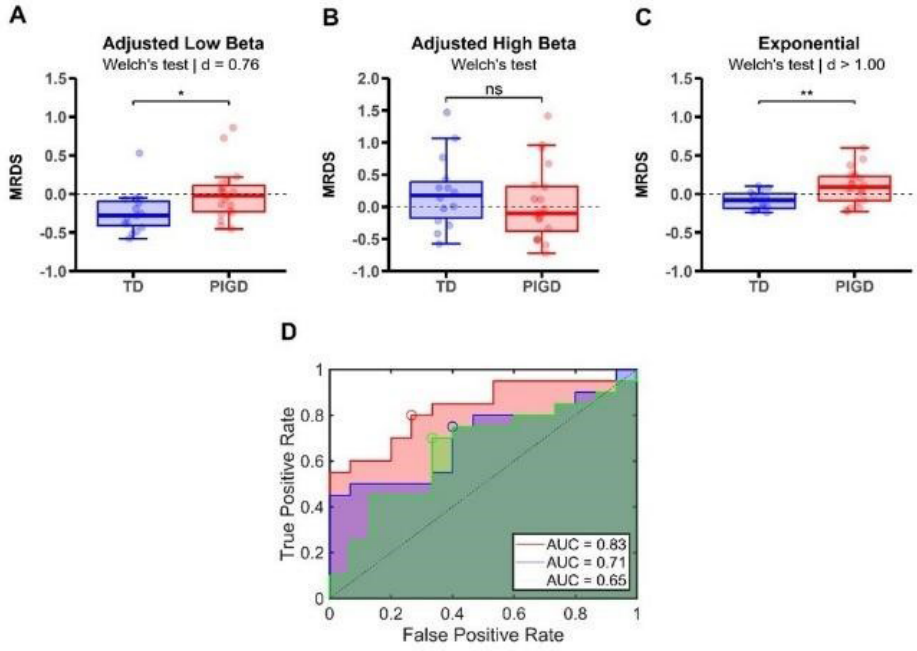

Figura 2. A logistic model combining adjusted low and high beta with exponent decay achieved strong phenotype classification (AUC = 0.83) (red area)