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Innovative Methodologies for Studying and Analyzing Intraoperative Microelectrode Recordings during GPi-DBS in Pediatric Dystonia

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Introduction: Dystonia is a neurological movement disorder characterized by sustained or intermittent muscle contractions, causing abnormal, often repetitive movements and postures. The pathophysiology of dystonia is linked to dysfunction in the basal ganglia and related motor pathways, leading to impaired motor control. Effective interventions like Deep Brain Stimulation (DBS) are crucial for symptom management, and MicroElectrode Recordings (MER) can provide valuable insights into neural activity to aid in this process. This study proposes an automated method for analyzing MER data to enhance the surgical procedure and help identify the most suitable implantation sites.

Methods: Data were collected from five pediatric patients with dystonia undergoing DBS at Meyer Children' s Hospital between 2020 and 2024. Male-to-female ratio was 2:3 and the median age at the time of surgery was 12.9 ⍰} 3.21 years. Recordings at multiple depths targeted the Globus Pallidus internus (GPi) bilaterally across three trajectories– anterior, central, and posterior. Data were annotated based on implantation depth and post-surgical patient outcomes, categorized by improvement status. Preprocessing involved the removal of high energy interferences and filtering within the MER signal bandwidth to

isolate relevant neural activity. An automated spike-sorting pipeline was applied to extract neuronal firing patterns, producing key features such as firing rate and regularity.

Results: Analysis revealed statistically significant differences between neurons at implantation sites associated with positive versus negative patient outcomes. Neurons linked to positive outcomes demonstrated a significantly lower mean firing rate (6.16 ± 1.51 Hz) compared to those related to negative outcomes (14.39 ± 2.83 Hz; $p < 0.05$). Additionally, neurons at positive-outcome sites displayed predominantly irregular firing patterns, while those at negative-outcome sites exhibited more regular, tonic firing.

Conclusion: These findings suggest that MER-derived features, particularly firing rate and regularity, can guide DBS target selection, enhancing surgical accuracy and potentially improving motor symptoms in dystonic patients.