Modulation of Cortical Oscillatory Activity Underlies Sustained Improvement in Segmental Dystonia with Pallidal Deep Brain Stimulation

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Abstract

Introduction: Segmental dystonia often responds only partially to deep brain stimulation (DBS), sometimes requiring additional or "rescue" strategies for sustained benefit. We report a 58-year-old woman with adulthood-onset idiopathic isolated focal upper limb dystonia, refractory to medications and botulinum toxin, who achieved long-term improvement after a novel approach: implantation of two electrodes within the same unilateral globus pallidus internus (GPi). This configuration yielded marked and durable relief, maintained for over nine years. To explore underlying mechanisms, we performed high-resolution quantitative EEG (qEEG) and connectivity analyses paired with clinical observations.

Clinical description: The patient developed painful dystonic contractions of the dominant right upper limb at age 48. Family history was negative. Despite 3–4 years of medical therapy and botulinum toxin, symptoms persisted. At age 58, unilateral DBS of the left GPi was performed with two electrodes in the same nucleus. This dual-electrode strategy provided striking and sustained benefit: pain markedly decreased, and involuntary movements nearly disappeared. qEEG revealed distinct patterns OFF vs ON stimulation. In the OFF state, dystonic movements correlated with asymmetric oscillations, including a prominent delta peak in left parietal/central cortices, reduced beta power (13–30 Hz), and mild gamma activity in the left motor cortex. ON stimulation reorganized cortical activity: delta abnormalities subsided; beta activity increased symmetrically in central–parietal regions, and gamma activity diminished. Connectivity analysis confirmed this reorganization: OFF showed hyper-connectivity in left central beta-2 networks and hypo-connectivity in short-range circuits, whereas ON restored beta-2 coherence, reduced gamma connectivity bilaterally, and produced more symmetrical, stable network dynamics. These changes coincided with complete resolution of dystonic movements.

Discussion: DBS of the GPi or STN is established for generalized and segmental dystonia, but focal presentations remain less studied. Dual-target strategies (GPi plus thalamus) have been attempted, yet this is the first description of two electrodes within one GPi for limb dystonia. The long-term benefit suggests that dual-electrode placement may improve modulation of the pallidal sensorimotor territory. Oscillatory findings support this: DBS restored physiologic beta synchronization, reduced pathological low-frequency activity, and suppressed abnormal gamma coupling, mirroring the patient's clinical outcome.

Conclusions: This case demonstrates the potential value of dual-electrode GPi stimulation in refractory focal dystonia, with sustained benefit over nine years. It also highlights qEEG as an exploratory biomarker to capture stimulation-induced reorganization and guide personalized DBS strategies.

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