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**THE EFFECTS OF SUBTHALAMIC NUCLEUS DEEP BRAIN
STIMULATION ON VOCAL TRACT DYNAMICS IN PARKINSON'S
DISEASE**

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An early observation associated with therapeutic ablative neurosurgery (i.e., pallidotomy) was that electrical stimulation of the anatomic targets resulted in the same clinical effects as lesioning. Chronic high-frequency stimulation of the globus pallidus using an implanted electrode and pacemaker in patients with PD resulted in significant improvement in all subscales of the Unified Parkinson Disease Rating Scale without the adverse effects often associated with pallidotomy (brain ablation) (Pahwa et al., 1997). However, the precise effects of electrode location and parameters of deep brain stimulation on speech, vocalization, and other skills involving respiratory/vocal tract muscle systems remains unknown.

In the current study, quantitative measures of vocal tract dynamics including speech aerodynamics, and orofacial force dynamics were sampled in a group of adult subjects with advanced Parkinson's disease who also received deep brain stimulator (DBS) implants in the subthalamic nucleus (STN). In a number of individual cases, significant changes in motor control and reorganization of vocal tract dynamics were observed following bilateral DBS proximal to the STN. Electrical stimulation of the STN is generally thought to decrease or inhibit its output. The changes found in motor control of the vocal tract will be discussed in relation to what is currently known about the functional role of the subthalamic nucleus in sensorimotor control of speech and voice production.

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Abstract

Parkinson's disease is a neurodegenerative condition that affects a growing number of Americans each year. It is currently estimated that nearly 1.5 million individuals manifest a constellation of sensorimotor impairments including tremor, slowness of movement, disturbances in gait and posture, movement initiation delays, decreases in the spatial acuity of somatosensory inputs, and significant delays in proprioceptive information from deep muscle afferents projecting to motor centers in the central nervous system (Markham, 1987). Collectively, these disturbances in neuromotor control severely affect patient mobility, manipulation, and speech.

Surgical treatment for Parkinson's disease (PD) was introduced in the 1950's after the serendipitous discovery that lesions of the globus pallidus ameliorated Parkinsonian features (Talairach, Paillas, & David, 1950). Enthusiasm for ablative surgical treatment waned after the discovery of the drug levodopa for the treatment of PD. However, long-term treatment with levodopa is complicated by motor fluctuations, dyskinesias, loss of efficacy, mental status changes (Koller & Hubble, 1990) and speech motor impairments (known as *dysarthria*) (Barlow et al., 1998). The addition of other antiparkinson medications like dopamine agonists often results in improvement of motor fluctuations and dyskinesias. However, this improvement is only temporary, and as the disease progresses the symptoms worsen. The long-term complications of levodopa treatment, together with advances in stereotactic and neuroimaging techniques that allow for greater accuracy and less surgical morbidity, have made surgical interventions appealing in recent years. One such surgical intervention that has re-emerged in the 1990's is known as posteroventral pallidotomy (PVP). In performing a PVP, the neurosurgeon intentionally lesions or ablates the internal segment of the globus pallidus with a 'hot' electrode. Pallidotomy has been reported to be effective for the treatment of tremor, rigidity, bradykinesia, and drug-induced dyskinesia among limb muscle systems in PD (Barlow et al., 1998; Iacono et al., 1995; Laitinen, Bergenheim, & Hariz, 1992). Unilateral pallidotomy is generally safe, but homonymous visual field defects, motor paresis, or intracranial hemorrhage

can occur (Lozano, Lang, & Galvez-Jimenez, 1995). Bilateral pallidotomy can cause cognition, memory, and frequently impairs speech and vocalization. Because pallidotomy involves irreversible brain ablation, it is not possible to 'undue' the negative effects associated with this neurosurgical procedure. Obviously this is a problem that has generated much controversy in the scientific and medical communities.

An early observation with surgery was that electrical stimulation of the anatomic targets resulted in the same clinical effects as lesioning. Chronic high-frequency stimulation of the globus pallidus using an implanted electrode and pacemaker in patients with PD resulted in significant improvement in all subscales of the Unified Parkinson Disease Rating Scale without the adverse effects often associated with pallidotomy (brain ablation) (Pahwa et al., 1997). However, the effects of electrode location and parameters of deep brain stimulation on speech, vocalization, and other skills involving respiratory/vocal tract muscle systems is unknown.

The short and long term effects of chronic deep brain stimulation on orofacial motor control and speech are unknown. The purpose of the present series of studies is to determine the efficacy of DBS implantation in advanced PD patients from a motor control perspective using objective measures of (1) muscle force dynamics and electrophysiology in the hand and lower face, and (2) speech aerodynamics before and after surgery in a group of patients with Parkinson's disease who became unresponsive to medical control. Muscle performance was assessed using a series of well established force control paradigms (Barlow et al., 1998; Barlow & Burton, 1990). Recruitment of force is an integral component of skilled movements and is known to involve many of the brain nuclei and pathways that are damaged or altered in Parkinson's disease. Speech aerodynamics is a useful method for examining the pressure-flow dynamics of the larynx and velopharynx associated with the repetition of consonant-vowel syllables.

Patients: Experiments were conducted on a series of patients [N=6] with advanced Parkinson's disease who were candidates for DBS implantation. All patients in Dr. Pahwa's PD Clinic completed neurological, cognitive, neuroimaging, and quality of life assessments.

Preoperatively, the 6 PD patients studied were free of any serious concurrent disease or illness and manifested the following characteristics: Hoehn and Yahr scores (Hoehn & Yahr,

1967) from 3-4 during 'ON' state, and 4-5 during the 'OFF' state. The exclusion criteria were as follows: Shy-Drager orthostatic hypotension, non-ambulatory, brain stem atrophy, olfaction intact, anticoagulations, and hypertension.

Speech physiology protocols were administered for this initial group of 6 STN DBS Parkinson patients at variable intervals post-implant with the Medtronic brain stimulator 'ON' and 'OFF', and were tolerated in medicated 'ON' and 'OFF' states.

Preliminary Results. Thus far, significant changes have been found in the vocal tract aerodynamics and force dynamics following DBS implantation. Changes were observed in laryngeal, velopharyngeal, and orofacial systems in virtually all patients following the implant. Statistical analyses and modeling are currently underway to document the nature of these changes in pressure-flow dynamics for the velopharynx, measures of laryngeal airway resistance, laryngeal engagement, and perioral force dynamics. These changes will be discussed in relation to what is currently known about the functional role of the subthalamic nucleus in sensorimotor control of speech and voice production.

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PARKINSON'S DISEASE

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