The Effects of Deep Brain Stimulation on Vocal Quality in an Individual with Cervical Dystonia

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Introduction

Dystonia is the third most common movement disorder in the US and affects 250,000+ Americans annually. One subtype, **cervical dystonia**, involves the muscles of the neck and causes uncontrollable contractions and twisting. The involuntary twisting also affects the laryngeal muscles involved in speech, making a person's voice sound strangled and 'interrupted'. This impacts the **vocal quality** of the individual, changing the characteristics of their distinctive voice. Common vocal symptoms include increased vocal jitter (frequency perturbation), increased vocal shimmer (amplitude perturbation), decreased fundamental frequency, and increased harmonics-to-noise-ratio (HNR) (Okun, 2009, p. 105).

Vocal quality can change following symptom management for patients with cervical dystonia . The type of change that occurs, whether an improvement or decline, is varied and may be treatment-related. One treatment option is **Deep Brain Stimulation (DBS)**, a surgically implanted medical device used when less-invasive treatment like botox is unsuccessful. This device uses a programmed external remote to send electrical impulses from an implanted pulse generator (IPG) in the chest to electrodes placed in either the globus pallidus interna (GPi), the subthalamic nucleus (STN), or the ventralis intermedius nucleus of the thalamus (Vim), depending on the types of symptoms exhibited. The impulses inhibit over-contracted muscles to reduce tremors and twisting.

With the increasing implementation and success of DBS, an important question became "How does DBS affect vocal quality in individuals with cervical dystonia?" The current study addresses acoustic parameters of vocal quality under manipulated combinations of electrical impulse strengths.

Research Questions

Q1: Do acoustic measures of vocal quality improve with DBS activation versus non-activation?

Q2: What is the relationship between impulse strength and the acoustic parameters of speech?

Method

Participant: A 66-year-old female diagnosed with cervical dystonia with bilateral Vim DBS implants participated. The device had 4 pre-programmed impulse settings per IPG (labeled A-D), with 16 different bilaterally combined impulse strengths (left side voltage + right side voltage).

Materials: : Audio samples were collected and analyzed using the Praat software and an external head-mounted microphone. Further analysis was performed through The R Project for Statistical Computing.

Procedure & Data Analysis. The participant provided audio samples of /a/, /i/, /u/, and a standard reading sentence in a noise-controlled environment. Samples were taken each under 16 manipulated impulse strengths and with the device turned off. Fundamental frequency, jitter, shimmer, mean HNR, and pitch range were computed through Praat. Correlation coefficients and p-values were calculated using The R Project to determine the significance of the relationships between impulse strength and acoustic parameters. Improvement between DBS activation versus non-activation was determined by observing data from each set and comparing the numerical outcomes.

Results

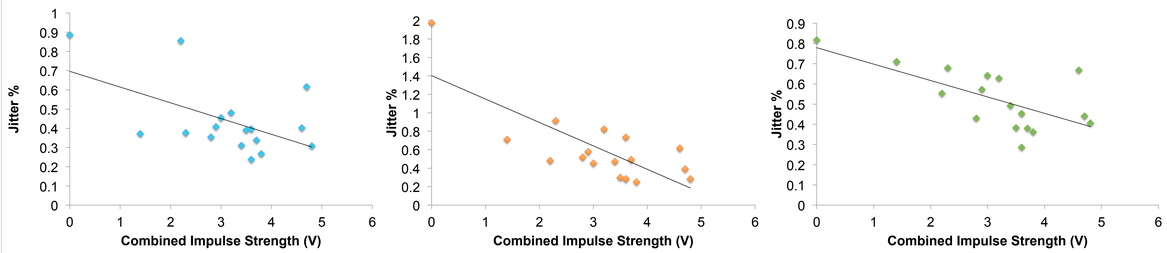

Figure 1. **Jitter % of vowel productions /a/ (left panel), /i/ (middle panel), and /u/ (right panel)**

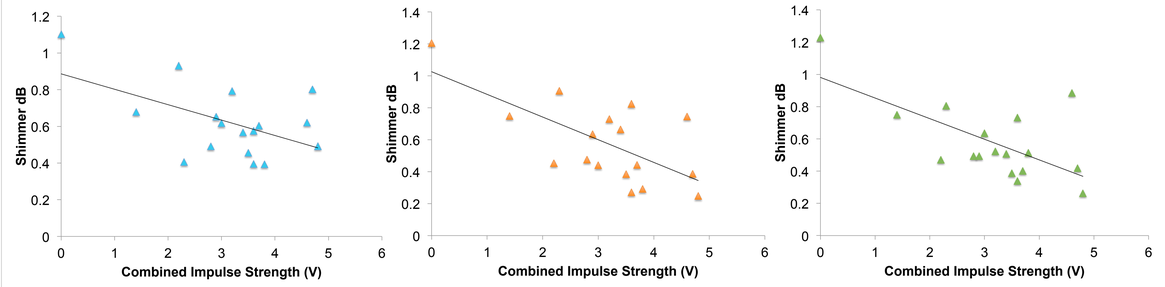

Figure 2. **Shimmer dB of vowel productions /a/ (left panel), /i/ (middle panel), and /u/ (right panel)**

Table 1. **Correlation coefficient and p-value data for determining significance and relationship between impulse strength and jitter, and impulse strength and shimmer**

Acoustic Parameter	R-value	P-Value
Jitter /a/	-0.53	0.028
Shimmer /a/	-0.52	0.032
Jitter /i/	-0.76	>.001
Shimmer /i/	-0.66	0.003
Jitter /u/	-0.67	0.003
Shimmer /u/	-0.64	0.005

Discussion

Reduced voice quality has been shown to negatively impact speech intelligibility, and quality of life (Murry, Medrado, Hogikyan, & Aviv, 2004). Our results indicate that DBS activation yielded improved vocal quality measures compared with non-activation, in jitter and shimmer. As the trend line for each graph indicates (Figures 1 & 2), jitter and shimmer results decrease as the impulse strength increases, which was found to be statistically significant (Table 1.) Although individual changes in jitter or shimmer may be difficult to perceptually detect, combinations of affected acoustic parameters can decrease quality and intelligibility.

Limitations

Sample size, number of trials, and manipulation of impulse settings were limitations to this study. Trials were limited to one per combination, due to the adverse physical effects of impulse changes. For each pulse generator, 4 pre-programmed settings were available for left + right-side combinations. Manipulation did not extend past combining the pre-set programs, so we were unable to identify a setting at which the impulse strength no longer improved jitter or shimmer outcomes of the vowels.

Analysis of sentence production revealed a significant relationship between increased impulse strength and decreased fundamental frequency, which contradicted the literature. This could be due to inconsistency of movement in cervical dystonia as well as the variation in cause and severity of the disorder. Further analysis is needed.

Future Directions

In addition to continued testing of DBS effects on vocal quality, we also want to understand how perceptible these effects are and how they impact quality of life. Further research is warranted to establish evidence for DBS efficacy by fostering an understanding of the role of electrical stimulation in motor control for speech. This understanding can lead to enhanced treatment, can help provide feedback for development of technology, and improve intelligibility and quality of life in those with dystonia.

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