Deep Brain Stimulation: Systematic Review of Parameters for Speech and Swallowing in Patients With Parkinson's Disease

Bridget Carlile BA, Brian Martin BA
University of North Carolina Chapel Hill, Division of Speech and Hearing Sciences

UNC SCHOOL OF MEDICINE

Background

Deep brain stimulation (DBS) is a relatively common intervention for individuals with Parkinson's Disease, used to alleviate tremor especially when medication is no longer effective on its own (Niketeghad, Nedrud, Hanrahan & Mahoor, 2014). Insertion of electrodes can occur at multiple cortical sites, with the subthalamic nucleus being one of the most commonly used in clinical practice as well as one of the most researched locations. While providing remarkable results in the management of tremor, STN-DBS does not restore prior neurophysiological function and has been associated with unwanted side effects involving speech and swallowing which impact overall quality of life (Guehl et al., 2006; Hammer et al., 2011; Klostermann et al., 2008; Ostergaard & Sunde, 2005). To ameliorate these undesirable side effects, researchers have manipulated different DBS parameter settings including: frequency, amplitude/voltage, and electrical current customization.

Objectives

Identify the effects of STN-DBS on speech and swallowing

Identify DBS parameters and how they can be adjusted to enhance speech and swallowing

Discuss new technologies/advances in STN-DBS and the potential effects on speech and swallowing

Methods

Clinical Question: "What are the programming parameters that can be used to optimize speech and swallowing outcomes for patients with Parkinson's after deep brain stimulation of the subthalamic nucleus?"

Search string: deep brain stimulation AND (speech OR swallow* OR dysphagia OR voice OR dysarthria) AND (program* OR setting OR management OR "current shaping" OR frequency OR current OR voltage OR pulse OR amplitude OR electrical parameters) AND parkinson*

PubMed Results: 112 articles, 13 were chosen as relevant to the clinical question and were appraised by the researchers.
In addition, 24 articles were reviewed to assess STN-DBS effects on speech and swallowing.

Summary of Articles

Clinical Control Trials (CCTs)

Study Name	No. of Pts	Age (years)	DBS Duration (months)	PD Duration (years)	Parameter Tested	Measurement of Speech or Swallowing	Outcome	Statistical Significance	Appraisal
Astrom et al., 2010	10	x=59 SD=n/a	Unknown	Unknown	Voltage 2V, 4V, OFF	Sustained "ah" for 3 repetitions, intelligibility (unspecified test), 60-second monologue.	High amplitude decreased speech intelligibility. Medial and posterior placement related to dysarthria	Unknown	Lesser Quality
Barbe et al., 2014	6	x=69 SD=6.91 R=58-78	x=69 SD=39.8 R=22-132	x=17.6 SD=11.7 R=7-33	Voltage ILS, csILS*	Maximum phonation time, oral diadochokinesis, spontaneous speech, and a read text. Subjective rating	Current-shaping stimulation improved DDK rate and reduced voicing during voiceless stop consonants	Yes	Lesser Quality
Hammer et al., 2011	17	x=59 SD=13.7 R=36-76	x=11.8 SD=10.0 R=3-32	x=12	Current settings assessed	Intraoral air pressure, Air flow, velopharyngeal (VP) area	Improved intraoral air pressure for lower frequency in right electrode, improved VP area associated with lower frequency in left electrode	Yes and No	Lesser Quality
Hammer et al., 2010	18	x=60 SD=13.4 R=36-76	x=12 SD= 9.8 R=3-32	x=11.5	individual settings assessed	Pressure below glottis, peak air flow, mean vocalic air flow, laryngeal resistance	Negative correlation between stimulation frequency and aerodynamic measures.	No	Good Quality
Moreau et al., 2011	11	x=69 SD=n/a	x=60 R=3-8	x=19 R=17-23	Frequency 60Hz, 130Hz, OFF	Median fundamental frequency (f0), SD f0, median relative intensity, maximum phonation time, forced expiratory volume, median intra-oral pressure, laryngeal resistance. UPDRS-III	LFS improved acoustic and aerodynamic measures, and subjective speech improvement.	Yes	Lesser Quality
Sidiropoulos et al., 2013	45	x=59 SD=7.8	x=39.5 SD=27.8	x=17.8 SD= 5.7	Frequency HFS: 120-185Hz LFS: <80Hz	UPDRS-III (item 18)	18/45 pts showed improvement in speech with LFS, 12/45 remained on LFS	No	Lesser Quality
Stegemoller et al., 2013	17	x=62 SD=9 R=43-73	x=38.5 SD=8.4 R=6-58	x=15.5 SD=1.8 R=8-23	Frequency: 60Hz, 130Hz, OFF Other setting maintained.	Verbal fluency	LFS improved speech in non-tremor dominant (NTD) group.	No	Lesser Quality
Tornqvist et al., 2005	10	x=65 SD=5.04	x=15 SD=5	x=14.7 SD=6.3 R=8-21	Amplitude: decreased or increased by 25% Frequency: 70,130, 185Hz	Intelligibility, articulation, voice quality, rate of speech, reading nonsense passages and completing subjective visual analogue scale	LFS increased intelligibility and articulation. Increased amplitude decreased intelligibility and articulation.	Yes	Lesser Quality
Tripoliti et al., 2008	14	x= 60 SD=6.5	x=13.6 SD=8.6	x=15.6 SD=5	Amplitude: off, 2V, 4V	Speech intelligibility, intensity, UPDRS-III (speech)	2V stimulation improved intelligibility	Yes	Good Quality
Xie et al., 2015	7	x=65 R=57-73	x=52.8	x=12.9 R=8-17.8	Frequency: 60Hz, 130Hz, OFF	Aspiration frequency through MBSS and perceived swallowing difficulty	LFS reduced aspiration frequency.	Yes	Good Quality

Systematic Reviews:

- **Mahlkecht, 2015**: Findings reveal low frequency stimulation (LFS) is associated with benefits in aspiration tendency, dysarthria, aerodynamic speech components, and stimulation induced fluency impairment.
- **Picillo et. al, 2016**: Findings explain benefits of different parameter settings and provide a rational and algorithm for STN-DBS programming.

Results

STN-DBS Effects on Speech and Swallowing	
Articulation	Decreased intelligibility, precision of articulation, and increased prevalence of dysarthria were associated with STN-DBS Dysarthria may be due to improper positioning of the electrode and/or stimulation of surrounding structures Of note, one study found no articulation changes with STN-DBS.
Voice	Strained voice, breathiness, and abnormal laryngeal muscle contraction were found to be side effects of STN-DBS. However, studies found improvement in overall voice quality, including voice tremor reduction and increased loudness..
Swallowing	Some studies find an overall worsening of swallowing both immediately after surgery and one-year post-surgery. However, other studies found that swallowing is unaffected/.

STN-DBS Parameter Effects on Speech and Swallowing	
Frequency	Commonly, a setting of 130 - 180 Hz is used to for patients with PD, however reduction of stimulation to between 50 - 80 Hz has been associated with benefits acoustic and aerodynamic aspects of speech, increased intelligibility and reduction of aspiration both objective and in self reported subjective measures.
Voltage	Some studies have shown that alteration of voltage, from the normal 4 V to a lower 2 V, has shown improvement in speech intelligibility.
Setting Customization	Interleaved stimulation, current-shaping, and closed-loop systems were associated with improved speech outcomes.

Discussion

Effects of STN-DBS parameter settings on speech and swallowing.

- Frequency: lower frequency stimulation correlated with improved speech intelligibility, swallowing, aerodynamic measures of speech, and subjective speech improvement
- Voltage: higher amplitude associated with decreased intelligibility and errors in articulation with some remediation of symptoms at lower amplitude
- Individualized settings: interleaved and current-shaping stimulation showed both objective and subjective improvements in speech
- New technologies: closed-looped dynamic systems and a directional electrode for variable titration of current may reduce stimulation of surrounding structures

Conclusion

STN-DBS has the potential to adversely affect articulation and swallowing characteristics in patients with Parkinson's disease. Lowering frequency, amplitude, and dynamic settings are all proposed solutions for these undesirable axial symptoms. Regardless, it is important in pre-surgical education to inform patients of the possibility of these symptoms. As professionals in the field of speech and swallowing, SLPs should advocate for patients undergoing STN-DBS and be adequately informed to provide the best, evidence based advice.

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