

examination of performance over time. However, this design lacks the use of control subjects and randomization of participants into different treatment groups.

Ciucci, Barkmeier-Kraemer and Sherman (2008) examined the effects of STN DBS on the oral and pharyngeal stages of deglutition in 12 male and 2 female subjects with PD. The participants received a videofluoroscopic swallowing study (VFSS) that looked at the effects of three independent variables: DBS state (ON/OFF), bolus state (5 or 10 mL water or 7 grams of cracker – in this order) and trial state (1, 2 or 3). Participants were tested following 12 hours without levodopa medication and 1 hour was given between changes in DBS states. Measures of pharyngeal transit time (PTT), maximal hyoid bone excursion (MHE), oral composite score (OCS) and pharyngeal composite score (PCS) were rated. The OCS included: number of swallows per bolus, number of festinated tongue movements, range of tongue movement, oral residue and premature loss of bolus to the pharynx. The PCS included: decreased velar elevation, decreased posterior pharyngeal wall displacement, laryngeal penetration, aspiration, vallecular residue, pyriform sinus residue and upper esophageal sphincter dysfunction.

The researchers used a 2x3x3 ANOVA and a Bonferonni t-test to examine the results. *PTT*: PTT significantly decreased in the DBS ON state. As the bolus changed and trials progressed the PTT increased. *MHE*: No significant changes were seen during the DBS and trial states. There was a significant increase as the bolus changed from liquid to solid. *OCS*: There was no change noted during either DBS state. However as the bolus changed and the trials progressed the OCS significantly decreased. *PCS*: The PCS significantly increased across all conditions when DBS was ON. Therefore, DBS of the STN demonstrated improvements in the pharyngeal swallow; however the bolus state affected the oral and pharyngeal stages of the swallow independent of the DBS state.

Limitations of this study include the disproportionate gender representation. Thus the findings cannot be generalized as readily to all persons with PD who have DBS. Also random presentation of the bolus state was not considered, making it difficult to determine patterns of interaction. Furthermore, pre-operative measures were not considered and therefore pre and post comparisons could not be made. Although this study has strong inter/intrarater reliability there was no mention of who rated the VFSS results and what their experience level in regards to swallowing parameters was. Another limitation includes not looking at effects on swallowing in comparison to time since implantation as all

participants were seen at different times post-implantation. Lastly, the participants were only tested while off their medications, but persons with PD and DBS STN typically require some amount of levodopa medication.

Even with these limitations, the findings provide suggestive evidence due to the detailed analysis and discussion, strong inter/intrarater reliability and the thorough description of met1 0 0 1 4ETBT14t1 0 0tBT14teqe qmade.

transit time, tongue movement and laryngeal elevation delay time. The Unified Parkinson's Disease Rating Scale (UPDRS) was also used to evaluate the swallowing function of these participants. The test foods included: 5ml of jelly, honey-thickened water, nectar-thickened water and plain water.

A paired t-test was used to compare oropharyngeal transit time (OTT), speed of tongue movement and laryngeal elevation delay time (LEDT). The Mann-Whitney U-test was used to analyze the UPDRS and VFSS scaled scores. Results indicate there was no difference between VFSS scores pre and post-operatively with DBS ON; however UPDRS scores significantly improved

study's findings are compelling due to its statistical analysis, presentation of results, discussion of the strengths and weaknesses of the findings, and strong inter/intrarater reliability.

Lengerer, Kipping, Rommel, Weiss, Breit, Gasser and Wachter (2012) retrospectively examined pre and post-operative STN DBS VFSS of 7 female and 11 male individuals with idiopathic PD (according to the British Bank criteria). Pre-operatively no participants reported any signs of dysphagia. VFSS records include examination of 3 consistencies (viscous, fluid and solid) and 3 conditions (pre-operatively, 20 month post-operatively DBS ON and 20 months post-operatively DBS OFF). The participants took their ordinary doses of medications for each condition. There was 10 minutes between DBS ON and OFF states during post-operative examinations. Participants with the most affected deglutition (7/18 considered to have mild impairment) were isolated to further explore the effects of DBS on the severity of the deglutition impairment.

T-tests were used to compare clinical parameters in between groups or conditions. Further the Friedman test for non-parametric data in SPSS with alpha <0.05 compared pre-surgery and post-surgery DBS ON and OFF. Significant results were examined using post hoc pairwise comparison using sign test for the qualitative data and the Wilcoxon tests for the quantitative measures. Qualitative measures were gathered with the New Zealand Index of Multidisciplinary Evaluation of Swallowing (NZIMES). On a scale of 0 (no impairment) to 4 (profound impairment) it examined lingual control, palatal closure, position of bolus at onset of swallow, relative timing of onset of swallow, velopharyngeal closure, pharyngeal contraction/bolus propulsion, laryngeal excursion, bolus propulsion through UES, clearance of pyriform sinus residual, upper esophageal parameters, aspiration/penetration and airway reaction. Researchers found across all three conditions there were no clinically relevant signs of dysphagia. A significant ($p=0.012$), but marginal decrease of NZIMES scores for pharyngeal contraction and bolus propulsion were seen between pre-operative and post-operative DBS OFF. No significant differences were seen for the subgroup of participants with mild deglutition.

Quantitative measures were evaluated with the Logemann-MBS parameters. The oral, pharyngeal, laryngeal and velar timing parameters were determined by the number of images from an acquisition rate of 15/s. MHE was determined with a computer program (Magic Web). With DBS ON, findings suggested a significant decrease of the pharyngeal delay time (PDT) (up to 70%), PTT (16%), pharyngeal response time

(PRT) (18%) and the cricopharyngeal opening duration (CPOD) (21%) when compared to the pre-operative and post-operative DBS OFF conditions. This difference was seen more prominently in the pre-operative condition in fluid consistency. The subgroup of participants with mild deglutition demonstrated a significant decrease of PRT only (8%) with DBS ON compared to pre-operative and

and the findings are based on one participant and therefore difficult to generalize. Furthermore, Cooper, et al. (2013) suggested once DBS is turned off there is a washout period. This case report suggests the participant noticed immediate improvements when his DBS was turned off. Greater detail in the types of improvements and a definition of immediate would strengthen this case report. Overall, this study provides suggestive evidence that STN DBS has negative effects on swallowing in persons with refractory PD.

Discussion

Overall, the results of this critical review suggest that the effects of STN DBS on swallowing in persons with PD are positive, but limited. The evidence from these 8 studies needs to be interpreted with some caution due to the:

- a) small sample sizes: Given the nature of the area being studied small sample sizes are understandable and most studies took this into consideration; however as STN DBS is increasing in use for treating persons with PD, it is suggestive studies with larger samples be completed.
- b) inconsistent findings: Of the 8 studies, 5 suggested there was an improvement seen in the swallowing function following STN DBS, 2 suggested no change and 1 suggested a negative impact on swallowing function following STN DBS.
- c) large range of improvements seen: Of the 6 studies that suggested an improvement in swallowing function following STN DBS, 2 suggested an overall improvement, 2 indicated the pharyngeal swallow improved and 2 suggested the oral swallow improved.

Studies only including an instrumental swallowing assessment were included in this critical review making it easier to compare and contrast the findings of each study. However each study chose to evaluate this instrumental assessment in a different manner. The different measurements made included: oral preparation, transit time, residue,

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