PARKINSON'S DISEASE AND ATYPICAL PARKINSONIAN SYNDROMES: COMPARISON OF VOICE AND SWALLOWING PARAMETERS

Georgia Deligiorgi[1], George Karamanis[2], Ioannis Papakyritsis[1], Kyriaki Zarnomitrou[1], Aggeliki Orfanaki[1], Christopher Kobylecki[3], Dimitra Veltsista[2], Elisabeth Chroni[2], Zinovia Kefalopoulou[2], Emilia Michou[1]

[1] Department of Speech and Language Therapy, School of Health Rehabilitation Sciences, University of Patras, Patras, Greece
[2] Medical School, University of Patras, Patras, Greece
[3] Manchester Centre for Clinical Neurosciences, Manchester, United Kingdom

ABSTRACT

Introduction: Parkinson's Disease (PD) and Atypical Parkinsonian Syndromes (APS) are neurodegenerative disorders causing dysphonia and dysphagia. This study investigates auditory and perceptual voice parameters in PD and APS patients, with and without dysphagia, compared to a healthy Control Group (CG), and explores potential correlations between phonation and swallowing biomarkers.

Methods: Twenty patients with parkinsonism [10 PD (2 females, H&Y: 2.8 ±1, years of age (yoa): 68.5(58-76) and 10 APS (5 females, H&Y: 3.9±1, yoa: 71(59-74) and 20 healthy participants (12 females, yoa: 53.5 (48-71) were recruited during their routine appointment at the Movement Disorders Clinic. Participants underwent perceptual and objective assessments of voice (VHI, V-RQOL, GRBAS, acoustic and aerodynamic measures) and swallowing (EAT-10, SWAL-QoL, Water Swallow Test 90cc). Data were analyzed using non-parametric tests (SPSS, $p<0.05$).

Results: Both patient groups showed statistically significant differences in voice and swallowing parameters compared to CG, with APS patients being more affected compared to PD patients. The two experimental groups (PS and APS) were differed in variables: GRBAS (U=19, p=0.019), nonverbal oromotor abilities (U=21, p=0.029), F_0SD (U=22, p=0.035) amongst others. Patients with swallowing impairments within each of the PD and APS groups differed significantly compared to patients with no swallowing impairments, in parameters including non-verbal diadochokinetic tasks and GRBAS. The acoustic voice parameters were not significantly different in PD and APS with and without swallowing impairments.

Conclusions: Subjective and objective assessments are valuable for evaluating voice and swallowing in PD and APS. Specific voice parameters, reflecting pitch variability, can distinguish dysphagic from non-dysphagic patients, highlighting their potential predictive role in clinical evaluation of voice and swallowing function.

Key words: Parkinson's disease, Atypical Parkinsonian Syndromes, Dysphonia, Dysphagia

ΝΟΣΟΣ ΠΑΡΚΙΝΣΟΝ ΚΑΙ ΑΤΥΠΑ ΠΑΡΚΙΝΣΟΝΙΚΑ ΣΥΝΔΡΟΜΑ: ΣΥΓΚΡΙΣΗ ΠΑΡΑΜΕΤΡΩΝ ΦΩΝΗΣ ΚΑΙ ΚΑΤΑΠΟΣΗΣ

Γεωργία Δελληγιώργη[1], Γεώργιος Καραμάνης[2], Ιωάννης Παπακυρίτσης[1], Κυριακή Ζαρνομήτρου[1], Αγγελική Ορφανάκη[1], Christopher Kobylecki[3], Δήμητρα Βελτσίστα[2], Ελισσάβετ Χρόνη[2], Ζηνοβία Κεφαλοπούλου[2], Αιμιλία Μίχου1

[1] Τμήμα Λογοθεραπείας, Σχολή Επιστημών Αποκατάστασης Υγείας, Πανεπιστήμιο Πατρών, Πάτρα, Ελλάδα
[2] Ιατρική Σχολή, Πανεπιστήμιο Πατρών, Πάτρα, Ελλάδα
[3] Κέντρο Κλινικών Νευροεπιστημών Μάντσεστερ, Μάντσεστερ, Ηνωμένο Βασίλειο

ΠΕΡΙΛΗΨΗ

Εισαγωγή: Η νόσος του Πάρκινσον (ΝΠ) και τα άτυπα σύνδρομα Πάρκινσον (ΑΠΣ) είναι νευροεκφυλιστικές διαταραχές που προκαλούν δυσφωνία και δυσφαγία. Η παρούσα μελέτη διερευνά τις ακουστικές και αντιληπτικές παραμέτρους της φωνής σε ασθενείς με ΝΠ και ΑΠΣ, με και χωρίς δυσφαγία, σε σύγκριση με μια ομάδα υγιών ατόμων (ΟΕ), και διερευνά πιθανές συσχετίσεις μεταξύ των βιοδεικτών φώνησης και κατάποσης.
Μέθοδοι: Είκοσι ασθενείς με παρκινσονισμό [10 PD (2 γυναίκες, H&Y: 2,8 ±1, ηλικία (yoa): 68,5(58-76) και 10 APS (5 γυναίκες, H&Y: 3,9±1, yoa: 71(59-74) και 20 υγιείς συμμετέχοντες (12 γυναίκες, ηλικία: 53,5 (48-71) εντάχθηκαν στη μελέτη κατά τη διάρκεια της τακτικής τους επίσκεψης στην Κλινική Κινητικών Διαταραχών.

ΕΛΛΗΝΙΚΗ ΝΕΥΡΟΛΟΓΙΚΗ ΕΤΑΙΡΕΙΑ

Οι συμμετέχοντες υποβλήθηκαν σε αντιληπτικές και αντικειμενικές αξιολογήσεις της φωνής (VHI, V-RQOL, GRBAS, ακουστικές και αεροδυναμικές μετρήσεις) και της κατάποσης (EAT-10, SWAL-QoL, Water Swallow Test 90cc). Τα δεδομένα αναλύθηκαν χρησιμοποιώντας μη παραμετρικές δοκιμές (SPSS, p<0,05).
Αποτελέσματα: Και οι δύο ομάδες ασθενών παρουσίασαν στατιστικά σημαντικές διαφορές στις παραμέτρους της φωνής και της κατάποσης σε σύγκριση με την ΟΕ, με τους ασθενείς με ΑΠΣ να επηρεάζονται περισσότερο σε σύγκριση με τους ασθενείς με ΝΠ. Οι δύο πειραματικές ομάδες (ΝΠ και ΑΠΣ) διέφεραν σε μεταβλητές: GRBAS (U=19, p=0,019), μη λεκτικές στοματοκινητικές ικανότητες (U=21, p=0,029), F_0SD (U=22, p=0,035) μεταξύ άλλων. Οι ασθενείς με διαταραχές κατάποσης σε καθεμία από τις ομάδες PD και APS διέφεραν σημαντικά σε σύγκριση με ασθενείς χωρίς διαταραχές κατάποσης, σε παραμέτρους που περιλαμβάνουν μη λεκτικές διαδοχοκινητικές εργασίες και GRBAS. Οι παράμετροι της ακουστικής φωνής δεν διέφεραν σημαντικά σε και ΝΠ και ΑΠΣ με και χωρίς διαταραχές κατάποσης.
Συμπεράσματα: Οι υποκειμενικές και αντικειμενικές αξιολογήσεις είναι πολύτιμες για την αξιολόγηση της φωνής και της κατάποσης σε ΝΠ και ΑΠΣ. Συγκεκριμένες παράμετροι της φωνής, που αντανακλούν την μεταβλητότητα του τόνου, μπορούν να διακρίνουν τους ασθενείς με δυσφαγία από τους ασθενείς χωρίς δυσφαγία, υπογραμμίζοντας τον πιθανό προγνωστικό τους ρόλο στην κλινική αξιολόγηση της φωνής και της λειτουργίας της κατάποσης.

Λέξεις-κλειδιά: Νόσος του Πάρκινσον, Άτυπα Συνδρόματα Πάρκινσον, Δυσφωνία, Δυσφαγία

INTRODUCTION

Parkinson's Disease (PD) and Atypical Parkinsonian Syndromes (APS) are neurodegenerative disorders characterized by parkinsonism—bradykinesia, rigidity, and postural instability. AP syndromes include multiple system atrophy (MSA), progressive supranuclear palsy (PSP), corticobasal syndrome (CBS), dementia with Lewy bodies (DLB), and vascular parkinsonism (VP). [1,2] These disorders may include a variety of neurological disorders similar to PD, but the clinical features are not only due to cell loss in the substantia nigra but also in other parts of nervous system that contain dopamine receptors, such as the striatum. Typically, the APS, commonly also known as 'PD-plus syndromes' are thought to be related to accumulations of alpha-synuclein (synucleinopathy) or tau (tauopathy) and these may affect multiple brain regions, including the pigmented nuclei in midbrain and brainstem, the olfactory tubercle, cerebral cortex, and parts of the peripheral nervous system.[2,3] Voice dysfunction is among the earliest clinical symptoms in people with PD (pwPD), affecting approximately 80-90% of patients.[4,5] Similar early voice changes are reported in PSP and MSA.[6-8] These conditions impair motor, behavioral, and sensory functions required for voice production,[9,10] disrupting respiratory support, vocal fold vibration, and resonance, which reduces voice quality, frequency, and intensity.[11-13]

Most pwPD develop hypokinetic dysarthria due to altered basal ganglia output consequent on dopamine denervation.[14,15] PD speech is characterized by monotonous pitch and loudness, weak and breathy voice from reduced vocal fold adduction, rough/hoarse voice from compensatory strategies or cricothyroid rigidity.[16-20] Patients with PSP and MSA often present with mixed dysarthria, exhibiting a combination of hypokinetic, spastic, and ataxic features. These clinical features likely arise as a result of more widespread multisystem neurodegenerative changes. Spasticity predominates in PSP, while motor and ataxic symptoms are more evident in MSA, affecting all speech subsystems.[21-23] CBS may also involve dysarthria reflecting cortical and motor dysfunction.[24]

Swallowing disorders are frequent in pwPD and a major cause of morbidity due to aspiration pneumonia.[25,26] Both oral and pharyngeal phases are affected, leading to abnormal bolus formation, multiple tongue elevations, delayed swallow reflex, prolonged pharyngeal transit time, and repeated swallows.[27] Pharyngeal motor nerve degeneration and dopaminergic deficits contribute to oropharyngeal dysphagia.[28] Dysphagia is also an early symptom in MSA, usually within three years after disease onset,[29] with oral and pharyngeal stages impaired in both MSA-P and MSA-C.[30] In PSP, swallowing dysfunction mainly affects the oral phase.[31] Dysphagia is also common in DLB and CBS, again reflecting broader motor and cortical impairments.[24]

Objective analysis of voice parameters in parkinsonism provides valuable information about voice disorders, respiratory/vocal insufficiency, and prognosis.[20,32] Perceptual assessments also help identify phonatory changes, while patient-reported outcomes reflect disease progression and quality of life.[33,34] Several studies report correlations between acoustic voice changes and swallowing difficulties in PD,[35,36] possibly due to a common pathophysiological mechanism.[12,37,38] However, voice measures alone show limited sensitivity for early dysphagia detection.

The aims of this study are 1) to compare the auditory and perceptual voice characteristics in pwPD and pwAPS, with and without dysphagia, against a

healthy control (HC) group and 2) to investigate the possible predictive value of specific voice parameters for detecting swallowing difficulties in pwPD and pwAPS.

MATERIALS AND METHODS

Participants

Patients with parkinsonism and age-matched healthy controls (HC) enrolled sequentially during routine visits at the Movement Disorders Clinic, Department of Neurology, General University Hospital of Patras between September 2023 and October 2024. Written informed consent was obtained from all participants before the experiments. All experiments were undertaken in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). The approval for the studies was granted by the Institutional Ethics Committee of the University Hospital of Patras (no. of approval 347/13-07-2023). Inclusion criteria were informed consent and age between 18–80 years. Exclusion criteria were speech, voice, or language disorders unrelated to PD/APS, orofacial anatomical disorders, and non-related respiratory conditions. Disease severity was assessed using the Hoehn and Yahr scale.[39] Patient evaluations were conducted at the hospital, usually lasting for 1 hour, while controls were assessed at their residence.

Procedures

Following consent, the patients' medical history was collected, followed by formal orofacial assessment (NOT-S),[40] informal nonverbal diadochokinetic tongue tasks, verbal diadochokinetic rate task (/pataka/ repetition) and perceptual and objective measures of voice and swallowing.

Swallowing tasks and recordings

Efficacy of swallowing was evaluated using the screening symptomatology list of EAT-10-GR [41] and Swallowing Quality-of-Life.[42] Swallowing efficiency was assessed with 90cc Water Swallowing Test.[43,44] Water swallowing procedures were performed with water at room temperature while the measurements of swallowing efficacy included time to complete swallowing of 90cc, measured with a stopwatch, remainder water quantity (mls), in the occasion when patients could not swallow full amount and any signs of dysphagia.

For the presence of dysphagia in the neurologically impaired population, the following parameters had to be present: 1) modified diet, 2) positive results on the screening tool EAT-10-GR [41] (score≥4), 3) swallowing speed in WST ≥10ml/s,[45] and 4) signs of penetration/aspiration (coughing, choking, wet voice quality, throat clearing, watering eyes, shortness of breath.[46]

Voice tasks and recordings

Voice assessment included the administration of the VHI,[47] V-RQOL scales,[48] GRBAS perceptual rating,[49] and acoustic/aerodynamic voice analyses.[46,50-54] Participants were asked to perform three repetitions of sustained vowel /a/, as long as possible at a comfortable pitch and loudness. Tasks were first demonstrated by the examiner. Voice was recorded and analyzed with Praat software (V6.1.16) During recordings in a quiet room without ambient noise, a sampling frequency of 44.1 kHz was used with a cardioid condenser microphone (Blue Snowball) placed 30 cm away from the level of the mouth. Acoustic and aerodynamic measures included maximum phonation time (MPT), mean fundamental frequency (mF0), F0 standard deviation (F0SD), maximum F0 (maxF0), minimum F0 (minF0), jitter (%), shimmer (%), noise-to-harmonic ratio (NHR), fraction of unvoiced frames (FUF), degree (%) (DVB) and number (NVB) of voice breaks, mean/maximum/minimum intensity.[46,50-54]

Inter-rater reliability of acoustic analysis

Inter-rater reliability analysis was conducted by 3 raters, one post-graduate speech-language therapist and two graduate students. All raters had received the same acoustic analysis training and used the same Praat version (V6.1.16). Cohen's weighted kappa was measured across the 3 raters (SPSS V.29), indicating good reliability (1 vs 2= k:0.726, 95%CI (0.597,0.856),1 vs 3= k:0.769, 95%CI (0.658, 0.880), 2 vs 3=k:0.85,95%CI (0.754,0.955)).

Statistical analysis

Statistical analysis was performed using SPSS (v.29). Levene's test (p-value < 0.01) was initially used to test the homogeneity of variances. For values not following normal distribution, non-parametric tests (Kruskal-Wallis) were used to identify any differences in the distribution of the median between the three groups. Non-parametric comparisons (Mann-Whitney Test) per two groups were performed for the variables that showed a significant difference between the three groups. Correlations were made with non-parametric tests (Spearman's correlation coefficient). Analysis of the extent to which specific parameters can be indicative of swallowing disorders was performed with receiver operating characteristic (ROC) curves and area under the curve (AUC) values, treated with non-parametric statistics. A $p < 0.05$ was taken as a measure of statistical significance. All data are presented as group mean ± SEM, unless stated otherwise.

RESULTS

The study included 20 patients with parkinsonism [10 with PD (2 females, H&Y: 2.8 ± 1, years of age (yoa): 68.3 ± 6) and 10 with APS (4 females, H&Y: 3.9 ± 1, yoa: 70.1 ± 4.3)] and 20 HC (12 females, yoa: 57.3 ± 7).

Patients recruited completed the study with no adverse events. Table 1 shows the participants' demographics. The APS group included people diagnosed with MSA, PSP, DLB, and VP (**Table 1**).

Table 1. Participant demographics

Clinical feature	**PD (n= 10)**	**APS (n= 10)**	**HC (n= 20)**
Age *(median, range)*	68.5 (58-76)	71 (59-74)	53.5 (48-71)
Duration *(median, range)*	6 (2-20)	4 (1.5-6)	-
Gender *(m/f)*	8/2	6/4	8/12
MSA *PSP* *DLB* *VP*		2/1 1/3 1 1/1	
Hoehn & Yahr score	2.5 (2-5)	4 (2.5-5)	-
MSA *PSP* *DLB* *VP*		4 (3-5) 4.5 (2.5-5) 3 3,5 (3-4)	
Swallowing impairments *(SI, n)*	5	5	-

Table 1 shows the participants' demographics per group and disease profile (SI: swallowing impairment). MSA: multiple system atrophy, PSP: progressive supranuclear palsy, DLB: Dementia with Lewy bodies, VP: vascular parkinsonism, HC: healthy controls.

Table 2. Differences in voice and swallowing variables across groups

Median (Range min-max)		**PD**	**APS**	**HC**	**Sig. Level**
Age		68.5 (58-76)	71 (59-74)	53.5 (48-71)	H(2) = 22.4 p < 0.001
Self-reported SI					
EAT-10		1.5 (0-29)	9.5 (0-17)	0	H(2)= 18.6 p < 0.001
Swal-QoL Total		138.5 (52-149)	111 (81-150)	148 (132-150)	H(2) = 17.9 p < 0.001
Self-reported VI					
VHI Total		14 (0-102)	43 (1-71)	1 (0-39)	H(2) = 9.31 p = 0.010
VHI L		6 (0-39)	12.5 (0-25)	0 (0-14)	H(2)= 9.44 p = 0.009
VHI F		4 (0-29)	13 (0-27)	0,5(0-15)	H(2)= 11.60 p = 0.003
VHI S		3.5 (0-34)	12.5 (0-27)	0 (0-10)	H(2)= 9.311 p = 0.010
VR QoL	**Voice now**	1.5 (1-4)	2 (1-3)	1 (1-3)	H(2)= 6.63 p = 0.036
	VR QOL TS	12.5 (10-44)	15.5 (10-36)	10 (10-21)	H(2)= 12.5 p = 0.020
	VR QOL Voice Today	3 (2-4)	2 (1-4)	4 (2-5)	H(2)= 11.1 p = 0.004

Oromotor measures					
Informal nonverbal DDK (sec)	**Tongue inwards-outwards**	10.6 (7.4-19.1)	12 (7.9-25.2)	8 (4.2-10.1)	H(2) = 7.49 p = 0.024
	Tongue upwards -downwards	13.7 (10.7-26.9)	26.7 (11.7-39.8)	8.8 (6.7-13.2)	H(2)= 12.97 p =0.002
	Tongue Left-Right	15.4 (5.9-18.6)	16.8 (8.5-35.5)	6.8 (4.9-13.7)	H(2)= 9.25 p =0.010
NOT-S		11 (5-14)	9 (3-13)	0	H(2) = 22.9 p < 0.001
Speech measures					
/pataka/ repetitions (sec)		5.7 (4.1- 8.8)	6.8 (6.5-46.8)	4.4 (3.2-5.6)	H(2)= 12.41 p =0.002
Swallowing measures					
No of swallows for 90 cc		11 (5-14)	9 (3-13)	2 (1-3)	H(2) = 22.9 p < 0.001
Time to complete 90 cc (sec)		11.9 (7.2-16.7)	14.1 (7.1-34.4)	5 (4- 7)	H(2) = 21.8 p < 0.001
Voice Acoustic measures					
GRBAS		3 (0-8)	5.5 (3-11)	1 (0-3)	H(2)=22.69 p<0.001
Jitter (%)		0.7 (0.2-2.1)	0.8 (0.5 -1.8)	0,3 (0.1-0.6)	H(2)= 15.18 p < 0.001
Shimmer (%)		5.1 (2.7- 12.8)	8.3 (4.2-18.5)	4.1 (2.1-9.1)	H(2)= 10.33 p =0.006
MPT(sec)		11.23 (4.9-19.5)	10.5 (5.6-13.5)	8.11 (4.12-31.5)	ns
medF0		128.6 (84.2-222)	120.7 (82.6-270)	168.4 (95.4-299.7)	ns
minF0		154.2 (88.4-392)	183.9 (113.6-279)	172.4 (98-304.9)	ns
maxF0		154.2 (88-392.9)	183 (113-275)	172.41 (98.7-304)	ns
F0SD		2.15 (1-56.6)	15.9 (2.19-48.5)	1.87 (0.7-22.9)	H(2)= 10.36 p =0.006
Harmonics-to-noise ratio		16.7 (10.8-20.8)	14.3 (2.7-19.1)	18.9 (12.8-30)	ns
Fraction of unvoiced frames (%)		0 (0- 63.7)	1 (0-47.6)	0 (0-0.7)	H(2)= 17.31 p < 0.001
Number of voice breaks		0 (0-8)	0.5 (0-10)	0 (0-2)	H(2)= 9.13 p =0.010
Degree of voice breaks (%)		0 (0-25.3)	2,05 (0-47.1)	0 (0-1.64)	H(2)= 9.89 p =0.007
Mean Intensity		60.2 (54.9-69)	60.5 (44-69.5)	60.9 (50.5-75.5)	ns
Minimum Intensity		52.2 (49-66)	52.2 (41-66)	57.4 (46.8-71)	ns
Maximum intensity		62.7 (57-71)	65.6 (47-71)	63.9 (59-77.9)	ns

Table 2 shows the participants' demographics per group and disease profile (SI: swallowing impairments, VI: voice impairments, VHI: voice handicap index, VR QOL: voice related Quality of Life, NOT-S: Nordic orofacial screening test, MPT: mean phonation time, F_0: fundamental frequency, ns: non-significant)

Several parameters, including voice variables, differed significantly across the 3 groups (Kruskal-Wallis test), as shown in **Table 2**.

Regarding the different outcome measures, marked differences were observed across the 3 groups as shown in **Table 2**. Further analysis using the Mann-Whitney test showed that both experimental groups exhibited differences across specific parameter categories compared to the HC, with pwAPS being more affected compared to pwPD. Notably, age was significantly different across groups, both for pwPD vs HC (U=17, p<0.001) and pwAPS vs HC (U=9.5, p<0.001), which is further discussed below.

For pwPD vs HC, significant differences were found for SWAL-QOL-GR (U=28, p<0.001), NOT-S (U=29, p<0.001), DDK tongue movements (p<0.05), /pataka/ repetition (U=32.5, p=0.005), GRBAS (U=40.5, p=0.007), Jitter (%) (U=20, p<0.001) and VHI total score (U=52.5, p=0.013).

For pwAPS vs HC, significant differences were found for SWAL-QOL-GR (U= 18, p< 0.001), /pataka/ repetition (U=18, p=0.003), GRBAS scores (U=1, p< 0.001), VHI total score (U=18, p<0.001), VRQoL (U=33, p=0.002) and Jitter(%) (U=36, p=0.004). Results from NOT-S-GR exam also exhibited statistical differences for pwAPS patients (U=8, p<0.001) as in pwPD vs HC groups. Compared to the differences shown above for the PD group, for the pwAPS additional statistically significant differences were found concerning the following voice variables: F0SD (U=22, p<0.001), shimmer(%) (U=28, p< 0.001), fraction of unvoiced frames(%) (U= 24, p<0.001) and DVB(%) (U=52.5, p=0.035). These results suggest that voice parameters were more affected in the pwAPS compared to pwPD.

The two experimental groups (PD and APS) were directly compared to review the level and extent of differences and possible markers for differential diagnosis. Indeed, the two groups differed in variables: GRBAS (U=19, p=0.019), NOT-S (U=21, p=0.029), F0SD (U=22, p=0.035) and FUF (U=24, p<0.05).

Following the swallowing impairments profiling based on the aforementioned classification, we performed analysis for the 4 subgroups (pwPD with and without SI and pwAPS with and without SI). Patients with swallowing impairments within each of the PD and APS group differed significantly compared to patients with no swallowing impairments, specifically for NOT-S (U=22.5, p=0.038), VQOL (U=9.5, p=0.004), non-verbal DDK (U=9, p=0.019 for tongue inwards outwards, U=6, p=0.009 downwards-upwards) and GRBAS (U=19.5, p=0.02). None of the acoustic voice parameters could differentiate the 4 subgroups.

DISCUSSION

This study examined subjective and objective voice parameters in PD and APS compared to a healthy control group and explored whether specific voice measures could be associated with swallowing impairments. Even though the groups were not age-matched, age-related differences for speech and voice swallowing problems were not observed (i.e. voice intensity etc), which allowed further direct comparison amongst the different groups. Statistically significant differences were observed between the patient groups and controls, as well as between the PD and APS cohorts, underscoring the clinical relevance and diagnostic potential of specific acoustic and perceptual voice markers that merit further discussion.

Voice and Swallowing Parameters in PD and APS

PD participants exhibited significant changes in both perceptual and acoustic measures, including increased GRBAS scores, elevated Voice Handicap Index (VHI) scores, higher jitter values, and reduced SWAL-QOL scores. These results align with previous findings by Bauer et al.[55]and Silva et al.[20] who reported higher perceptual scores and reduced maximum phonation time in PD. Jitter increases, commonly attributed to impaired neuromotor control of the vocal folds, are further corroborated by Abraham & Geetha (2023).[56]

In line with Silva et al.[20] our study confirms that PD patients exhibit measurable dysphonia, with increased jitter likely reflecting decreased laryngeal motor control. Furthermore, patient-reported outcomes in our cohort mirrored findings by Silbergleit et al.[57] and Van Hooren et al.[34], both of whom documented the progressive impact of PD on voice and swallowing-related quality-of-life. Notably, voice and swallowing complaints appeared to co-occur and intensify with disease duration and severity.

In the APS group, voice impairments were generally more severe and hetergoneous. Perceptual and acoustic measures, particularly jitter, shimmer, GRBAS grade, fraction of unvoiced frames (FUF), and degree of voice breaks—demonstrated significantly worse values compared to both PD patients and controls. These findings are consistent with Miller et al.[58], who showed that individuals with MSA-P and PSP experienced greater speech deterioration than those with idiopathic PD, although individual acoustic parameters were insufficient to distinguish APS subtypes reliably. The more extensive neurodegeneration observed in APS likely contributes to the broader disruption of laryngeal and articulatory control mechanisms.

Finger et al.[59] further support this interpretation, noting that patients with APS experience earlier and more pronounced voice and swallowing difficulties

than those with PD or essential tremor. This may reflect the faster disease progression and more extensive brainstem and cerebellar involvement typical of APS, particularly in MSA and PSP subtypes.

Concerning self-perception of swallowing difficulties, in our study there was a statistical significance concerning SWAL-QOL-GR questionnaire, where PD patients scored significantly lower than healthy controls. Plowman-Prine et al.[60] assessed 36 idiopathic PD patients (with and without dysphagia) using SWAL-QOL, PDQ-39, and Beck Depression Inventory (BDI), showing that dysphagia negatively impacted both swallowing-related and overall QoL. Similarly, Carneiro et al. (2014)[61] compared 62 idiopathic PD patients with 41 controls and found significantly lower SWAL-QOL scores across all domains in the patient group.

Regarding acoustic analysis, Holmes et al.[62] and Rahn III et al.[63] also found higher jitter (%) in PD than controls, attributed to irregular laryngeal contractions during phonation, impaired motor control of the vocal folds and aperiodicity in the acoustic signal.[53] Our study further revealed significant impairments in verbal diadochokinesis, reflecting fine motor speech deficits. Overall, these results confirm that PD patients experience measurable vocal impairments and reduced self-perceived voice/swallowing function, with consequences for QoL.

Based on our study's findings, along with those from other research, it is evident that specific acoustic voice parameters are significantly impacted in individuals with both pwPD and pwAPS. However, pwAPS demonstrated greater difficulties in certain voice parameters compared to pwPD. This includes more severe impairments in acoustic features like shimmer, F0SD, FUF and DVB indicating that vocal dysfunction in APS is more pronounced and widespread, reflecting the more rapid disease progression and greater motor involvement in APS compared to PD.

Voice parameters and their role in identifying swallowing impairments

The results showed that acoustic parameters could not be utilized currently to indicate the presence of swallowing impairments in pwPD and APS. This is in line with the above discussed literature, showing high heterogeneity in acoustic parameters, that were also used in our study. Nevertheless, across dysphagic patients within both PD and APS groups, there was a noticeable reduction in non-verbal diadochokinetic repetitions and overall reduced voice quality assessed by GRBAS, showing the degree of hoarseness, roughness, breathiness, asthenia (weakness), and strain. Some indications for differences in F_0SD were also observed with dysphagic patients exhibiting significantly altered F_0SD values, but further research is needed in order to evaluate the utility of the parameter as a potential marker.

Although as a marker the F0SD has not appeared in dysphagia literature, in a large-scale study, Skodda et al.[64] investigated how various prosodic speech parameters - including F0SD- change in pwPD and how these relate to motor symptoms. The researchers found that F0SD was significantly reduced in both male and female PD patients compared to age- and gender-matched healthy controls, supporting the clinical observation of monopitch speech in PD. Notably, the study revealed a strong inverse correlation between F0SD and disease severity, particularly in female PD patients, where F0SD significantly declined with higher scores on the UPDRS motor scale and Hoehn & Yahr stages. These findings suggest that reduced pitch variability (F0SD) is a robust and measurable marker of dysprosody in PD, potentially linked to akinesia and axial motor symptoms, and may reflect the effects of Parkinsonian hypokinesia on laryngeal control mechanisms.

The underlying rationale to investigate further the acoustic parameters in a larger cohort is that there is a shared physiological basis between voice and swallowing mechanisms, particularly involving the laryngeal musculature controlled by brainstem nuclei. Neuromuscular rigidity, bradykinesia, and coordination deficits may compromise both phonatory and deglutitive functions.[63,65]

Supporting Literature on Voice-Swallow Interactions

Subjective measures such as the VHI functional subscale and GRBAS perceptual scores were significantly worse in patients with swallowing impairments, suggesting that these perceptual indicators may provide early warnings for clinicians. Dumican & Watts reported a strong predictive relationship between voice complaints and perceived dysphagia severity in PD, particularly in non-tremor dominant phenotypes.[66]

Therapeutically, this overlap presents opportunities. For example, Park et al.[67] demonstrated that Lee Silverman Voice Treatment (LSVT) not only improved voice quality in MSA and PD but also enhanced swallowing function in both oral and pharyngeal phases. This cross-domain benefit underscores the interconnected nature of vocal and deglutitive subsystems. However, it is important to note that not all acoustic measures may be equally informative: Chang et al.[68] found no significant differences in shimmer, jitter, or NHR between aspirating and non-aspirating patients during VFSS, suggesting that voice analysis should be complemented with clinical assessments.

Some further insights have been added to the literature on shared connections of voice and swallowing from studies on Deep brain stimulation (DBS).

The modulation of bulbar motor output in PD with DBS has been associated with changes in swallowing timing parameters (e.g., pharyngeal transit time, latency of swallow initiation), while its effects on swallowing safety indices such as penetration–aspiration and pharyngeal residue remain inconsistent across studies. [69, 70] Changes in voice acoustics under DBS—particularly parameters reflecting phonatory stability, loudness regulation, and temporal control—are conceptually linked to the same basal ganglia–brainstem circuitry influencing oropharyngeal timing; however, current evidence suggests only partial correspondence, with stronger associations emerging for swallowing efficiency and timing metrics rather than safety outcomes.

Our study comes with limitations discussed further. While this study presents a sample that allows for comparisons with the existing literature, it is important to emphasize the need for further research with a larger sample size. The participants in the healthy control group were not age-matched, and this initially would not have allowed for further comparisons. However, parameters that would have differed due to aging such as voice intensity, showed similar values across the groups, which allowed further between-groups comparisons. Some parameters, which were treated with non-parametric tests based on the results of Levene's test, have been treated as parametric by other researchers, suggesting that a larger sample might offer more robust insights. Incorporating objective voice assessments, alongside subjective tools such as the VHI and GRBAS scales, allows for a comprehensive understanding of the patient's voice function. Moreover, self-reported questionnaires like the SWAL-QoL and EAT-10 provide insights into the patients' perception of their swallowing difficulties, which can guide tailored therapeutic approaches.

CONCLUSION

The findings from this study also reinforce the hypothesized link between voice and swallowing mechanisms in neurodegenerative conditions. Both voice production and swallowing rely heavily on laryngeal and pharyngeal muscle function, which are commonly affected by the motor deficits seen in PD and APS. This common pathophysiological basis further justifies the use of voice parameters as indicators of swallowing dysfunction. The results show that certain auditory and perceptual voice characteristics, alongside swallowing measures, can serve as valuable tools in differentiating between dysphagic and non-dysphagic patients.

Implications for Clinical Practice: The study highlights the importance of incorporating voice assessments into routine clinical evaluations of patients with PD and APS, particularly for the early detection of dysphagia. Given that swallowing disorders are a leading cause of mortality in these populations due to aspiration pneumonia, early identification through non-invasive voice measures could provide crucial preventive interventions.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Keener AM, Bordelon YM. Parkinsonism. Semin Neurol. Aug 2016;36(4):330-4. doi:10.1055/s-0036-1585097

[2] Udagedara TB, Dhananjalee Alahakoon AM, Goonaratna IK. Vascular Parkinsonism: A Review on Management updates. Ann Indian Acad Neurol. Jan-Mar 2019;22(1):17-20. doi:10.4103/aian.AIAN_194_18

[3] Braak H, Bohl JR, Müller CM, Rüb U, de Vos RA, Del Tredici K. Stanley Fahn Lecture 2005: The staging procedure for the inclusion body pathology associated with sporadic Parkinson's disease reconsidered. Mov Disord. Dec 2006;21(12):2042-51. doi:10.1002/mds.21065

[4] Köllensperger M, Geser F, Ndayisaba JP, et al. Presentation, diagnosis, and management of multiple system atrophy in Europe: final analysis of the European multiple system atrophy registry. Mov Disord. Nov 15 2010;25(15):2604-12. doi:10.1002/mds.23192

[5] Pringsheim T, Jette N, Frolkis A, Steeves TD. The prevalence of Parkinson's disease: a systematic review and meta-analysis. Mov Disord. Nov 2014;29(13):1583-90. doi:10.1002/mds.25945

[6] Roncevic D, Palma JA, Martinez J, Goulding N, Norcliffe-Kaufmann L, Kaufmann H. Cerebellar and parkinsonian phenotypes in multiple system atrophy: similarities, differences and survival. J Neural Transm (Vienna). May 2014;121(5):507-12. doi:10.1007/s00702-013-1133-7

[7] Huh YE, Park J, Suh MK, et al. Differences in early speech patterns between Parkinson variant of multiple system atrophy and Parkinson's disease. Brain Lang. Aug 2015;147:14-20. doi:10.1016/j.bandl.2015.04.007

[8] Glasmacher SA, Leigh PN, Saha RA. Predictors of survival in progressive supranuclear palsy and multiple system atrophy: a systematic review and meta-analysis. J Neurol Neurosurg Psychiatry. May 2017;88(5):402-411. doi:10.1136/jnnp-2016-314956

[9] Sulica L, Louis ED. Clinical characteristics of essential voice tremor: a study of 34 cases. Laryngoscope. Mar 2010;120(3):516-28.

doi:10.1002/lary.20702
[10] McFarland NR. Diagnostic Approach to Atypical Parkinsonian Syndromes. Continuum (Minneap Minn). Aug 2016;22(4 Movement Disorders):1117-42. doi:10.1212/con.0000000000000348
[11] Logemann JA, Fisher HB, Boshes B, Blonsky ER. Frequency and cooccurrence of vocal tract dysfunctions in the speech of a large sample of Parkinson patients. J Speech Hear Disord. Feb 1978;43(1):47-57. doi:10.1044/jshd.4301.47
[12] Stachler RJ, Francis DO, Schwartz SR, et al. Clinical Practice Guideline: Hoarseness (Dysphonia) (Update). Otolaryngol Head Neck Surg. Mar 2018;158(1_suppl):S1-s42. doi:10.1177/0194599817751030
[13] Sapienza CM, Hoffman B. Voice disorders. Fourth edition. ed. Plural Publishing; 2022.
[14] Darley FL, Aronson AE, Brown JR. Clusters of deviant speech dimensions in the dysarthrias. J Speech Hear Res. Sep 1969;12(3):462-96. doi:10.1044/jshr.1203.462
[15] Ho AK, Iansek R, Marigliani C, Bradshaw JL, Gates S. Speech impairment in a large sample of patients with Parkinson's disease. Behav Neurol. Jan 1 1999;11(3):131-7.
[16] Obenour WH, Stevens PM, Cohen AA, McCutchen JJ. The causes of abnormal pulmonary function in Parkinson's disease. Am Rev Respir Dis. Mar 1972;105(3):382-7. doi:10.1164/arrd.1972.105.3.382
[17] Baumgartner CA, Sapir S, Ramig TO. Voice quality changes following phonatory-respiratory effort treatment (LSVT) versus respiratory effort treatment for individuals with Parkinson disease. J Voice. Mar 2001;15(1):105-14. doi:10.1016/s0892-1997(01)00010-8
[18] Midi I, Dogan M, Koseoglu M, Can G, Sehitoglu MA, Gunal DI. Voice abnormalities and their relation with motor dysfunction in Parkinson's disease. Acta Neurol Scand. Jan 2008;117(1):26-34. doi:10.1111/j.1600-0404.2007.00965.x
[19] Skodda S, Schlegel U. Speech rate and rhythm in Parkinson's disease. Mov Disord. May 15 2008;23(7):985-992. doi:10.1002/mds.21996
[20] Silva LF, Gama AC, Cardoso FE, Reis CA, Bassi IB. Idiopathic Parkinson's disease: vocal and quality of life analysis. Arq Neuropsiquiatr. Sep 2012;70(9):674-9. doi:10.1590/s0004-282x2012000900005
[21] Kluin KJ, Foster NL, Berent S, Gilman S. Perceptual analysis of speech disorders in progressive supranuclear palsy. Neurology. Mar 1993;43(3 Pt 1):563-6. doi:10.1212/wnl.43.3_part_1.563
[22] Kluin KJ, Gilman S, Lohman M, Junck L. Characteristics of the dysarthria of multiple system atrophy. Arch Neurol. Jun 1996;53(6):545-8. doi:10.1001/archneur.1996.00550060089021
[23] Rusz J, Bonnet C, Klemp-- J, et al. Speech disorders reflect differing pathophysiology in Parkinson's disease, progressive supranuclear palsy and multiple system atrophy. J Neurol. 2015;262(4):992-1001. doi:10.1007/s00415-015-7671-1
[24] Deutschländer AB, Ross OA, Dickson DW, Wszolek ZK. Atypical parkinsonian syndromes: a general neurologist's perspective. Eur J Neurol. Jan 2018;25(1):41-58. doi:10.1111/ene.13412
[25] Kalf JG, de Swart BJ, Bloem BR, Munneke M. Prevalence of oropharyngeal dysphagia in Parkinson's disease: a meta-analysis. Parkinsonism Relat Disord. May 2012;18(4):311-5. doi:10.1016/j.parkreldis.2011.11.006
[26] Nicaretta DH, Rosso AL, Mattos JP, Maliska C, Costa MM. Dysphagia and sialorrhea: the relationship to Parkinson's disease. Arq Gastroenterol. Jan-Mar 2013;50(1):42-9. doi:10.1590/s0004-28032013000100009
[27] Dawes C, Kubieniec K. The effects of prolonged gum chewing on salivary flow rate and composition. Arch Oral Biol. Aug 2004;49(8):665-9. doi:10.1016/j.archoralbio.2004.02.007
[28] Mu L, Sobotka S, Chen J, et al. Alpha-synuclein pathology and axonal degeneration of the peripheral motor nerves innervating pharyngeal muscles in Parkinson disease. J Neuropathol Exp Neurol. Feb 2013;72(2):119-29. doi:10.1097/NEN.0b013e3182801cde
[29] Wenning GK, Tison F, Ben Shlomo Y, Daniel SE, Quinn NP. Multiple system atrophy: a review of 203 pathologically proven cases. Mov Disord. Mar 1997;12(2):133-47. doi:10.1002/mds.870120203
[30] Ohshima Y, Nakayama H, Matsuyama N, et al. Natural course and potential prognostic factors for sleep-disordered breathing in multiple system atrophy. Sleep Med. Jun 2017;34:13-17. doi:10.1016/j.sleep.2017.01.020
[31] Johnston BT, Castell JA, Stumacher S, et al. Comparison of swallowing function in Parkinson's disease and progressive supranuclear palsy. Mov Disord. May 1997;12(3):322-7. doi:10.1002/mds.870120310
[32] Kent RD, Kim YJ. Toward an acoustic typology of motor speech disorders. Clin Linguist Phon. Sep 2003;17(6):427-45. doi:10.1080/0269920031000086248
[33] Michou E, Hamdy S, Harris M, et al. Characterization of corticobulbar pharyngeal neurophysiology in dysphagic patients with Parkinson's disease. Clin Gastroenterol Hepatol. Dec 2014;12(12):2037-45.e1-4. doi:10.1016/j.cgh.2014.03.020
[34] van Hooren MR, Baijens LW, Vos R, et al.

Voice- and swallow-related quality of life in idiopathic Parkinson's disease. Laryngoscope. Feb 2016;126(2):408-14. doi:10.1002/lary.25481
[35] Silbergleit AK, Johnson AF, Jacobson BH. Acoustic analysis of voice in individuals with amyotrophic lateral sclerosis and perceptually normal vocal quality. J Voice. Jun 1997;11(2):222-31. doi:10.1016/s0892-1997(97)80081-1
[36] Ko EJ, Chae M, Cho SR. Relationship Between Swallowing Function and Maximum Phonation Time in Patients With Parkinsonism. Ann Rehabil Med. Jun 27 2018;42(3):425-432. doi:10.5535/arm.2018.42.3.425
[37] Altman KW, Atkinson C, Lazarus C. Current and emerging concepts in muscle tension dysphonia: a 30-month review. J Voice. Jun 2005;19(2):261-7. doi:10.1016/j.jvoice.2004.03.007
[38] Farneti D. Voice and Dysphagia. In: Ekberg O, ed. Dysphagia: Diagnosis and Treatment. Springer International Publishing; 2019:257-274.
[39] Hoehn, M. M., & Yahr, M. D. (1967). Parkinsonism: onset, progression, and mortality. Neurology, 17(5), 427-427.
[40] Bakke M, Bergendal B, McAllister A, Sjögreen L, Asten P. Development and evaluation of a comprehensive screening for orofacial dysfunction. Swed Dent J. 2007;31(2):75-84.
[41] Printza A, Kyrgidis A, Pavlidou E, Triaridis S, Constantinidis J. Reliability and validity of the Eating Assessment Tool-10 (Greek adaptation) in neurogenic and head and neck cancer-related oropharyngeal dysphagia. Eur Arch Otorhinolaryngol. Jul 2018;275(7):1861-1868. doi:10.1007/s00405-018-5001-9
[42] Georgopoulos VC, Perdikogianni M, Mouskenteri M, Psychogiou L, Oikonomou M, Malandraki GA. Cross-Cultural Adaptation and Validation of the SWAL-QoL Questionnaire in Greek. Dysphagia. Feb 2018;33(1):91-99. doi:10.1007/s00455-017-9837-8
[43] DePippo KL, Holas MA, Reding MJ. Validation of the 3-oz water swallow test for aspiration following stroke. Arch Neurol. Dec 1992;49(12):1259-61. doi:10.1001/archneur.1992.00530360057018
[44] Hinds NP, Wiles CM. Assessment of swallowing and referral to speech and language therapists in acute stroke. Qjm. Dec 1998;91(12):829-35. doi:10.1093/qjmed/91.12.829
[45] Nathadwarawala KM, Nicklin J, Wiles CM. A timed test of swallowing capacity for neurological patients. J Neurol Neurosurg Psychiatry. Sep 1992;55(9):822-5. doi:10.1136/jnnp.55.9.822
[46] Allen JE, Miles A. Parkinson Disease. In: Weissbrod PA, Francis DO, eds. Neurologic and Neurodegenerative Diseases of the Larynx. Springer International Publishing; 2020:143-159.
[47] Helidoni ME, Murry T, Moschandreas J, Lionis C, Printza A, Velegrakis GA. Cross-cultural adaptation and validation of the voice handicap index into Greek. J Voice. Mar 2010;24(2):221-7. doi:10.1016/j.jvoice.2008.06.005
[48] Hogikyan ND, Sethuraman G. Validation of an instrument to measure voice-related quality of life (V-RQOL). J Voice. Dec 1999;13(4):557-69. doi:10.1016/s0892-1997(99)80010-1
[49] Hirano M. Clinical examination of voice. Disorders of Human Communication. 1981 1981;5:1-99.
[50] Dejonckere PH, Bradley P, Clemente P, et al. A basic protocol for functional assessment of voice pathology, especially for investigating the efficacy of (phonosurgical) treatments and evaluating new assessment techniques. Guideline elaborated by the Committee on Phoniatrics of the European Laryngological Society (ELS). Eur Arch Otorhinolaryngol. Feb 2001;258(2):77-82. doi:10.1007/s004050000299
[51] Teixeira JP, Oliveira C, Lopes C. Vocal Acoustic Analysis – Jitter, Shimmer and HNR Parameters. Procedia Technology. 2013/01/01/ 2013;9:1112-1122. doi:https://doi.org/10.1016/j.protcy.2013.12.124
[52] Patel RR, Awan SN, Barkmeier-Kraemer J, et al. Recommended Protocols for Instrumental Assessment of Voice: American Speech-Language-Hearing Association Expert Panel to Develop a Protocol for Instrumental Assessment of Vocal Function. Am J Speech Lang Pathol. Aug 6 2018;27(3):887-905. doi:10.1044/2018_ajslp-17-0009
[53] Chiaramonte R, Bonfiglio M. Acoustic analysis of voice in bulbar amyotrophic lateral sclerosis: a systematic review and meta-analysis of studies. Logoped Phoniatr Vocol. Dec 2020;45(4):151-163. doi:10.1080/14015439.2019.1687748
[54] Rusz J, Tykalova T, Ramig LO, Tripoliti E. Guidelines for Speech Recording and Acoustic Analyses in Dysarthrias of Movement Disorders. Mov Disord. Apr 2021;36(4):803-814. doi:10.1002/mds.28465
[55] Bauer V, Aleri- Z, Janci- E, Miholovi- V. Voice quality in Parkinson's disease in the Croatian language speakers. Coll Antropol. Sep 2011;35 Suppl 2:209-12.
[56] Abraham EA, Geetha A. Acoustical and Perceptual Analysis of Voice in Individuals with Parkinson's Disease. Indian J Otolaryngol Head Neck Surg. Jun 2023;75(2):427-432. doi:10.1007/s12070-022-03282-z
[57] Silbergleit AK, Schultz L, Hamilton K, LeWitt PA, Sidiropoulos C. Self-Perception of Voice and Swallowing Handicap in Parkinson's Dis-

ease. J Parkinsons Dis. 2021;11(4):2027-2034. doi:10.3233/jpd-212621
[58] Miller N, Nath U, Noble E, Burn D. Utility and accuracy of perceptual voice and speech distinctions in the diagnosis of Parkinson's disease, PSP and MSA-P. Neurodegener Dis Manag. Jun 2017;7(3):191-203. doi:10.2217/nmt-2017-0005
[59] Finger ME, Madden LL, Haq IU, McLouth CJ, Siddiqui MS. Analysis of the prevalence and onset of dysphonia and dysphagia symptoms in movement disorders at an academic medical center. J Clin Neurosci. Jun 2019;64:111-115. doi:10.1016/j.jocn.2019.03.043
[60] Plowman-Prine EK, Sapienza CM, Okun MS, et al. The relationship between quality of life and swallowing in Parkinson's disease. Mov Disord. Jul 15 2009;24(9):1352-8. doi:10.1002/mds.22617
[61] Carneiro D, das Graças Wanderley de Sales Coriolano M, Belo LR, de Marcos Rabelo AR, Asano AG, Lins OG. Quality of life related to swallowing in Parkinson's disease. Dysphagia. 2014 Oct;29(5):578-82.
[62] Holmes RJ, Oates JM, Phyland DJ, Hughes AJ. Voice characteristics in the progression of Parkinson's disease. Int J Lang Commun Disord. Jul-Sep 2000;35(3):407-18. doi:10.1080/136828200410654
[63] Rahn DA, 3rd, Chou M, Jiang JJ, Zhang Y. Phonatory impairment in Parkinson's disease: evidence from nonlinear dynamic analysis and perturbation analysis. J Voice. Jan 2007;21(1):64-71. doi:10.1016/j.jvoice.2005.08.011
[64] Skodda S, Visser W, Schlegel U. Gender-related patterns of dysprosody in Parkinson disease and correlation between speech variables and motor symptoms. J Voice. Jan 2011;25(1):76-82. doi:10.1016/j.jvoice.2009.07.005
[65] Zeng Z, Yang M, Lin Z, et al. Effect of high, low, and asymmetric frequency subthalamic stimulation on speech and voice in Parkinson's disease: a randomized trial. NPJ Parkinsons Dis. Jul 30 2025;11(1):223. doi:10.1038/s41531-025-01090-0
[66] Dumican M, Watts C. Self-perceptions of speech, voice, and swallowing in motor phenotypes of Parkinson's disease. Clin Park Relat Disord. 2020;3:100074. doi:10.1016/j.prdoa.2020.100074
[67] Park A, Jang SJ, Kim NE, et al. Swallowing Outcomes Following Voice Therapy in Multiple System Atrophy with Dysphagia: Comparison of Treatment Efficacy with Parkinson's Disease. Dysphagia. Feb 2022;37(1):198-206. doi:10.1007/s00455-021-10265-9
[68] Chang HY, Torng PC, Wang TG, Chang YC. Acoustic voice analysis does not identify presence of penetration/aspiration as confirmed by videofluoroscopic swallowing study. Arch Phys Med Rehabil. Nov 2012;93(11):1991-4. doi:10.1016/j.apmr.2012.05.028.
[69] Gandhi P, Steele CM. Effectiveness of Interventions for Dysphagia in Parkinson Disease: A Systematic Review. Am J Speech Lang Pathol. 2022 Jan 18;31(1):463-485. doi: 10.1044/2021_AJSLP-21-00145
[70] Pflug C, Nienstedt JC, Gulberti A, Müller F, Vettorazzi E, Koseki JC, Niessen A, Flügel T, Hidding U, Buhmann C, Weiss D, Gerloff C, Hamel W, Moll CKE, Pötter-Nerger M. Impact of simultaneous subthalamic and nigral stimulation on dysphagia in Parkinson's disease. Ann Clin Transl Neurol. 2020 May;7(5):628-638. doi: 10.1002/acn3.51027.