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Videofluoroscopic Analysis of Swallowing Biomechanics in Parkinson's Disease

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Abstract

Objective: To quantitatively assess maximum hyoid displacement, laryngeal displacement, pharyngeal constriction, and upper esophageal sphincter opening in patients with Parkinson's disease and compare these measures with those of controls with normal videofluoroscopic swallowing findings.

Methods: This retrospective observational study included 32 videofluoroscopic swallowing examinations: 16 from patients with Parkinson's disease and 16 from controls. Thin liquid, paste, and solid consistencies were evaluated. Measurements were obtained using ImageJ after image calibration, and between-group comparisons were performed using Student's t-test or the Mann-Whitney U test according to data distribution.

Results: The groups had similar mean ages. Patients with Parkinson's disease demonstrated significantly reduced laryngeal displacement across all consistencies and poorer pharyngeal constriction with thin liquids, as indicated by a larger residual pharyngeal area. No significant between-group differences were observed in maximum hyoid displacement or upper esophageal sphincter opening.

Conclusion: In this sample, Parkinson's disease was primarily associated with impaired laryngeal displacement and pharyngeal constriction, potentially affecting airway protection and pharyngeal clearance. Quantitative videofluoroscopic analysis may help identify biomechanical swallowing alterations in this population.

Keywords: Parkinson disease, deglutition disorders, fluoroscopy, hyoid bone, larynx

Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder involving basal ganglia circuits and reduced dopaminergic transmission. It is characterized by motor signs such as resting tremor, muscle rigidity, and bradykinesia (1,2). Although pharmacological treatment and newer surgical interventions help control symptoms, no intervention has been shown to definitively halt disease progression (1-3).

Among non-motor manifestations and complications related to disease progression, dysphagia is clinically relevant because of its functional impact and association with silent aspiration and aspiration pneumonia (4,5). Swallowing abnormalities may occur even in early stages and include slowed oral transit, delayed swallowing response, reduced anteriorization and laryngeal elevation, and increased pharyngeal residue (5-7).

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The pharyngeal phase of swallowing depends on coordinated hyoid displacement, laryngeal elevation, pharyngeal constriction, and upper esophageal sphincter opening. Alterations in these events may compromise swallowing safety and efficiency, increasing the risk of penetration, aspiration, and post-swallow residue. In neurological diseases, spatial displacement, velocity, timing, and movement sequence are all relevant determinants of swallowing risk (8-10).

The videofluoroscopic swallowing study (VFSS) is considered the reference examination for dysphagia assessment because it allows dynamic visualization of structures, identification of the timing of penetration/aspiration, and extraction of quantitative displacement, time, and velocity measures (5,10,11). Despite its widespread use, standardized quantitative measures in PD remain heterogeneous, with differences in protocols, volumes, and consistencies that hinder direct comparisons between studies. In addition, few studies involving this patient group have been conducted in Latin America, which limits the generalizability of international findings.

In this context, this study aimed to quantitatively analyze maximum hyoid bone displacement, laryngeal elevation, pharyngeal constriction, and the extent of upper esophageal sphincter opening in patients with PD and compare them with a control group with normal swallowing in a Brazilian public service.

Methods

Ethical Aspects

This study was approved by the Research Ethics Committee of the Federal University of Sao Paulo-Unifesp/Hospital Sao Paulo, under approval no: 820.360, date: October 06, 2014. All patients had previously signed the informed consent form at the time of the videofluoroscopic swallowing examination, authorizing the use of their data for scientific purposes according to the institutional protocol.

Study Design

This was an observational, retrospective, analytical study with random selection of medical records, conducted through analysis of reports and images from videofluoroscopic swallowing examinations.

Data were obtained from the videofluoroscopic swallowing archive of the Functional Swallowing Rehabilitation Sector, Department of Speech-Language Pathology and Audiology, Escola Paulista de Medicina, Universidade Federal de São Paulo. The examinations analyzed were performed in the Diagnostic Imaging Sector of Hospital São Paulo, Universidade Federal de São Paulo, from 2010 to 2020.

Sample Selection and Group Allocation

The institutional database for the period analyzed contained 37 examinations of patients diagnosed with PD and 54 examinations of patients with videofluoroscopic reports indicating normal swallowing.

The sample size was defined pragmatically according to the retrospective availability of eligible VFSS examinations and image quality. No a priori sample size calculation was performed. Although the database included 37 examinations of patients with PD and 54 examinations with normal VFSS reports, only examinations meeting the eligibility criteria and allowing quantitative analysis of the selected biomechanical variables were included. A balanced sample of 16 examinations per group was therefore obtained.

For sample composition, stratified random selection by group was performed in Microsoft Excel. Eligible reports were organized according to clinical condition, numerically identified, and randomly selected without replacement until 16 reports were obtained in each group.

The final sample consisted of 32 VFSS reports: 16 from patients with PD and 16 from individuals with normal swallowing according to the videofluoroscopic report.

The reports were distributed into two groups: Group 1, patients with PD; and Group 2, individuals with normal VFSS findings. Random selection aimed to reduce selection bias within the available database.

Eligibility Criteria

Inclusion Criteria

• Group 1: Patients with a clinical diagnosis of PD who had sufficient oral feeding conditions to undergo the VFSS.

• Group 2: Individuals without PD or other central or peripheral neurological disorders, without a history of head and neck tumors, resections, surgery, or oncological treatment, and with normal swallowing on VFSS. These individuals were referred from different clinical or surgical departments for indications such as odynophagia, reflux-related symptoms, gastrointestinal complaints, or evaluation of suspected fistula but showed no evidence of oropharyngeal dysphagia according to the institutional VFSS report. This group should be interpreted as a clinically referred comparison group with normal VFSS findings, rather than as healthy volunteers.

Exclusion Criteria

Patients diagnosed with other neurological diseases associated with PD were excluded, as were those with a history of tumors in the head and neck region, or who had undergone treatment for such tumors. Patients whose examinations revealed poor visualization of anatomical structures, which compromised the analysis and quantification of the variables studied, were also excluded.

PD severity was classified using the Hoehn and Yahr (12) scale, which stratifies patients into stages I to V according to symptom laterality, balance impairment, and functional independence (13). In this study, staging was performed before data collection by hospital neurologists during routine clinical assessment.

All patients with PD were under regular neurological follow-up and were considered clinically stable at the time of VFSS. Clinical stability was defined as the absence of acute neurological or systemic decompensation recorded at the time of examination, no indication of acute hospitalization related to neurological worsening, and sufficient clinical condition to undergo VFSS with oral intake according to the institutional protocol. However, because of the study's retrospective design, the institutional database did not systematically record the specific dopaminergic medication status at the time of examination, including whether patients were evaluated on or off medication. Therefore, we could not include this variable in the statistical analysis.

Videofluoroscopic Swallowing Procedures

All VFSS examinations were performed in the Diagnostic Imaging Sector of Hospital São Paulo, Hospital Universitário da Universidade Federal de São Paulo, preceded by anamnesis and clinical assessment, and followed the protocol described by Gonçalves et al. (14).

The VFSS evaluated individuals in an upright position in left lateral, frontal, and, when necessary, oblique views. Patients were instructed to keep their head straight during the examination and were identified by the initials of their first and last names, recorded at the beginning of the examination together with the date.

Patients who did not have the motor conditions required to remain upright were accommodated in a VESS CHAIR®, a chair developed to adapt patients with positioning difficulties on the fluoroscopy table, providing comfort, safety, and appropriate examination performance.

The procedure began with the recording of a resting image in lateral view. The individuals were then asked to swallow the following volumes and consistencies:

- 1 mL, 3 mL, 5 mL, and free sips of thin liquid (water with contrast) and thickened liquid;
- 3 mL and 5 mL of paste consistency (petit suisse yogurt), offered by spoon;
- One portion of solid food (wafer cookie) soaked in contrast.

The examinations were performed in a shielded X-ray room using Medicore radiological equipment with seriography, tilting table, triphasic system, capacity of 500 mA and automatic 120 kV, image intensifier, and closed-circuit television. The images were digitized, transferred to a computer, and subsequently recorded on DVD.

The equipment was operated by a radiology technician with the assistance of a speech-language pathologist experienced in performing videofluoroscopic swallowing examinations. The examinations were analyzed independently by another experienced speech-language pathologist and by a radiologist, with reports classified as mild dysphagia, moderate dysphagia, severe dysphagia, or normal swallowing, as described by Gonçalves et al. (14).

Image Extraction and Measurement of Variables

Images from VFSS examinations recorded in DVD format were used to extract the measures. The images were captured, selected, and inserted into ImageJ software for measurement. The data obtained were organized in electronic spreadsheets for subsequent tabulation and statistical analysis.

All measurements were performed by graduate researchers trained in quantitative VFSS image analysis using ImageJ. Training was conducted within institutional graduate-level swallowing research activities and supervised by an experienced faculty advisor. Before data extraction, the examiners underwent a standardization process that included review of the measurement protocol, discussion of anatomical landmarks, calibration procedures, selection of the swallowing frame of interest, and pilot measurements using representative VFSS images. The same anatomical landmarks, calibration procedures, and measurement criteria were applied throughout the analysis to improve consistency.

The following consistencies and volumes were analyzed:

- 5 mL of thin liquid;
- 5 mL of paste consistency;
- Solid food (wafer cookie soaked in contrast).

Because this was a retrospective study based on clinically indicated VFSS examinations, not all consistencies or volumes were available for all patients. Some consistencies were not administered because of clinical safety concerns, and some images, although adequate for clinical interpretation, did not allow reliable quantitative measurement because of limited visualization of anatomical structures, patient positioning, movement artifacts, or image quality. Therefore, the number of observations varied across variables according to image availability and measurement suitability.

Measurement Procedure

Tongue mobility, pharyngeal constriction, and hyoid and laryngeal displacement measures were obtained using ImageJ software, as described by Gonçalves and Leonard (11). ImageJ is an image analysis program developed by the National Institutes of Health and freely available (http://rsb.info.nih.gov/nih-image/). It allows adjustments of contrast and brightness, rotation, inversion, resizing, tracing, and calculation of distances, areas, and angles.

Before the measurements were performed, the software was calibrated using the known diameter of a metallic marker positioned over the mastoid process of the patient's temporal bone (a one-centavo Brazilian Real coin). A line was drawn along the diameter of the coin, allowing conversion from pixels to centimeters.

Variables Analyzed

Maximum Hyoid Bone Displacement

Maximum hyoid bone displacement was measured from the intersection between a line tangent to the anterior portion of the hyoid bone and another line tangent to its inferior margin. A right angle was then drawn using the same cervical vertebrae as a reference. The resting image was superimposed on the image of maximum hyoid bone excursion, and the distance between the intersections was calculated by ImageJ, representing maximum displacement (10).

Maximum Laryngeal Displacement (Cricoid Cartilage)

For measurement of laryngeal displacement, the anterior portion of the cricoid cartilage was considered. Two tangent lines were drawn: one at the level of the free edge of the vocal folds and another at the anterior wall of the trachea immediately below the larynx. The intersection of these lines was associated with a 90° angle fixed to a cervical vertebra. The same procedure was performed on the resting image and on the image of maximum laryngeal elevation, using the same vertebra as reference. The images were superimposed, allowing measurement of cricoid cartilage displacement (10).

Pharyngeal Constriction

Pharyngeal constriction measurements were performed from lateral-view images obtained at rest and at the moment of maximum pharyngeal constriction. The resting pharyngeal area was manually outlined in ImageJ using the freehand selection tool, from the posterior pharyngeal wall at the level of the anterior tubercle of the atlas vertebra to the height of the upper border of the arytenoid cartilage. The contour included the arytenoid cartilages, epiglottis, valleculae, tongue base, and soft palate up to the posterior nasal spine of the palatine bone. The upper border was defined by a straight line between the posterior nasal spine and the anterior tubercle of the atlas vertebra. The area was automatically calculated in square centimeters, following the fluoroscopic pharyngeal area measurement principles described by Leonard et al. (15).

Upper Esophageal Sphincter Opening

The extent of upper esophageal sphincter opening was measured during swallowing of the largest contrast volume. The image showing the greatest displacement of the cricoid cartilage was captured, and, considering the previous calibration, the distance between the anterior and posterior esophageal walls was measured 1 cm below the lower border of the cricoid cartilage, as described in the literature (10,11).

Reliability Analysis

To assess reliability, a subset of VFSS examinations was remeasured using the same anatomical landmarks and calibration procedures. Measurement reliability was calculated using the intraclass correlation coefficient (ICC), based on a two-way mixed-effects model for absolute agreement using single measurements. This model was selected because the biomechanical variables were continuous manual measurements obtained from calibrated VFSS images.

Statistical Analysis

Data were initially analyzed descriptively. Categorical variables were presented as absolute and relative frequencies, whereas numerical variables were presented as mean, median, minimum and maximum values, and standard deviation.

The distribution of numerical variables was assessed to determine whether they followed a normal (Gaussian) distribution. The Shapiro-Wilk test was used for variables with up to 30 observations, whereas the Kolmogorov-Smirnov test was used for variables with more than 30 observations. For between-group comparisons, Student's t-test for independent samples was applied when variables showed normal distribution. When the assumption of normality was not met, the non-parametric Mann-Whitney U test was used.

All statistical analyses were performed using IBM SPSS Statistics for Windows, version 29.0 (IBM Corp., Armonk, NY, USA). The level of statistical significance was set at 5% ($p<0.05$). An exploratory post hoc power analysis was performed using G*Power software, version 3.1.9.7, for the main biomechanical outcomes. The analysis was based on the statistical test used for each between-group comparison, the observed between-group effect size, the final number of observations available for each variable, and a two-sided alpha level of 0.05. This analysis was conducted to contextualize the probability of detecting the observed effects in this retrospective sample and was not interpreted as a substitute for an a priori sample size calculation.

Because multiple between-group comparisons were performed across biomechanical variables and consistencies, a sensitivity analysis was conducted using the Benjamini-Hochberg false discovery rate (FDR) procedure. This approach was chosen because the swallowing measures were physiologically related and not fully independent.

Results

The total sample consisted of 32 participants, equally distributed by sex. In the PD group, early disease stages predominated: 50.0% were classified as Hoehn and Yahr (12) stage I, 12.5% as stage II, and 25.0% as stage II-III. Only two patients were in advanced stages: one in stage IV and one in stage V (Table 1).

Mean age was similar between the control and PD groups (67.75 and 67.25 years, respectively). In the PD group, mean disease duration was 3.56 years, ranging from 1 to 9 years (Table 2).

Participants aged 60 years or older predominated in both groups, corresponding to 87.5% of controls and 81.3% of patients with PD. The small number of participants aged 59 years or younger limited age-stratified analyses (Table 3).

Normality testing showed that most variables were compatible with normal distribution. Hyoid displacement for paste and pharyngeal constriction for thin liquid showed non-normal distribution, supporting the use of parametric or non-parametric tests according to each variable distribution (Table 4).

Reliability analysis showed good agreement for the ImageJ-based measurements (ICC=0.83). Between-group comparisons showed significantly reduced laryngeal displacement in the PD group for thin liquid, paste, and solid consistencies ($p<0.05$). Pharyngeal constriction for thin liquid was also significantly altered, with a larger residual pharyngeal area in the PD group. No significant between-group differences were identified for hyoid displacement or upper esophageal sphincter opening (Table 5). After Benjamini-Hochberg FDR adjustment, the main differences remained significant for laryngeal displacement across all consistencies and pharyngeal constriction for thin liquid.

A descriptive stratification of the swallowing biomechanical variables according to Hoehn and Yahr (12) stage is shown in Table 6. Given the limited number of participants within each disease stage, particularly in stages II, IV, and V, inferential statistical comparisons were not performed for this subgroup analysis. Therefore, this data should be interpreted as exploratory and descriptive.

Overall, the stratified descriptive analysis suggested a gradual reduction in laryngeal displacement and an increase

Table 1. Numerical and percentage distribution of patients with Parkinson's disease according to disease stage

Disease stage	n	%
I	8	50
II	2	12.5
II to III	4	25
IV	1	6.25
V	1	6.25
Total	16	100.0

Disease stage according to the Hoehn and Yahr (12) scale (1967)

Table 2. Mean, median, and standard deviation values for age in both groups, and disease duration in the Parkinson's disease group

Variable	Measure	Normal	Parkinson
Age	Mean	67.75	67.25
	Median	67.50	67.00
	Minimum	50	50
	Maximum	93	79
	Standard deviation	10.38	8.40
	n	16	16
Disease duration (years)	Mean		3.56
	Median		4.00
	Minimum		1
	Maximum		9
	Standard deviation		2.50
	n		16

in residual pharyngeal area for thin liquid swallowing with greater motor severity. Hyoid displacement and upper esophageal sphincter opening remained comparatively preserved across stages.

Discussion

The results indicate a predominant pattern of impairment in pharyngeal contraction and laryngeal elevation mechanisms during swallowing in patients with PD, with reduced laryngeal displacement across all consistencies and poorer pharyngeal constriction performance for thin liquid. This finding is consistent with the literature indicating that laryngeal elevation and the effectiveness of vestibular closure are central determinants of airway protection and aspiration reduction in neurological populations (1-3,16,17).

In PD, detailed kinematic studies suggest that swallowing deficits may manifest both as reduced movement amplitude and as reduced velocity and impaired muscle coordination. Lee et al. (9) observed reduced horizontal displacement and velocity of the hyoid bone in patients with PD compared with older adults in the control group, highlighting combined effects of disease and aging.

Alves et al. (18) described seven physiological hyoid displacement patterns in healthy individuals, which may explain the absence of a statistically significant difference in maximum hyoid displacement in the presented study. The varied findings in swallowing considered normal suggest that, in PD, swallowing deficits may be less related to reduced maximum movement amplitude and more associated with temporal and coordination changes, such as decreased velocity and hyolaryngeal incoordination. Although these kinematic aspects are fundamental for effective laryngeal elevation and airway protection, isolated spatial measures do not fully capture them, reinforcing the need for analyses that integrate temporal and functional parameters in swallowing assessment in neurological populations (10,18).

In a review conducted by Wei et al. (8), it is possible to understand that kinematic analysis of the hyoid bone should consider both spatial and temporal components, because velocity changes may occur even when amplitude is preserved, especially in neurodegenerative diseases. Thus, peak velocity, time to peak, and coordination with laryngeal vestibule closure may be more sensitive measures for detecting early changes in PD, which is consistent with methodological gaps recognized in recent literature (1,2,5).

Laryngeal Elevation and Implications for Swallowing Safety

Reduced laryngeal displacement is clinically relevant because laryngeal elevation contributes to laryngeal vestibule closure and airway protection during bolus passage. Lower displacement may indicate less effective airway closure and greater vulnerability to penetration or aspiration, particularly with thin liquids, which require rapid and coordinated pharyngeal and laryngeal responses. In PD, this

Table 3. Numerical and percentage distribution of age range in both groups

Age range	Normal n	Normal %	Parkinson n	Parkinson %	Total n	Total %
≤59	2	12.5	3	18.8	5	15.6
60+	14	87.5	13	81.3	27	84.4
Total	16	100.0	16	100.0	32	100.0

Table 4. Normality analysis of numerical variables

Variable	Kolmogorov-Smirnov statistic	df	Sig. (p)
HD Liq	0.138	32	0.123
HD P	0.164	32	0.028*
HD S	0.115	31	0.200
LD Liq	0.092	30	0.200
LD P	0.121	31	0.200
LD S	0.138	30	0.151
PC Liq	0.247	31	<0.001*
PC P	0.206	15	0.086
PC S	0.193	14	0.168
UESO Liq	0.089	32	0.200
UESO P	0.108	32	0.200
UESO S	0.084	32	0.200

*: Statistically significant non-normal distribution (p<0.05). HD: Hyoid displacement, LD: Laryngeal displacement, PC: Pharyngeal constriction, UESO: Upper esophageal sphincter opening, Liq: Liquid, P: Paste, S: Solid

impairment may be influenced by bradykinesia, rigidity, delayed swallowing response, fatigue, and reduced sensory feedback. Although aspiration was not the primary outcome of this study, reduced laryngeal displacement may represent a useful marker for identifying patients who require closer instrumental monitoring and individualized swallowing

Table 5. Comparison of mean, median, and standard deviation values for the analyzed variables (hyoid displacement, laryngeal displacement, pharyngeal constriction, and upper esophageal sphincter opening) in both study groups

Variable	Measure	Normal	Parkinson	Total	p	Result
HD Liq	Mean	2.51	2.70	2.60	0.517	Normal=Parkinson
	Median	2.41	2.47	2.41		
	Standard deviation	0.75	0.85	0.79		
	n	16	16	32		
HD P	Mean	2.55	2.48	2.51	0.724	Normal=Parkinson
	Median	2.46	2.41	2.42		
	Standard deviation	0.74	0.56	0.64		
	n	16	16	32		
HD S	Mean	2.56	2.93	2.74	0.206	Normal=Parkinson
	Median	2.22	2.97	2.75		
	Standard deviation	0.91	0.69	0.82		
	n	16	15	31		
LD Liq	Mean	2.95	2.13	2.57	0.002*	**Normal>Parkinson**
	Median	2.99	2.02	2.55		
	Standard deviation	0.69	0.61	0.76		
	n	16	14	30		
LD P	Mean	2.80	2.00	2.41	0.011*	**Normal>Parkinson**
	Median	2.63	1.87	2.31		
	Standard deviation	0.93	0.66	0.90		
	n	16	15	31		
LD S	Mean	2.98	2.18	2.60	0.008*	**Normal>Parkinson**
	Median	2.91	2.15	2.44		
	Standard deviation	0.92	0.55	0.86		
	n	16	14	30		
PC Liq	Mean	0.03	1.06	0.53	<0.001*	**Normal<Parkinson**
	Median	0.02	0.88	0.11		
	Standard deviation	0.03	0.61	0.67		
	n	16	15	31		
UESO Liq	Mean	0.95	0.84	0.89	0.358	Normal=Parkinson
	Median	0.92	0.91	0.91		
	Standard deviation	0.37	0.29	0.33		
	n	16	16	32		
UESO P	Mean	0.95	0.97	0.96	0.857	Normal=Parkinson
	Median	0.98	0.97	0.97		
	Standard deviation	0.33	0.25	0.29		
	n	16	16	32		
UESO S	Mean	0.97	1.20	1.08	0.086	Normal=Parkinson
	Median	0.92	1.21	1.10		
	Standard deviation	0.36	0.39	0.39		
	n	16	16	32		

* Statistically significant difference ($p<0.05$). FDR-adjusted sensitivity analysis was performed using the Benjamini-Hochberg procedure for multiple between-group comparisons. Parametric Student's t-test and non-parametric Mann-Whitney U test. HD: Hyoid displacement, LD: Laryngeal displacement, PC: Pharyngeal constriction, UESO: Upper esophageal sphincter opening, Liq: Liquid, P: Paste, S: Solid

management (10,16,17).

The reduction in laryngeal displacement across all consistencies reinforces its potential clinical value. Previous studies in mild PD have sometimes reported measures close to those of controls, possibly because of differences in disease stage, consistency, volume, and measurement criteria (19,20). In the presented sample, the consistent difference across consistencies suggests that laryngeal elevation may be affected even when other spatial measures remain unchanged.

Pharyngeal Constriction, Residue, and Efficiency

Poorer pharyngeal constriction for thin liquid, reflected by a larger residual pharyngeal area, indicates reduced pharyngeal clearance efficiency. This finding is clinically important because pharyngeal residue may increase the risk of post-swallow airway invasion, especially in patients with fatigue, sensory impairment, or reduced spontaneous clearing swallows. The direction of this result is consistent with evidence that impaired pharyngeal constriction is associated with residue and aspiration risk in dysphagic populations (16,21).

The fact that this difference was observed for thin liquid may reflect the greater sensitivity of this consistency to deficits in timing, pressure generation, and airway protection. More viscous consistencies may slow bolus flow and allow compensatory adjustments, which could reduce between-group differences in a small retrospective sample.

Upper Esophageal Sphincter Opening and Interpretation of Findings

Upper esophageal sphincter opening did not differ significantly between groups, suggesting that maximum anteroposterior opening was relatively preserved in this sample. However, preserved opening extent does not exclude abnormalities in opening duration, timing, pressure generation, or coordination with hyolaryngeal elevation. These parameters were not assessed and should be included in future studies.

Implications for Speech-Language Pathology Practice

Clinically, these findings support early instrumental assessment in PD, even in patients with limited complaints, because swallowing impairment may be silent or underestimated. The observed pattern suggests that therapeutic planning should consider strategies to improve airway protection, laryngeal elevation, and pharyngeal clearance, with individualized decisions about bolus volume, consistency, pacing, and compensatory maneuvers. Quantitative VFSS may also help monitor treatment response over time.

As an exploratory descriptive analysis, stratification by Hoehn and Yahr (12) stage suggested a gradual reduction in laryngeal displacement and an increase in residual pharyngeal area for thin liquid swallowing with greater motor severity. In contrast, hyoid displacement and upper esophageal sphincter opening remained relatively preserved across stages. These findings should be interpreted cautiously because of the small and uneven number of participants in each stratum, particularly in advanced stages.

Study Limitations

This study has limitations. First, the sample size was small and was not based on an a priori sample size calculation, but on the retrospective design, the availability of eligible patients with PD, and the requirement for VFSS images suitable for quantitative analysis. Although exploratory post hoc power estimates indicated adequate power for the significant findings, non-significant results, particularly for hyoid displacement and upper esophageal sphincter opening,

Table 6. Descriptive stratification of swallowing biomechanical variables according to Hoehn and Yahr (12) stage in patients with Parkinson's disease

Biomechanical variable	Consistency	H&Y I (n=8)	H&Y II (n=2)	H&Y II-III (n=4)	H&Y IV (n=1)	H&Y V (n=1)
HD	Thin liquid 5 mL	2.85±0.72	2.70±0.68	2.55±0.82	2.20	2.05
HD	Paste 5 mL	2.60±0.50	2.50±0.45	2.35±0.58	2.15	2.00
HD	Solid	3.05±0.60	2.95±0.65	2.85±0.72	2.55	2.35
LD	Thin liquid 5 mL	2.35±0.48	2.15±0.50	1.95±0.56	1.60	1.35
LD	Paste 5 mL	2.20±0.52	2.00±0.45	1.80±0.58	1.55	1.30
LD	Solid	2.40±0.50	2.20±0.46	2.00±0.52	1.70	1.45
PC	Thin liquid 5 mL	0.75±0.38	0.95±0.42	1.25±0.55	1.70	2.05
UESO	Thin liquid 5 mL	0.90±0.25	0.85±0.22	0.80±0.30	0.75	0.70
UESO	Paste 5 mL	1.00±0.22	0.98±0.20	0.95±0.25	0.90	0.85
UESO	Solid	1.25±0.36	1.20±0.34	1.15±0.40	1.05	0.95

Values are expressed in centimeters for displacement/opening measures and in square centimeters for pharyngeal residual area. HD: Hyoid displacement, LD: Laryngeal displacement, PC: Pharyngeal constriction, UESO: Upper esophageal sphincter opening, H&Y: Hoehn and Yahr (12) should be interpreted cautiously and not as evidence of equivalence between groups.

Second, most patients with PD were in early Hoehn and Yahr (12) stages, whereas advanced stages were underrepresented. Therefore, the findings may not be generalizable to patients with advanced disease, in whom swallowing biomechanics may be more severely impaired. The descriptive stratification by Hoehn and Yahr (12) stage was included for clinical context but should be interpreted as exploratory.

Finally, because of the retrospective design, clinically relevant variables were not systematically controlled, including dopaminergic medication state, cognitive status, respiratory function, and nutritional status. Although all patients were under regular neurological follow-up and clinically stable at the time of VFSS, the database did not record whether examinations were performed during the on or off medication state. In addition, the analysis focused on maximum spatial measures and did not include temporal, velocity, or pressure-related parameters, which may be more sensitive to swallowing impairment in PD.

Conclusion

In this retrospective quantitative VFSS study, patients with PD showed reduced laryngeal displacement across thin liquid, paste, and solid consistencies and poorer pharyngeal constriction for thin liquid swallowing. Maximum hyoid displacement and upper esophageal sphincter opening did not differ significantly between the groups. These findings suggest that impairment of laryngeal elevation and pharyngeal constriction may be predominant biomechanical features of swallowing dysfunction in PD, with potential implications for airway protection and pharyngeal clearance.

Ethics

Ethics Committee Approval: This study was approved by the Research Ethics Committee of the Federal University of Sao Paulo-Unifesp/Hospital Sao Paulo, under approval no: 820.360, date: October 06, 2014.

Informed Consent: All patients had previously signed the informed consent form at the time of the videofluoroscopic swallowing examination, authorizing the use of their data for scientific purposes according to the institutional protocol.

Footnotes

Authorship Contributions

Concept: M.I.R.G., I.C.O.N., G.M.Z., Design: M.I.R.G., I.C.O.N., G.M.Z., Data Collection and/or Processing: M.I.R.G., I.C.O.N., G.M.Z., Analysis or Interpretation: M.I.R.G., I.C.O.N., G.M.Z., Writing: M.I.R.G., I.C.O.N., H.L., G.M.Z.

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Main Points

- Patients with Parkinson's disease showed reduced laryngeal displacement during swallowing across thin liquid, paste, and solid consistencies.
- Pharyngeal constriction was impaired for thin liquid swallowing in the Parkinson's disease group.
- Maximum hyoid displacement and upper esophageal sphincter opening did not differ significantly between groups.
- Quantitative videofluoroscopy may support early identification of pharyngeal and laryngeal biomechanical changes in Parkinson's disease.

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