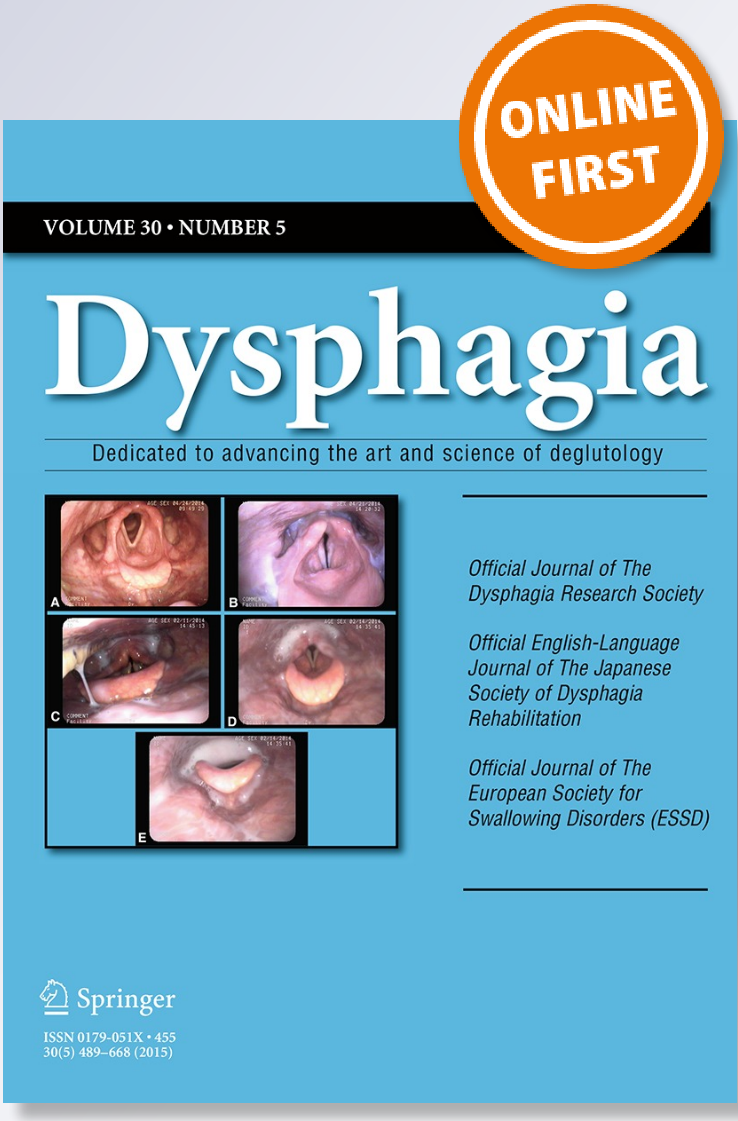
Videofluoroscopic Predictors of Penetration–Aspiration in Parkinson's Disease Patients

Natalie Argolo, Marília Sampaio, Patrícia Pinho, Ailton Melo & Ana Caline Nóbrega

Dysphagia
Dedicated to advancing the art and science of deglutology

ISSN 0179-051X

Dysphagia
DOI 10.1007/s00455-015-9653-y



Springer

Dysphagia
DOI 10.1007/s00455-015-9653-y

ORIGINAL ARTICLE

Videofluoroscopic Predictors of Penetration–Aspiration in Parkinson's Disease Patients

Natalie Argolo[1] · Marília Sampaio[1,2] · Patrícia Pinho[1] · Ailton Melo[1] · Ana Caline Nóbrega[1,2]

Received: 9 October 2014 / Accepted: 26 September 2015

Abstract Parkinson's disease (PD) patients show a high prevalence of swallowing disorders and tracheal aspiration of food. The videofluoroscopic study of swallowing (VFSS) allows clinicians to visualize the visuoperceptual and temporal parameters associated with swallowing disorders in an attempt to predict aspiration risk. However, this subject remains understudied in PD populations. Our aim was to identify the predictors of penetration–aspiration in PD patients using the VFSS. Consecutive patients were evaluated using VFSS with different consistencies and volumes of food. A speech-language pathologist measured the type of intra-oral bolus organization, loss of bolus control, bolus location at the initiation of the pharyngeal swallow, the presence of multiple swallows, piecemeal deglutition, bolus residue in the pharyngeal recesses and temporal measures. Scores $\geq$3 on the penetration–aspiration scale (PAS) indicated the occurrence of penetration–aspiration. Using logistic marginal regression, we found that residue in the vallecula, residue in the upper esophageal sphincter and piecemeal deglutition were associated with penetration–aspiration (odds ratio (OR) = 4.09, 2.87 and 3.83; $P = 0.0040$, 0.0071 and 0.0009, respectively). Penetration/aspiration occurred only with fluids (both of thin and thick consistency), and no significant differences were observed between fluid types or food volumes. The mechanisms underlying dysphagia and penetration/aspiration in PD patients and indications for further studies are discussed.

Keywords Parkinson's disease · Deglutition disorders · Penetration/aspiration

✉ Natalie Argolo
nataliefono@gmail.com; natyargolo@hotmail.com

1 Division of Neurology and Epidemiology, Federal University of Bahia, Rua Padre Feijó, 29 (4° floor) – Canela, Salvador, Bahia 40.110-170, Brazil

2 Department of Speech-Language Pathology, Health Sciences Institute, Federal University of Bahia, Salvador, Bahia, Brazil

Introduction

Dysphagia is common in Parkinson's disease (PD) patients, and objective measurements have determined its prevalence to be approximately 72–87 % [1]. Tracheal aspiration occurs in more than 50 % of PD patients [2] and results in a high risk of aspiration pneumonia and death in this population [3, 4]. Despite the broad impact of dysphagia on morbidity, mortality and quality of life, the correlation with disease severity and its physiopathological mechanisms remains controversial [5–7]. Swallowing disorders appear to result from a combination of rigidity and bradykinesia associated with respiratory incoordination and the pharyngeal sensory deficits present in PD [8, 9].

The videofluoroscopic study of swallowing (VFSS) is the gold-standard method to evaluate swallowing dynamics. This assessment method allows clinicians to visualize the movements and alterations of deglutition. Moreover, the VFSS can be used to help determine the safety of continuing oral food intake and to better understand the pathophysiological mechanisms underlying dysphagia and aspiration. In PD patients, visuoperceptual alterations, such as piecemeal deglutition, lingual pumping, preswallow spill, oral and pharyngeal residue, laryngeal penetration and tracheal aspiration have been reported [5, 6, 10]. A recent systematic review [11] reported that several kinematic measures of structural displacement can be extracted from VFSS videos and that hyoid movement is one of the most frequently assessed parameters. Temporal measures have also been extensively described, but there are several inconsistencies between the published definitions. Among one series of measures, the most widely used intervals are the stage transition duration, the pharyngeal transit time and the duration from laryngeal closure to upper esophageal sphincter (UES) opening.

Perlman et al. [12] reported that additional indicators of oropharyngeal dysphagia are usually present when food enters the airway. Thus, recognizing the risk factors associated with penetration/aspiration may help clinicians make optimal choices regarding the best possible therapeutic plan. In stroke patients, vallecular stasis, reduced hyoid elevation, deviant epiglottic function, diffuse hypopharyngeal stasis, delayed initiation of the pharyngeal stage of swallowing [12] and several temporal measures [14] have been described as videofluoroscopic predictors of food aspiration.

In the dysphagic population as a whole, pharyngeal residue is cited as a predictor of aspiration on the subsequent swallow [13, 14]. In addition, a series of measures related to tongue strength, anatomically normalized hyoid movement, respiratory measures and the length of time the bolus remains in the pharynx with the airway open have also been associated with an increased risk of aspiration [15].

Because aspiration status has been associated with a number of swallowing measures, clinicians should understand how these associations occur in swallowing of PD patients. However, our literature search failed to identify studies addressing the videofluoroscopic predictors of tracheal food aspiration in PD populations. Some authors found that PD patients with severe sialorrhea [16], voluntary cough abnormalities [17] and respiratory incoordination [8] had more aspiration. Regarding food consistencies, swallowing thin liquids is associated with higher scores in PAS in the PD population [2, 18].

We hypothesized temporal measures as oral and pharyngeal transit times could be increased in individuals with PD and penetration–aspiration mainly because of bradykinesia of the oropharyngeal muscles found in this population. In addition, the residue of food and liquids in pharyngeal recesses may enhance the chance of penetration–aspiration because the respiratory incoordination in PD patients.

The process of swallowing is complex and integrated. Therefore, it is important to study the mechanisms that underlie dysphagia, especially in PD, as the causative agents of dysphagia are not well established in this population. Thus, the aim of this study was identify VFSS predictors of penetration–aspiration in PD patients.

Methods

Study Population

Consecutive idiopathic PD patients from the Ambulatory Care Center for Movement Disorders of the Federal University of Bahia were enrolled in this study, regardless of the presence of swallowing complaints. All patients had taken anti-PD medications. Disease severity was evaluated according to the Hoehn and Yahr scale. Exclusion criteria included diagnoses of other neurologic diseases, cognitive or psychiatric disorders, depression, head and neck cancer or severe dysphagia that precluded complete evaluations of swallowing. PD diagnoses were made by a certified neurologist in accordance with the United Kingdom Parkinson's Disease Brain Bank guidelines [16].

This study was approved by the local ethics committee of Bahia, Brazil and was conducted in accordance with the Helsinki declaration (1964). All patients signed an informed consent form before undergoing any procedures related to the study.

Swallowing Assessments

The VFSS was performed using a Flexavision HB/Package (Shimadzu®, Japan) with 70 Kv and 20 mAs of radiation and were digitalized with a resolution of 30 frames per second. The exam was conducted by a radiologist and a speech-language pathologist (SLP) and was performed using an edible barium sulfate radiopaque agent (Bariogel® 100 %). Subjects completed the exam in a lateral position in a single phase. No instructions to hold the food or liquid in the mouth before swallowing were provided, so our study therefore examined uncued swallowing. To evaluate the patients' ability to swallow a thin fluid, each patient was asked to swallow barium mixed with water at a 1:1 ratio in 5, 10 and 20 ml portions. For thick fluids, patients were asked to swallow 5, 10 and 20 ml of pure barium. Paste barium was composed of 5, 10 and 15 ml of barium mixed with Nestlé® natural yogurt at a 2:1 ratio. For soft solid foods, half of a biscuit dipped in barium was used. Because the 20 ml bolus was fractionated in almost all patients, our analysis of this volume was limited. The 5, 10 and 15 ml portions were provided in a spoon, but the 20 ml volumes of thin and thick fluids were provided in a glass. Caregivers were trained to offer the food, except for the 20 ml trials, in which the participants drank by themselves.

The superior, inferior, anterior and posterior limits of the fluoroscopic image were the hard palate, the UES, the lips and the posterior pharyngeal wall (C3–C5), respectively.

Measurements

The VFSS videos were analyzed by three trained SLPs in real time, frame by frame and in slow motion using Avidemux 2.5.3 open-source software. The following visuoperceptual parameters of VFSS were measured:

- The type of intra-oral bolus organization [17] was defined as *closed* (the bolus was positioned above the tongue dorsum), *open anterior-restricted* (the bolus was positioned anterior to the tongue), *open expanded* (the bolus was positioned anterior and above the tongue), *prolonged* (the bolus extended above the tongue from the tip to the soft palate) and *unstable* (the position of the bolus was oscillating with or without intra-oral food spill).
- A loss of bolus control was considered to have occurred when the bolus was observed to fall into the oral sulci before swallowing was initiated.
- The bolus position at the initiation of the pharyngeal swallow was defined as the location of the contrasted material when laryngeal elevation occurred.
- Multiple swallows were defined as the occurrence of more than three hard swallows after the posterior bolus propulsion.
- Piecemeal deglutition was considered to have occurred when the bolus was fractioned in many swallows. Piecemeal deglutition for volumes less than 20 ml is considered abnormal [19].
- Residue in the tongue and pharyngeal recesses was evaluated after the first swallow in the tongue, vallecula, pyriform sinuses, posterior pharyngeal wall and UES, and was rated on a scale from 0 to 3. A score of 0 scores indicated that no residue was visible. A score of 1 was considered mild (up to 25 % of the level of the height of the structure). Scores of 2 were considered moderate (the level of contrasted material constituted between 25 and 50 % of the height of the structure). Scores equal to or greater than 3 indicated severe residue (i.e., the barium level was higher than 50 % of the height of the structure) [13]. In addition to this analysis, we also transformed this variable into a dichotomous variable, with no residue or mild residue in one group and moderate or severe residue in the other group.

The PAS [18] was used to measure the status of penetration–aspiration. We considered that penetration–aspiration occurred (food entering in the airways) when the PAS score was $\geq$3, which is consistent with a previous study that reported PAS scores of 1 and 2 in a healthy population [20]. These analyses were made at the level of the swallow, rather than at the level of the participant; this approach enabled the determination of the precise factors that led to food entering in the airways during each swallowing event.

The temporal parameters included oral transit time (OTT), which was measured from the first backward movement of the bolus until the head of the bolus passed the angle of the mandible. The pharyngeal transit time (PTT) was measured from the time the head of the bolus passed the angle of the mandible until the tail of the bolus left the cricopharyngeal region (the last frame in which material in the UES could be observed). The stage transition duration (STD) was measured from the time at which the bolus passed the angle of the mandible until the onset of laryngeal elevation [10].

When multiple swallows or piecemeal deglutition were observed, we evaluated only the first swallow in the series for each bolus.

Statistical Analysis

Data were analyzed using R software version 3.0.2. Descriptive statistics are presented as the mean ± standard deviation. The Shapiro test was used to assess the normality of the data. We used Cochran–Mantel–Haenszel tests in bivariate analyses to select the videofluoroscopic variables to use for logistic marginal regression analysis to control for food consistency and volume. In this selection, the variables for which $P < 0.15$ were chosen. The regressions were subsequently adjusted using the backward method. The final model was a logistic marginal regression stepwise model that combined forward and backward procedures. The logistic marginal regression was also performed separately between penetration–aspiration status and OTT, STD and PTT. The results from the logistic marginal regression analysis between penetration–aspiration status and food consistencies and volumes were corrected via multiple comparisons using the Holm-Bonferroni method.

Results

Of the 71 patients enrolled in the study, 69 completed the VFSS protocol. Two patients were excluded because they had severe dysphagia that precluded a complete evaluation of all food consistencies. A total of 690 swallowing events (10 per patient) were assessed in the current study. There were 44 men and 25 women in the study population, and the mean age of the participants was 63.36 ± 11.62 years. The mean disease duration was 7 ± 5.2 years, and the mean Hoehn and Yahr stage was 2.3 ± 0.9. Regarding food entering in the airways, PAS $\geq$ 3 occurred in 11 (15.94 %) patients and in 23 (3.33 %) swallowing events.

Table 1 Videofluoroscopic findings according to penetration–aspiration status

Swallowing abnormalities	Penetration–aspiration		
	Absent (%)	Present (%)	*P* value
Bolus positioning			
Closed	45.8	34.8	0.1861
Open anterior-restricted	11.5	8.7	
Open expanded	11.9	26.1	
Prolonged	12.0	13.0	
Unstable	18.7	17.4	
Loss of bolus to anterior sulci			
Absent	88.3	87.0	0.2036
Present	11.7	13.0	
Loss of bolus to lateral sulci			
Absent	95.05	95.65	0.2915
Present	4.95	4.35	
Loss of bolus to mouth floor			
Absent	78.3	60.9	0.9715
Present	21.7	39.1	
Posterior loss of bolus			
Absent	68.8	60.9	0.4404
Present	31.2	39.1	
Bolus location at the initiation of the pharyngeal swallow			
Tongue base/vallecula	78.6	43.5	0.0081*
PS/ AEF/ UES	21.4	56.5	
Multiple swallows			
Absent	44.4	43.5	0.6698
Present	55.6	56.5	
Piecemeal deglutition			
Absent	76.9	39.1	0.0064*
Present	23.1	60.9	
Residue on tongue			
Absent/mild	95.20	91.30	0.376
Moderate/severe	4.80	8.70	
Residue in vallecula			
Absent/mild	80.96	30.4	0.0120*
Moderate/severe	19.04	69.6	
Residue in PS			
Absent/mild	93.7	73.9	0.0621*
Moderate/severe	6.3	26.1	
Residue in AEF			
Absent/mild	98.65	91.3	0.8080
Moderate/severe	1.35	8.7	
Residue in UES			
Absent/mild	95.35	69.6	0.0271*
Moderate/severe	4.65	30.4	

PS pyriform sinus, *AEF* aryepiglottic fold, *UES* upper esophageal sphincter

* $P < 0.15$

Table 1 presents the associations that were identified using the bivariate analyses between penetration–aspiration status and VFSS visuoperceptual factors. The results of the logistic marginal regression revealed that piecemeal deglutition, residue in the vallecula and residue in the UES were all significantly associated with PAS $\geq$ 3 (as shown in Table 2).

With respect to the temporal VFSS factors, the means, standard deviations and results of the logistic marginal regression analyses between OTT, STD and PTT and penetration–aspiration for each consistency/volume are shown in Table 3. A statistically significant difference was observed for patients swallowing 10 ml of thin fluid; specifically, patients with PAS scores $\geq$3 showed higher PTTs. A significant P-value was also obtained in trials using 5 ml of thick fluid for OTT, STD and PTT, but only one patient aspirated while swallowing this consistency/volume. For trials in which 10 ml of thick fluid was swallowed, the STD and PTT were significantly reduced in subjects who exhibited PAS scores $\geq$3.

With respect to food entering in the airways according to food consistencies, thin liquid was associated with a higher prevalence of penetration/aspiration (12 swallows) than thick fluid (11 swallows), but this difference was not statistically significant (as shown in Fig. 1). Food entering in the airways was only observed in patients swallowing thin and thick liquids. Statistically significant differences were observed for the comparisons between paste vs. thin, paste vs. thick, solid vs. thin and solid vs. thick, and all of the *P*-values were less than 0.0001. Regarding food volume, no significant associations were observed between PAS scores $\geq$3 and different food volumes.

Discussion

The videofluoroscopic findings of residue in the vallecula, residue in the UES and piecemeal deglutition were observed to be significant predictors of penetration–aspiration in PD patients.

In the studied group, rigidity and bradykinesia may lead to intra-oral abnormalities in the capture, organization and posterior propulsion of food and liquids to the pharynx. Slower and smaller tongue movements [21, 22], in combination with pharyngeal dysmotility [6], result in an increased difficulty associated with the safe transport of food. Concurrently, upward and forward laryngeal movements are also important because they promote the opening of the cricopharyngeal muscle, which permits the passage of the food bolus. When this movement is reduced, the food remains in the pharyngeal recesses, including in the region of the UES, which contributes to post-swallowing aspiration. The residue in UES may be also related with disorders in the cricopharyngeal muscle relaxation. Some studies [5] suggest PD patients show an incomplete UES relaxation and a reduced UES opening. However, there is still controversy about this topic [23].

At the same time, vallecular residue is also associated with reduced hyoid elevation, deviant epiglottic function and oral impairments [24], a fact that highlights the strong relationship between the oral and pharyngeal phases of swallowing. Steele et al. [15] previously reported a reduction in the tongue-palate pressures for bolus propulsion and reduced laryngeal elevation in dysphagic populations with aspiration.

It is important to emphasize that in the PD population, the occurrence of post-swallowing pharyngeal residue is even more troubling because patients with decreased swallowing safety, such as those with higher PAS scores, perform more inspiratory cycles after swallowing and have a shorter duration of swallowing apnea [8]. This respiratory incoordination can result in residue being retained in the pharyngeal recesses, where it can then transit down to the lungs with the inspiratory flow. This is especially serious because PD patients have a diminished cough reflex, impairments in voluntary coughing [25, 26] and a high prevalence of silent aspiration, which enhances the risk of aspiration pneumonia [4], the major cause of death in this population [3].

Regarding piecemeal deglutition, a majority of our patients fractioned the 20 ml content, which was also associated with a higher prevalence of penetration–aspiration. In the healthy population, including healthy elderly individuals, a typical bolus size is usually 21 ml [27], but higher PAS scores have been observed with this volume [28]. We hypothesized that PD patients at risk of

Table 2 Logistic marginal regression data of VFSS predictors

Coefficients	OR	95 % CI	*P* value
Residue in the vallecula	4.09	1.56–10.7	0.0040
Residue in the UES	2.87	1.33–6.17	0.0071
Piecemeal deglutition	3.83	1.73–8.5	0.0009

VFSS videofluoroscopic swallowing study, *UES* upper esophageal sphincter, *OR* odds ratio, *CI* confidence interval

Table 3 Temporal measures according to consistency, volume and penetration–aspiration status analyzed by log-linear and linear marginal regression

Cons/vol	PAS ≥ 3	*N*	OTT				STD				PTT			
			Mean	SD	Exp(β)	*P* value	Mean	SD	β	*P* value	Mean	SD	Exp(β)	*P* value
Thin 5	No	67	1.706	1.428	1.19	0.660	0.754	1.627	−0.37	0.160	1.480	1.655	0.79	0.420
	Yes	2	2.025	1.525			0.384	0.354			1.170	0.614		
Thin 10	No	66	1.522	1.334	0.75	0.160	0.318	0.669	1.07	0.096	1.040	0.679	2.06	0.032*
	Yes	3	1.146	0.417			1.390	1.356			2.140	1.483		
Thick 5	No	68	2.166	1.698	0.43	<0.001*	0.900	1.433	0.50	0.004*	1.650	1.495	1.36	0.005*
	Yes	1	0.935	NA			1.401	NA			2.230	NA		
Thick 10	No	66	1.953	1.321	0.93	0.790	0.914	1.417	−0.60	0.010*	1.670	1.450	0.69	0.029*
	Yes	3	1.812	1.015			0.312	0.336			1.160	0.321		

Cons/Vol consistency/volume, *PAS* penetration/aspiration scale, *N* number of individuals, *OTT* oral transit time, *STD* stage transition duration, *PTT* pharyngeal transit time

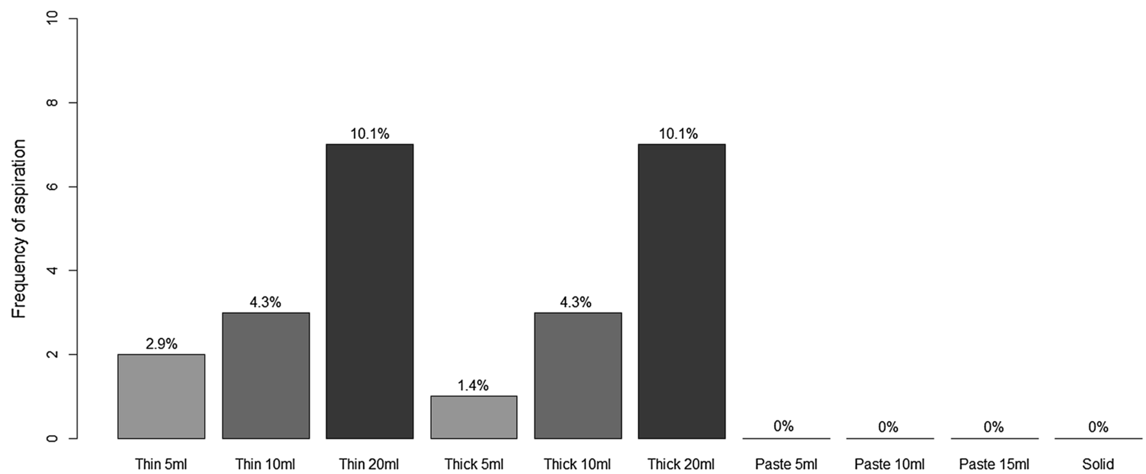


Fig. 1 Prevalence of aspiration according to food consistency and volume

penetration/aspiration may fractionate bolus volumes of 20 ml as a protective measure to reduce the likelihood of food entering in the airways.

Although residue in the pyriform sinus was shown to be statistically significant in the bivariate analyses, it was not verified as a significant predictor after the logistic marginal regression. Despite the fact that the prevalence of pyriform sinus residue in subjects with PAS scores ≥3 was fourfold higher than in subjects with PAS < 3, we believe that the low occurrence of this symptom in our population reduced the statistical impact. Nevertheless, we highlight the importance of examining this parameter during VFSS because it appears to be associated with a similar risk of post-swallowing penetration–aspiration as that observed for residue in the vallecula and residue in the UES. The study of Michou et al. [29] supported this recommendation because they found an association between the residue in pyriform sinuses and the PA scores in PD patients.

Similarly, the bolus location at the initiation of the pharyngeal swallow was also shown to be significant only in bivariate analyses. A previous study [30] reported that the bolus position at the initiation of the pharyngeal stage does not by itself differentiate between normal and dysphagic swallowing in healthy elderly individuals. This parameter can also vary between various swallows in the same individual [30], suggesting that multiple factors influence the initiation of the pharyngeal phase. Given that most of our patients who had PAS scores ≥3 performed laryngeal elevation only when the food had reached the very low regions of the airway, we emphasize that this factor should be evaluated along with other potential risk factors for penetration–aspiration.

Although some authors have reported that PD patients with a history of aspiration pneumonia have longer swallowing durations [31], there has been a great deal of variability in the timing measures reported in these studies, and no clear patterns have been established [11]. Some of the variability likely results from differences in bolus volume, age, sex, barium density and methodologies, including whether the swallow is cued or uncued [11]. Steele and Cichero [15] have reported that the STD is a good measure for aspiration risk; these authors concluded that if a bolus is sitting in the pharynx while the airway is open, this increases the risk of aspiration. However, our study revealed no patterns in temporal measure variations between swallowing with or without food entering in the airways. This outcome is most likely related to the small number of cases of penetration/aspiration in which OTT, STD and PTT were measured. The highest prevalence of food entering in the airways was observed for the 20 ml volume, and because most patients fractionated this volume, the corresponding time intervals were not measured. Thus, it is difficult to interpret the importance of this finding because of the fact that the observed differences could have occurred by chance. Fractionation of the content was likely also the reason that we observed no differences between the penetration–aspiration status and the bolus volume.

Another point to be stressed is that thin and thick barium liquids elicited a higher frequency of penetration/aspiration events than the other food consistencies, which is clinically relevant. As to be expected, thin liquids are more dangerous in patients who exhibit a delay in triggering the pharyngeal swallow, impaired oral control or reduced airway protection during swallowing [2]. PD patients usually show motor disturbances, such as rigidity and bradykinesia of the oral and pharyngeal muscles, which prevents them from properly and safely swallowing thin liquids [22]. We would like to highlight the fact that the thick fluid that we observed to be aspirated was composed of pure barium and was not diluted like the other materials, a fact that could enhance some rheological characteristics leading to greater swallowing difficulties. Other authors have stressed that patients with reduced tongue strength may have more problems with thickened liquids because more viscous material requires the generation of greater tongue pressure [2, 32]. However, Logemann et al. [2] observed reduced aspiration of a nectar-like barium solution compared to a thin liquid, reporting that the greatest improvements occurred with honey-like materials. One limitation of our study is the fact that we did not have an exact measure of the viscosity of the fluids used in the VFSS evaluations, which makes it difficult to compare our results with those reported in other studies. Furthermore, the presence of piecemeal deglutition prevented a reliable analysis of the differences between the tested volumes. Although we found no statistically significant differences between frequency of penetration–aspiration and food volumes, the professional involved in evaluation and treatment of swallowing should be aware of a possible increased risk of penetration and/or aspiration with the increased bolus volume [33]. The absence of a reliability measure in SLP analysis are another limitation of our study.

In conclusion, our data show that piecemeal deglutition, residue in the vallecula and residue in the UES are all significantly associated with penetration–aspiration in PD patients. Recognizing the factors associated with food entering in the airways is necessary to implement preventive measures and to identify the most effective therapeutic strategies. We suggest that further studies expanding the parameters of swallowing should be performed to better understand the risk factors associated with the penetration–aspiration in the PD population.

Compliance with Ethical Standards

Financial Disclosure/Conflict of Interest There was no financial support and no conflicts of interest related to this research.

References

1. Kalf JG, de Swart BJM, Bloem BR, Munneke M. Prevalence of oropharyngeal dysphagia in Parkinson's disease: a meta-analysis. Parkinsonism Relat Disord. 2012;18(4):311–5. doi:10.1016/j.parkreldis.2011.11.006.
2. Logemann JA, Gensler G, Robbins J, Lindblad AS, Brandt D, Hind JA, et al. A randomized study of three interventions for aspiration of thin liquids in patients with dementia or Parkinson's disease. J Speech Lang Hear Res JSLHR. 2008;51(1):173–83. doi:10.1044/1092-4388(2008/013).
3. Wang X, You G, Chen H, Cai X. Clinical course and cause of death in elderly patients with idiopathic Parkinson's disease. Chin Med J (Engl). 2002;115(9):1409–11.
4. Nobrega A, Rodrigues B, Melo A. Is silent aspiration a risk factor for respiratory infection in Parkinson's disease patients? Parkinsonism Relat Disord. 2008;14(8):646–8. doi:10.1016/j.parkreldis.2007.12.007.
5. Ali GN, Wallace KL, Schwartz R, DeCarle DJ, Zagami AS, Cook IJ. Mechanisms of oral-pharyngeal dysphagia in patients with Parkinson's disease. Gastroenterology. 1996;110(2):383–92. doi:10.1053/gast.1996.v110.pm8566584.
6. Leopold NA, Kagel MC. Pharyngo-esophageal dysphagia in Parkinson's disease. Dysphagia. 1997;12(1):11–20. doi:10.1007/PL00009512.
7. Nilsson H, Ekberg O, Olsson R, Hindfelt B. Quantitative assessment of oral and pharyngeal function in Parkinson's disease. Dysphagia. 1996;11(2):144–50. doi:10.1007/BF00417900.
8. Troche MS, Huebner I, Rosenbek JC, Okun MS, Sapienza CM. Respiratory-swallowing coordination and swallowing safety in patients with Parkinson's disease. Dysphagia. 2010;26(3):218–24. doi:10.1007/s00455-010-9289-x.
9. Rodrigues B, Nóbrega AC, Sampaio M, Argolo N, Melo A. Silent saliva aspiration in Parkinson's disease. Mov Disord. 2011;26(1):138–41. doi:10.1002/mds.23301.
10. Nagaya M, Kachi T, Yamada T, Igata A. Videofluorographic study of swallowing in Parkinson's disease. Dysphagia. 1998;13(2):95–100. doi:10.1007/PL00009562.
11. Molfenter SM, Steele CM. Temporal variability in the deglutition literature. Dysphagia. 2012;27(2):162–77. doi:10.1007/s00455-012-9397-x.

12. Perlman AL, Booth BM, Grayhack JP. Videofluoroscopic predictors of aspiration in patients with oropharyngeal dysphagia. Dysphagia. 1994;9(2):90–5. doi:10.1007/BF00714593.
13. Eisenhuber E, Schima W, Schober E, Pokieser P, Stadler A, Scharitzer M, et al. Videofluoroscopic assessment of patients with dysphagia: pharyngeal retention is a predictive factor for aspiration. AJR Am J Roentgenol. 2002;178(2):393–8. doi:10.2214/ajr.178.2.1780393.
14. Molfenter SM, Steele CM. The relationship between residue and aspiration on the subsequent swallow: an application of the normalized residue ratio scale. Dysphagia. 2013;28(4):494–500. doi:10.1007/s00455-013-9459-8.
15. Steele CM, Cichero JAY. Physiological factors related to aspiration risk: a systematic review. Dysphagia. 2014;29(3):295–304. doi:10.1007/s00455-014-9516-y.
16. Gibb WR, Lees AJ. The relevance of the Lewy body to the pathogenesis of idiopathic Parkinson's disease. J Neurol Neurosurg Psychiatry. 1988;51(6):745–52. doi:10.1136/jnnp.51.6.745.
17. Yamada EK, de Siqueira KO, Xerez D, Koch HA, Costa MMB. The influence of oral and pharyngeal phases on the swallowing dynamic. Arq Gastroenterol. 2004;41(1):18–23.
18. Rosenbek JC, Robbins JA, Roecker EB, Coyle JL, Wood JL. A penetration–aspiration scale. Dysphagia. 1996;11(2):93–8. doi:10.1007/BF00417897.
19. Ertekin C, Aydogdu I, Yüceyar N. Piecemeal deglutition and dysphagia limit in normal subjects and in patients with swallowing disorders. J Neurol Neurosurg Psychiatry. 1996;61:491–6.
20. Robbins J, Coyle J, Rosenbek J, Roecker E, Wood J. Differentiation of normal and abnormal airway protection during swallowing using the penetration–aspiration scale. Dysphagia. 1999;14:228–32.
21. Van Lieshout PHHM, Steele CM, Lang AE. Tongue control for swallowing in Parkinson's disease: effects of age, rate, and stimulus consistency. Mov Disord. 2011;26(9):1725–9. doi:10.1002/mds.23690.
22. Leopold NA, Kagel MC. Prepharyngeal dysphagia in Parkinson's disease. Dysphagia. 1996;11(1):14–22. doi:10.1007/BF00385794.
23. Ertekin C, Tarlaci S, Aydogdu I, Kiylioglu N, Yuceyar N, Turman AB, et al. Electrophysiological evaluation of pharyngeal phase of swallowing in patients with Parkinson's disease. Mov Disord. 2002;17(5):942–9. doi:10.1002/mds.10240.
24. Perlman AL, Grayhack JP, Booth BM. The relationship of vallecular residue to oral involvement, reduced hyoid elevation, and epiglottic function. J Speech Hear Res. 1992;35(4):734–41. doi:10.1044/jshr.3504.734.
25. Ebihara S. Impaired efficacy of cough in patients with parkinson disease. Chest. 2003;124(3):1009–15. doi:10.1378/chest.124.3.1009.
26. Pitts T, Bolser D, Rosenbek J, Troche M, Sapienza C. Voluntary cough production and swallow dysfunction in Parkinson's disease. Dysphagia. 2008;23(3):297–301. doi:10.1007/s00455-007-9144-x.
27. Adnerhill I, Ekberg O, Groher ME. Determining normal bolus size for thin liquids. Dysphagia. 1989;4(1):1–3. doi:10.1007/BF02407395.
28. Butler SG, Stuart A, Case LD, Rees C, Vitolins M, Kritchevsky SB. Effects of liquid type, delivery method, and bolus volume on penetration–aspiration scores in healthy older adults during flexible endoscopic evaluation of swallowing. Ann Otol Rhinol Laryngol. 2011;120(5):288–95.
29. Michou E, Hamdy S, Harris M, Vania A, Dick J, Kellett M, et al. Characterization of corticobulbar pharyngeal neurophysiology in dysphagic patients with Parkinson's disease. Clin Gastroenterol Hepatol. 2014;12(12):2037–45. doi:10.1016/j.cgh.2014.03.020.
30. Stephen JR, Taves DH, Smith RC, Martin RE. Bolus location at the initiation of the pharyngeal stage of swallowing in healthy older adults. Dysphagia. 2005;20(4):266–72. doi:10.1007/s00455-005-0023-z.
31. Lin C-W, Chang Y-C, Chen W-S, Chang K, Chang H-Y, Wang T-G. Prolonged swallowing time in dysphagic Parkinsonism patients with aspiration pneumonia. Arch Phys Med Rehabil. 2012;93(11):2080–4. doi:10.1016/j.apmr.2012.07.010.
32. Reimers-Neils L, Logemann J, Larson C. Viscosity effects on EMG activity in normal swallow. Dysphagia. 1994;9(2):101–6. doi:10.1007/BF00714596.
33. Butler SG, Stuart A, Leng LX, Rees C, Williamson J, Kritchevsky SB. Factors influencing aspiration during swallowing in healthy older adults. Laryngoscope. 2010;120(11):2147–52. doi:10.1002/lary.21116.

Natalie Argolo PhD

Marília Sampaio PhD

Patrícia Pinho PhD

Ailton Melo PhD

Ana Caline Nóbrega PhD