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ORIGINAL ARTICLE

Wet Voice as a Sign of Penetration/Aspiration in Parkinson's Disease: Does Testing Material Matter?

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Abstract Wet voice is a perceptual vocal quality that is commonly used as an indicator of penetration and/or aspiration in clinical swallowing assessments and bedside screening tests. Our aim was to describe the clinimetric characteristics of this clinical sign using various fluid materials and one solid food in the Parkinson's disease (PD) population. Consecutive PD individuals were submitted for simultaneous fiberoptic endoscopic evaluation of swallowing (FEES) and voice recording. Speech therapists rated the presence or absence of wetness and other voice abnormalities. Two binary endpoints of FEES were selected for comparison with an index test: low penetration (LP) and low penetration and/or aspiration (LP/ASP). The accuracy of wet voice changed according to the testing material in PD patients. Overall, the specificity of this indicator was better than its sensitivity, and the wafer cookie and yogurt drink yielded the best indices. Our data show that wet voice is clearly indicative of LP or LP/ASP in PD patients in case of positive test. However, in the case of a negative result, the wet voice test should be repeated or combined with other clinical tests to include or exclude the risk of LP or LP/ASP.

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Introduction

Oropharyngeal dysphagia is a common feature of Parkinson's disease (PD) that may cause harmful effects [1], especially when related to diurnal sialorrhea and silent aspiration of food or saliva [2, 3]. This symptom is under reported by PD individuals, which alludes to the necessity of a proactive clinical approach that includes the use of screening instruments and assessment by a speech–language pathologist [1].

Wet voice is a perceptual vocal quality that is commonly used as an indicator of penetration and/or aspiration in a clinical swallowing assessment or bedside screening test (CSA/BST) [4, 5]. Wet voice is detected in PD patients [6] and can be a consequence of misdirected prandial material to the larynx in dysphagic patients when laryngeal function and airway protection are compromised [7].

When tested alone [8] or in combination with another CSA/BST [9], wet voice has received controversial accuracy indices in diagnostic studies [8, 10] due to differences in methodologies, reference test implementation, and endpoints [11, 12]. Past studies indicate that previous vocal cord disorders can interfere in material behavior and in the perceptual evaluation of wet voice [7, 13]. Furthermore,the accuracy of wet voice as a predictor of penetration and aspiration may vary due to different material viscosities [14].

To date, diagnostic studies of wet voice have focused on stroke patients or heterogeneous medical conditions [11, 12]. Considering the importance of better understanding the role of wet voice in PD patients, here, we describe the

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clinimetric characteristics of this clinical sign of penetration and/or aspiration using various fluid materials and one solid food in this population.

Methods

Study Design and Ethical Issues

This was a prospective, observational, and blind study approved by the Federal University's ethics committee and was conducted according to the Declaration of Helsinki [15]. All participants signed an informed consent form to participate in the study before any procedures were conducted. To describe the clinimetric characteristics of wet voice as a clinical sign of penetration and/or aspiration, all participants with idiopathic PD were submitted to simultaneous fiberoptic endoscopic evaluation of swallowing (FEES) and voice recording using four types of fluid materials (saliva, water, yogurt drink and spoon-thick yogurt) and one solid food (wafer cookie).

Study Population

PD patients were recruited at the Neurosciences Outpatient Unit in a Federal University Hospital. Thesamplesize was determined by convenience selection. Researchers invited all patients who could potentially participate in the study and were unaware of the swallowing performance of individual patients.

Patients were included in the study if they met the following criteria: (a) hadidiopathic Parkinson's disease; (b) hadundergone treatment with a dopaminergic agent; (c) had a minimum phonation time of 3 s [16]; (d) had a minimum vocal intensity of up to 50 dB; and (e) were classified as having any Hoehn and Yahr (H&Y) disease stage [17]. Patients were excluded if they (a) had any other neurological disease ormovement disorders; (b) had a documented history of a neoplastic disease; (c) had been tracheostomized; or (d) were unable to undergo the FEES or understand verbal orders.

Standardization and Interpretation of the Reference Test

The FEES was conducted with patients in an upright sitting position and without administration of a topical anesthetic to the nasal mucosa. The tip of the flexible transnasal scope (Machida® ENT-PIII/3.2 mm, Japan) was kept above the epiglottis, at the level of the uvula. When necessary, the scope was positioned more deeply to adequately view laryngeal penetration and aspiration [9, 18].

First, we evaluated penetration/aspiration of blue-dyed saliva only. After examination and voice recordings using dyed saliva, we conducted FEES with blue-dyed foods. The viscosities of the yogurt drink and spoon-thick yogurt were measured with a Brookfield digital rheometer (model DV III + Middleborough, MA, USA) with a sc4-31 spindle at 25 °C; the shear rates (SRs) were measured at 56 % ± 2 of torque using a 13 ml sample adapter. Patients were asked to swallow sequential sips of 50 ml of water from a cup (0.89 cP [19]), sequential sips of 50 ml of Bliss®yogurt drink (574 cP, SR 10 s^{-1}) from a cup, one 10 ml spoonful and one 15 ml spoonful of Nestle®Natural Yogurt (1791 cP, SR 3 s^{-1}), and half a wafer cookie. Exams were digitized for posterior analysis, for which the audio was turned off for blinding purposes. The Penetration-Aspiration Scale was used in the assessments [20]. Bolus flow events were interpreted at six time points per patient (after saliva swallowing and after intake of each food material) during phonation. The results were obtained by consensus of two experienced speech-language pathologists (SLPs) and an otorhinolaryngologist. Two binary endpoints were selected for comparison with an index test: (1) presence/absence of low penetration (LP; presence of material near or above the vocal folds) and (2) presence/absence of low penetration and/or aspiration (LP/ASP; presence of material near/above and/or beyond the vocal folds).

Standardization and Interpretation of the Index Test

Patients were asked to phonate an /ɛ/ sound after swallowing dyed secretions and each food material during the FEES. Voice samples were recorded (SAMSON Q7® microphone; 5 cm distance from the mouth) and digitized (PRAAT software; 5.3.57; The Netherlands). Three SLPs specialized in dysphagia management listened to the vocal samples with headphones for proper external noise isolation. They independently rated the presence or absence of wetness, hoarseness, and tremor while blinded to the reference test results. After calculating the intra- and inter-rater agreement of ratings, the vocal abnormalities investigated were considered *positive* if at least two of the judges arrived at this conclusion [8].

Statistical Analysis

Means ± standard deviations (SD), prevalence, sensitivity, specificity, positive and negative predictive values (PPV and NPV), and positive and negative likelihood ratios (LR±) are presented as descriptive results. A 2 × 2 contingency table was used to calculate the accuracy of the data, and results were reported using the 95 % confidence interval (CI). To calculate the intra-and inter-rater percentages of agreement between the judges of the index test, 10 % of the voice samples were reanalyzed.

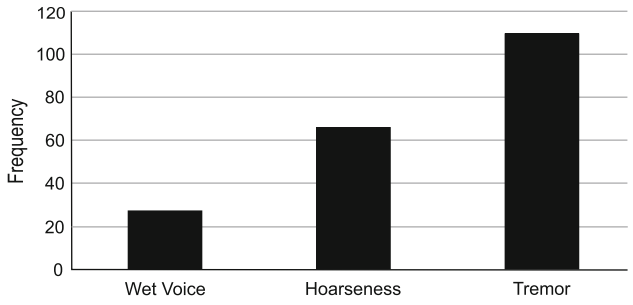

Fig. 1 Frequency of perceptual voice analysis ($N = 114$)

Results

Twenty-eight patients were assessed by the FEES, but nine were excluded from the study because their voice samples did not meet the minimum conditions for reliable perceptual voice assessment (short phonation time and/or low voice intensity). Thus, nineteen patients with idiopathic Parkinson's disease were included in the study (13 men; mean age 64.8 ± 10.3 years; mean H&Y 2.5 ± 1.3; mean PD duration 7 ± 4 years), and a total of 114 measurements were performed.

Wet voice was the least perceived vocal abnormality by the judges among the 114 voice samples (22.8 %), followed by hoarseness (59.6 %), while tremor was perceived in almost all samples (95.6 %) (Fig. 1). The judges of the index test showed a substantial mean intra-rater percentage of agreement for perceptual analysis of wet voice (0.87 ± 0.07), hoarseness (0.93 ± 0.0), and tremor (0.96 ± 0.04). However, the mean inter-rater percentage of agreement varied; it was substantial for wet voice (0.73 ± 0.13) and tremor (0.71 ± 0.04) but low for hoarseness (0.47 ± 0.2).

Regarding the accuracy characteristics of wet voice, specificity indices were higher than sensitivities (Table 1), and both varied according to fluid or solid testing material (71–93 % and 20–100 %, respectively). The tests with the yogurt drink, spoon-thick yogurt (15 ml), and wafer cookie presented the best sensitivities, and the best LR+ was found with the wafer cookie and the yogurt drink (Table 1).

Discussion

This is the first study to investigate the accuracy of the isolated sign of wet voice in PD. We showed that wet voice has better specificity than sensitivity for predicting LP and LP/ASP in PD individuals. In daily clinical practice, higher specificities indicate that a positive result *includes* the event of low penetration and/or aspiration, i.e., when wet voice is detected, the presence of LP and LP/ASP is certain [21]. In contrast, a low sensitivity means that in the case of a negative result, the wet voice test should be repeated or combined with other clinical tests to include or exclude the risk of low penetration and/or aspiration. High specificities and low sensitivities of wet voice have been observed in other studies [16, 22], but the results are inconsistent due to the heterogeneity between groups and different end points.

Clinical tests are rarely 100 % accurate, so false-positives and false-negatives can occur and can vary due to the methodology applied and other factors [21, 23]. Regarding swallowing disorders in PD, there is a lack of diagnostic studies of clinical tests in this population. Recent studies have shown that motor and sensory pharyngeal nerves are affected in PD, contributing to dysphagia and aspiration [24, 25]. Thus, early detection of the clinical signs of dysphagia in PD is crucial.

Another important finding of our study is that the accuracy of wet voice may vary depending on the fluid/solid testing material in PD patients. Considering both end points, the wafer cookie and yogurt drink materials yielded the most accurate results, especially the LR+, which is a powerful statistical measure with great clinical usefulness [26]. A higher LR+ means that a positive result of wet voice is associated with a higher probability of LP and LP/ASP [21].

Control over the viscosities of swallowed food in diagnostic studies has been limited [22]. Indeed, the scarce data on swallowing events according to viscosity, volume, and population may be an obstacle for achieving reliable accuracy measurements. Water is the most tested material; nevertheless, results of studies using acoustical parameters and other viscosities are consistent with the notion that accuracy may change according to the material used [5, 27]. Murugappan et al. [13] observed an increase in the aerodynamic load of the vocal folds and subglottal pressure with increasing food volume and viscosity. In addition, Groher et al. [14] noted that wet voice was significantly associated with videofluoroscopic findings of aspiration with thick liquids but not with thin liquids. Wet voice is explained by the generation of sound when moving fluids come into contact with glottal airflow [13]. As such, the clinical impressions may be influenced by volume and consistency behaviors, including the quick transit and low cohesion of thin liquids and the residues of thicker liquids [14].

Our judges were experienced in the area of clinical swallowing practices, as evidenced by the large intra-rater percentage of agreement. The judges had not previously undergone perceptual training to reflect the real situation of daily practice. Based on our findings, we suggest that the concomitant vocal abnormalities commonly found in PD, such as hoarseness, tremulousness [28] and reduced vocal intensity [29], may have induced the false-negative signs of

Table 1 Accuracy of wet voice to identify penetration and/or aspiration of fluids and solid materials ($N = 19$)

Material	Prevalence (%)	Sensitivity (%) (95 % CI)	Specificity (%) (95 % CI)	PPV (%) (95 % CI)	NPV (%) (95 % CI)	LR+ (95 % CI)	LR− (95 % CI)
Saliva							
Low penetration	26.3	20.0 (3.3–71.2)	85.7 (57.2–97.8)	33.3 (5.5–88.5)	75.0 (47.6–92.6)	1.40 (0.16–12.29)	0.93 (0.57–1.52)
Water (20 ml)							
Low penetration	21.1	25.0 (4.1–79.7)	80.0 (51.9–95.4)	25.0 (4.1–79.7)	80.0 (51.9–95.4)	1.25 (0.17–9.0)	0.94 (0.50–1.7)
LP/ASP	31.6	33.3 (5.3–77.3)	84.6 (54.5–97.6)	50.0 (8.3–91.7)	73.3 (44.9–92.1)	2.17 (0.39–11.92)	0.79 (0.43–1.45)
Yogurt drink (20 ml)							
Low penetration	21.1	50.0 (8.3–91.7)	93.3 (68–98.9)	66.7 (11.6–94.5)	87.5 (61.6–98.1)	7.50 (0.89–63.24)	0.54 (0.20–1.44)
LP/ASP	26.3	40.0 (6.5–84.6)	92.9 (66.1–98.8)	66.7 (11.6–94.5)	81.3 (54.3–95.7)	5.60 (0.64–49.17)	0.65 (0.31–1.34)
Spoon-thick yogurt (10 ml)							
Low penetration	15.8	33.3 (5.5–88.5)	81.3 (54.3–95.7)	25.0 (4.1–79.7)	86.7 (59.5–98.0)	1.78 (0.27–11.86)	0.82 (0.36–1.89)
Spoon-thick yogurt (15 ml)							
Low penetration	21.1	50.0 (8.3–91.7)	73.3 (44.9–92.1)	33.3 (5.3–77.3)	84.6 (54.5–97.6)	1.87 (0.52–6.81)	0.68 (0.24–1.90)
LP/ASP	26.3	40.0 (6.6–84.6)	71.4 (41.9–91.4)	33.3 (5.3–77.3)	76.9 (46.2–94.7)	1.40 (0.36–5.43)	0.84 (0.38–1.85)
Wafer cookie							
Low penetration	10.5	100.0 (19.3–100.0)	76.5 (50.1–93.0)	33.3 (5.3–77.3)	100.0 (75.1–100.0)	4.25 (1.8–10.01)	0.00
LP/ASP	21.1	75.0 (20.3–95.9)	80.0 (51.9–95.4)	50.0 (12.4–87.6)	92.31 (63.9–98.7)	3.75 (1.18–11.96)	0.31 (0.06–1.74)

LP/ASP low penetration and/or aspiration, *PPV* positive predictive value, *NPV* negative predictive value, *LR+* positive likelihood ratio, *LR–* negative likelihood ratio

wet voice and variations in the inter-rater agreement. Wet voice is presumed to be perceptually distinct from other voice disturbances; however, the perceptual nature of this vocal abnormality, as well as its distinction from other types of abnormal phonation, needs to be evaluated further [7]. Material in the larynx generates irregularity and aperiodicity in the phonatory signal, which can result in varying perceptual interpretations [7, 13]. Thus, Groves-Wright et al. [7] proposed rating vocal samples as *normal/abnormal* to achieve more reliable measurements. Daniels et al. [30] identified *dysphonia* and *dysarthria* as strong indicators of aspiration in stroke adults. On the contrary, Waito et al. [16] observed poor accuracy of the *G* score in the GRBAS scale in a heterogeneous group. Therefore, it is important to understand the relationship between perceptual vocal abnormalities and swallowing disorders in different laryngeal pathologies, while avoiding the under/overestimation of clinical impressions and judgment bias.

The evaluation of oropharyngeal secretions before the presentation of any food or liquid during the FEES is an important factor for swallowing ability and diet recommendation outcomes [31]. Murray [32] and Donzelli et al. [31] observed a strong association between presence of secretions in the laryngeal vestibule and aspiration of food and liquid. Takahachi et al. [33] identified the aspiration of saliva as a significant risk factor for pneumonia. Therefore, evaluating wet voice first with saliva alone may be useful for predicting the results with foods and for preventing clinical complications. Although we have found low accuracy rates with saliva, further investigation of wet voice with saliva would be useful during clinical swallowing evaluations in the PD population exhibiting diurnal sialorrhea and silent aspiration of food or saliva [3]. Because pooling of secretions without any previous food or liquid ingestion may occur in patients with dysphagia, possibly altering vocal parameters, we recommend that studies with methodologies that focus on comparing vocal parameters pre-and post-swallowing control for this variable.

To achieve a higher level of methodological quality, we sought to follow the criteria adopted by the Cochrane [34]. Because we discarded data containing insufficient voice quality, the sample size was reduced, thus diminishing the study power. Despite the small sample size in our study, we would like to note the importance of this preliminary study for future meta-analyses and for understanding the role of wet voice as a clinical sign of low penetration and/or aspiration in PD.

In conclusion, our data demonstrate that the accuracy of wet voice as a sign of low penetration and/or aspiration changed according to fluid or solid testing material in consecutive PD patients. Combining this test with assessments of other clinical signs may enhance the accuracy of the evaluation, but it is important to understand how different populations, viscosities, voice disturbances, and swallowing disorders affect the clinical impressions associated with each clinical test.

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