Original Article

Artigo Original

Postswallow voice modification: compatibility with videofluoroscopy findings

Modificação da voz após deglutição: compatibilidade com achados da videofluoroscopia

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Keywords

Deglutition
Voice Quality
Deglutition Disorders
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ABSTRACT

Purpose: Verify whether voice modification after swallowing is associated with videofluoroscopic examination data. **Methods:** 27 patients with oropharyngeal dysphagia underwent recording of sustained phonation of vowel /a/ before and after swallowing during videofluoroscopy. The GRBAS scale and the wet voice parameter were used to evaluate the data. Videofluoroscopy results showed stasis of food in the valleculae and piriform recesses, laryngeal penetration, tracheal aspiration, and degree of dysphagia. **Results:** Decreased dysphonia grade and asthenia and increased strain were observed after swallowing, with no difference for the wet voice parameter. Sensitivity and specificity of ± 50% were observed for food stasis in the valleculae and piriform recesses. Sensitivity values of 80 and 66-75% were observed for detection of laryngeal penetration and tracheal aspiration and modification of vocal strain, respectively. Negative predictive values of 77-91% were found for the three assessment parameters with no correlation with the degree of oropharyngeal dysphagia. **Conclusion**: Modification of the GRBAS scale parameters after swallowing showed good compatibility with videofluoroscopy findings.

Descritores

Deglutição
Qualidade da Voz
Transtornos de Deglutição
Voz
Aspiração Respiratória

RESUMO

Objetivo: Verificar se a modificação da voz após a deglutição relaciona-se com os dados do exame de videofluoroscopia. **Método:** 27 indivíduos com disfagia orofaríngea realizaram a gravação da vogal sustentada /a/ antes e após a deglutição durante exame de videofluoroscopia. Utilizou-se a escala GRBAS e acrescentou-se o aspecto voz molhada para avaliação dos dados. Em relação ao exame, verificou-se estase de alimento em valéculas e recessos piriformes, penetração laríngea, aspiração traqueal e grau de disfagia. **Resultados:**Houve diminuição do grau de alteração e astenia e aumento da tensão fonatória após a deglutição, sem diferença para o parâmetro voz molhada. Obteve-se sensibilidade e especificidade de ±50% para estase em recessos piriformes e valéculas; porém, sensibilidade de 80% para detecção de penetração e de 66-75% para aspiração e modificação da tensão fonatória, com 77-91% de valores preditivos negativos para os três parâmetros de avaliação, sem correlação com o grau de disfagia. **Conclusão:**A modificação dos parâmetros da escala GRBAS após a deglutição apresentou boa compatibilidade com achados da videofluoroscopia.

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INTRODUCTION

Deglutition is a dynamic phenomenon linked to maintenance of an individual's health, which is associated with the intake, absorption, and incorporation of adequate nutrients by the organism[1]. A significant number of diseases are associated with swallowing disorders. Neurological problems are the most frequent cause of these conditions, and those that usually affect swallowing dynamics the most[2].

Clinical evaluation of swallowing (CES) is a component that enables understanding dysphagia, obtaining information on its location, nature - structural or functional, and underlying etiology, in addition to determining the effectiveness of clinical management. CES is interpretive and based on the observation of swallowing and signs suggestive of changes in the oral and pharyngeal phases[3].

CES is conducted both directly and indirectly. The indirect assessment includes anamnesis, and structural and sensory evaluation of the oral cavity and laryngeal functioning. The direct evaluation comprises the swallowing of foods of different consistencies (pasty, solid, and liquid), in which cervical auscultation is performed at rest, during swallowing of saliva, and before, during, and after swallowing of food to assess the effectiveness of the oral and pharyngeal stages of deglutition[3]. Once CES is conducted, the speech-language pathologist determines whether the patient is eligible for objective videofluoroscopic examination - the gold standard measure for the diagnosis of dysphagia[4].

According to the American Speech-Language-Hearing Association - ASHA[4], patients should be referred to videofluoroscopic assessment when the signs and symptoms are inconsistent in the clinical evaluation; to verify the necessity to confirm a diagnostic suspicion or to assist with determination of a differential diagnosis; if dysphagia is suspected to contribute to the patients' pulmonary or nutritional impairment; if there is concern about the safety and efficiency of swallowing; and when patients are identified as possible candidates for rehabilitation and specific information is needed to guide treatment. Thus, clinical information contributes to the adequate referral of patients to videofluoroscopy and serves as a basis for appropriate monitoring of the case.

In this context, conducting a detailed clinical evaluation that allows adequate referral to complementary assessments is of fundamental importance. Currently, clinical aspects are being studied in order to minimize the need for complementary diagnostic methods, especially regarding laryngeal and vocal aspects that may contribute to the detection of swallowing disorders. Wet voice is a widely used term that denotes a change in postswallow vocal quality; it is considered an important clinical sign of dysphagia.

During CES, patients are asked to sustain phonation of vowel /a/ before and after swallowing of the food evaluated consistencies so that the speech-language pathologist can observe whether there is a change in vocal quality[5]. Physiologically, wet voice is considered a consequence of vocal production with prandial material in the larynx, causing modification of mass at the vocal fold level and altering the vocal quality of individuals[6,7]. Therefore, postswallow vocal modification indicates laryngeal penetration, which is defined as the passage of food through the larynx within the vocal fold level[8], consequently presenting a significant risk of tracheal aspiration, which is defined as food passage beyond the vocal fold level[9].

This phenomenon frequently occurs in patients with incoordination between airway protection and deglutition, because food can enter the laryngeal vestibule during the pharyngeal phase. It is also commonly observed in individuals who cannot clear secretions from the larynx vestibule through coughing, and especially in those with reduced sensory feedback. Thus, detection of foreign material in the larynx is a potential clinical indicator of swallowing disorders[10].

In spite of being an important clinical feature in the diagnosis of dysphagia, the wet voice parameter is poorly studied, presenting scarce scientific data. Consequently, it is unclear which vocal alteration pattern is associated with dysphagia, and which deglutition disorder causes this vocal quality modification in patients. In this context, other widely studied auditory-perceptual characteristics of vocal quality can contribute substantially to the identification of swallowing disorders.

Based on the previously presented data, this study aims to verify whether postswallow voice modification in individuals with dysphagia is associated with videofluoroscopy findings through test validity measures of vocal auditory-perceptual aspects.

METHODS

This cross-sectional, prospective, descriptive study aims to verify the relationship between videofluoroscopy findings and postswallow vocal modification. The study was approved by the Research Ethics Committee of the aforementioned Institution under process no. 293.856.

Two assessment methods were used to achieve the proposed objectives: videofluoroscopic examination and recording and analysis of the vocal production of individuals.

Patients referred to videofluoroscopy were invited to participate in the study provided that they were willing to undergo the proposed assessments and fulfilled the inclusion and exclusion criteria. Participants were informed about the research objectives and procedures and signed an Informed Consent Form prior to study commencement.

Before the examination, vocal production was recorded using an external microphone connected to a Powerpack DVR-576.BK recorder so that the habitual voice production of the individual could be compared with that after swallowing. Patients were requested to perform usual inspiration followed by sustained phonation of vowel /a/; ≥4 sec phonation was considered valid for further analysis. The examination procedures began after completion of the initial recordings.

For videofluoroscopy, an Axion Icons R100 Siemens fluoroscope coupled to a computerized image recording system was used. This device allows further detailed analysis of the examination. The protocol consisted in the evaluation of swallowing of three prepared and offered consistencies, namely, pasty, *petitsuisse* yogurt with liquid barium (Bariogel®) – 1:1 ratio (20 ml yogurt:20 ml barium); liquid, distilled water with liquid

barium (Bariogel®) - 1:1 ratio (40 ml water:40 ml barium); and solid, bread soaked in liquid barium (Bariogel®). The patients remained seated while lateral and frontal anterior-posterior images were captured, with upper and lower limits ranging from the oral cavity to the stomach. After the swallowing of at least three food boluses in the assessment of each consistency, recording of vocal production was once again performed so that it could be compared with that recorded before the examination.

At each stage of deglutition, specific parameters were evaluated to determine the conditions of each food bolus transit stage and, consequently, the degree of oropharyngeal dysphagia. In this study, we only assessed data collected during the pharyngeal stage of swallowing, and compared them with those of the vocal recordings, considering that changes at this stage can directly compromise vocal quality because of its close relationship with the larynx. Each item evaluated was considered with respect to its presence or absence: food stasis in the valleculae and piriform recesses, laryngeal penetration, and tracheal aspiration, for each of the consistencies. In addition, the degree of oropharyngeal dysphagia was also obtained for comparison with vocal production data. This aspect was also considered for the inclusion of individuals in the study, whose sample was composed only of individuals who had a diagnosis of oropharyngeal dysphagia in the examination and who presented degree of dysphagia between 1 and 5 (severe to mild) on the dysphagia outcome and severity scale[11].

Patients of both sexes, aged 18-60 years, capable of responding to the research protocol and of swallowing at least one of the standardized consistencies of the examination were included in the study. Exclusion criteria comprised individuals with a history of surgeries or removal of tumors from structures involved in swallowing and phonation, who had received tracheostomy, who were diagnosed with laryngeal diseases, and were unable to respond verbally.

As for analysis of the vocal productions, three judges performed the auditory-perceptual analysis of the data. The raters received all the recordings performed during the videofluoroscopic examination, including those of individuals who obtained degrees 6 and 7 (normal in all situations and within functional limits/modified independence) on the dysphagia outcome and severity scale used, in order to avoid bias in the diagnosis of dysphagia. The evaluators were not informed about this inclusion and were also blinded as to the type of recording conducted - pre- or postswallow. The recordings were provided in steps, containing no more than one recording of each individual per step in order to avoid comparison. This analysis consisted in the application of the dysphonia GRBAS scale[12], in which scores from 0 to 3 - referring to without alteration, and mild, moderate and severe alterations - are sequentially assigned to the measured parameters: overall grade (G), roughness (R), breathiness (B), asthenia (A), and strain (S). The vocal perception variable Wet Voice was also added, which should be measured in the same way, as it is a characteristic commonly attributed to the postswallow phonation of individuals with oropharyngeal dysphagia.

The collected data were analyzed by descriptive statistics and statistical tests. The Kappa concordance test was applied to evaluate interrater reliability regarding the auditory-perceptual data of vocal assessment. Concordance of 0.82 (α=0.05) was verified, interpreted as almost perfect agreement, allowing unification of the data for analysis. Normality of the analyzed variables was assessed using the Shapiro Wilk test. The means of the values assigned by the judges in the auditory-perceptual analysis were calculated so that a single score could be considered for each variable. For comparison between pre- and postswallow vocal quality for each consistency, the paired sample *t*-test, presented in mean and (standard deviation), was used for the parametric variables, whereas the Wilcoxon U test, presented in median and (interquartile range), was applied for the non-parametric variables. In addition, the Spearman's correlation test was used to investigate the correlation between degree of dysphagia and the auditory-perceptual variables with significant postswallow alteration. For analysis of test validity, we evaluated the aspects of sensitivity, specificity, positive predictive value, and negative predictive value of the variables that were statistically significant in the comparison between pre- and postswallow vocal quality data. For preparation of the 2×2 contingency table for the test validity analyses, the vocal production continuous variables were converted into categorical variables, and "yes" or "no" were attributed to the values according to the difference between pre- and postswallow recordings for each variable, which are detailed in the table that presents the results of the test validity measures. Results were considered statistically significant at a maximum significance level of 5% (p<0.05). Data were processed using the SPSS 20.0 statistical software.

RESULTS

Fifty-two videofluoroscopic examinations were performed, of which 27 were included in the study. Participants were 14 men and 13 women with mean ages of 71.07 and 76.69 years, respectively. With respect to the causes of oropharyngeal dysphagia, 22 (81.48%) individuals had a medical diagnosis of neurological alteration as etiology and the other five individuals were under clinical investigation and still without diagnosis of the underlying disease, but structural changes in the pharyngo-laryngeal tract had already been discarded. As for neurological alterations, swallowing disorders were observed in 14 (51.85%) individuals after ischemic stroke; in four (14.81%) patients due to Parkinson's disease; in two (7.41%) individuals as a consequence of amyotrophic lateral sclerosis; and in two (7.41%) patients caused by traumatic brain injury (TBI).

According to the number of patients included in the study, we expected to obtain 108 vocal recordings; however, not all participants were able to swallow all the consistencies evaluated, and a total of 101 vocal productions were obtained, with differences in the sample sizes according to the assessed consistency. The largest reduction in sample size occurred for the swallowing of solid consistency because of chewing limitations, such as reduced number of teeth and masticatory deficit. Table 1

shows the difference between pre- and postswallow assessment results for each consistency evaluated. Analysis performed through application of the *t*-test for the paired samples showed significant vocal variability only for dysphonia overall grade for the pasty consistency, with a decrease in grade observed after swallowing.

Analysis conducted using the Wilcoxon U test shows a significant decrease in asthenia and an increase in strain after swallowing of pasty consistency (Table 2). Regarding the results obtained in the videofluoroscopic examinations, 18 (66.6%) individuals presented degree of dysphagia of 5; five (18.51%) patients had degree 4; one (3.70%), degree 3; three (11.11%), degree 2; and none of the individuals presented degree 1. The Spearman's correlation test showed no correlation between degree of dysphagia and changes in dysphonia grade, asthenia, and strain after swallowing ($p>0.05$).

Table 3 presents the results for test validity measures between the auditory-perceptual aspects with postswallow statistical significance - dysphonia grade, asthenia, and strain after swallowing of pasty consistency - and the videofluoroscopy findings for the pharyngeal phase of this consistency.

For preparation of the 2×2 contingency analysis table, the continuous variables were converted into categorical variables, and "yes" was attributed when a positive difference was observed between pre- and postswallow assessments and "no" was assigned when a negative difference or results equal to zero were found for the G (grade) and A (asthenia) variables, considering that a decrease in these aspects was verified after swallowing. As for conversion of the S (strain) variable, "yes" was attributed when a negative difference was observed between pre- and postswallow assessments and "no" was assigned when a positive difference or results equal to zero were found, considering that an increase in this aspect was verified after swallowing.

Table 1. Difference between pre- and postswallow assessment for the variables dysphonia grade, roughness, and breathiness

Compared stage of deglutition Pre- and postswallow	G	*p*	R	*p*	B	*p*
Pasty consistency (n = 27)	**0.21 (0.37)**	**0.008**	-0.17 (0.56)	0.134	0.07 (0.55)	0.5
Liquid consistency (n = 26)	0.14 (0.48)	0.156	-0.10 (0.65)	0.439	0.01 (0.55)	0.91
Solid consistency (n = 21)	0.14 (0.55)	0.267	-0.08 (0.63)	0.581	0.02 (0.64)	0.914

Caption: Dysphonia grade (G); Roughness (R); Breathiness (B); mean (standard deviation); $p<0.05$ (bold)

Table 2. Difference between pre- and postswallow assessment for the variables asthenia, strain, and wet voice parameter

Compared stage of deglutition Pre- and postswallow	A	*p*	S	*p*	WV	*p*
Pasty consistency (n = 27)	**0.30 (-1;1.33)**	**0.011**	**-0.25 (-2;0.66)**	**0.028**	-0.12 (-1;1.33)	0.142
Liquid consistency (n = 26)	0.19 (-1.33;1.33)	0.71	-0.20 (-1.33;1.66)	0.077	-0.07 (-1;1.33)	0.345
Solid consistency (n = 21)	0.09 (-1.66;1.33)	0.428	-0.10 (-1.66;1.66)	0.586	-0.07 (-1.33; 0.66)	0.444

Caption: Asthenia (A); Strain (S); Wet Voice (WV) parameter; median (interquartile range); $p<0.05$ (bold)

Table 3. Test validity measures for the auditory-perceptual aspects after swallowing of pasty consistency

Videofluoroscopy examination	Measurement	Auditory-perceptual assessment Pasty consistency postswallow		
		GP (%)	AP (%)	SP (%)
Food stasis in valleculae	Sensitivity	57	50	64
	Specificity	54	31	54
	Positive predictive value	57	44	60
	Negative predictive value	54	36	58
Food stasis in piriform recesses	Specificity	50	60	70
	Specificity	47	41	53
	Positive predictive value	36	37	41
	Negative predictive value	61	63	75
Laryngeal penetration	Specificity	40	80	80
	Specificity	45	45	50
	Positive predictive value	14	25	26
	Negative predictive value	76	90	91
Tracheal aspiration	Specificity	25	75	66
	Specificity	43	43	47
	Positive predictive value	7	18	26
	Negative predictive value	77	91	83

Caption: Dysphonia grade (G); Asthenia (A); Strain (S)

DISCUSSION

Postswallow voice modification has been highlighted as a parameter for detection of dysphagia during clinical evaluation. Nevertheless, few studies have been conducted aiming to identify the best method to perform this assessment and what its results objectively mean.

Previous studies that verified the use of wet voice for this purpose presented diverging results, considering that in one research group this parameter proved to be reliable to identify tracheal aspiration and laryngeal penetration[13], whereas in another group no correlation was found between these aspects[14]. In the present study, no significant modification of this measure was observed after swallowing in dysphagic individuals in a blinded assessment, demonstrating that wet voice is not a reliable parameter to identify individuals with swallowing disorders. Despite being a vocal parameter attributed to the postswallow phonation of dysphagic individuals, no definitions are found in the specific scientific literature regarding this vocal characteristic and, unlike other well-established vocal measures, such as those used in the dysphonia GRBAS scale, it does not present widely conducted auditory-perceptual training because of lack of studies demonstrating its real applicability[13]. In addition, postswallow voice modifications are perceived by raters as vocal changes commonly analyzed in the voice area, and not associated with the wet voice parameter[13,15]. In this study, it was possible to verify that this may be a reliable hypothesis, because the evaluators perceived a decrease in grade and an increase in strain after swallowing.

As previously mentioned, food stasis in the larynx causes changes in vocal fold mass that can affect effective phonation, altering vocal quality. The results presented in Tables 1 and 2 show that there was a significant change in dysphonia grade and asthenia, with decreases in these aspects and an increase in strain after swallowing. Thus, it is necessary to associate these aspects with deglutition characteristics indicative of swallowing disorder, as well as with objective videofluoroscopic examination data[16].

Dysphonia overall grade is an auditory-perceptual parameter associated with rater perception of the negative impact caused by the phonation assessed[12]. When associated with the parameters evaluated in the videofluoroscopic examination, this vocal parameter was a reasonable indicator of the presence of postswallow stasis in the valleculae and piriform recesses, with test validity measures of approximately 50%. This percentage indicates that this vocal parameter can identify approximately half the patients who truly present swallowing disorders[16].

It is believed that decreased dysphonia grade occurs because of attenuation of the glottal noise caused by food stasis along the vocal tract, which acts as a barrier that performs diffraction of the bass sounds that may originate form glottal noise[17]. Nevertheless, this vocal parameter was not very useful in identifying laryngeal penetration and tracheal aspiration, showing lower values of sensitivity and specificity. This fact can be explained because these aspects of swallowing disorder do not directly affect the overall vocal quality of individuals, considering that food stasis in these regions does not significantly change the vocal tract, and that vocal quality modification is perceived only when food is in direct contact with the vocal folds, generating a change in the vibration behavior as a function of alteration of the vocal fold mass[18,19]. Aiming to relate the data globally, the predictive values of this variable in relation to the aspects of laryngeal penetration and tracheal aspiration are analyzed together with the other variables.

With respect to postswallow phonation strain, it should be noted that during the auditory-perceptual evaluation the judges need to classify the voice as asthenic or strained according to their perception of phonatory effort[12]. The results obtained for presence of food stasis in the valleculae and piriform recesses were very similar to those observed for the variable overall dysphonia grade. Nevertheless, high percentages of sensitivity were observed for occurrence of laryngeal penetration (80%) and tracheal aspiration (66-75%), demonstrating that increased phonatory effort in the presence of food stasis, mainly within the laryngeal cavity or reaching the lower airways, is able to correctly identify individuals presenting these swallowing disorders, corroborating the findings on tracheal aspiration reported in a previous study[19], despite the risk of also identifying some individuals without these changes because of reasonable specificity, approximately 50%. It is believed that increased postswallow strain is associated with an attempt to maintain the usual phonation pattern, considering that food stasis causes an obstruction that prevents the normal passage of air during phonation[20]. It is worth noting that the sample of this study was predominantly composed of individuals with mild degree of oropharyngeal dysphagia and that this degree is not directly associated with modification of phonatory strain. Therefore, changes in strain caused by presence of prandial material can be observed even in cases of mild dysphagia, becoming a very useful way to identify dysphagia by the increase in phonation effort.

As for the predictive values obtained in the food stasis assessment tests, the data are very similar to the results found for sensitivity and specificity. Nevertheless, regarding the aspects of laryngeal penetration and tracheal aspiration, low positive predictive values are verified, because these aspects occur more seldom in the studied sample[21]. It is known that aspects of tracheal aspiration and laryngeal penetration present prevalence according to the underlying disease, being more frequent in neurological patients with influence of dysphagia severity[22], and are often observed in the more severe cases of alteration[23]. In this study, the participants were not divided according to cause and severity of dysphagia, which may be an aspect to be addressed in further works in order to better define the positive predictive value of these assessments. In spite of this, the three auditory-perceptual parameters presented good negative predictive values, that is, the decreases in overall grade and asthenia and the increase in strain show good identification indices for the proportion of individuals without laryngeal penetration and tracheal aspiration who do not present these aspects[21], corroborating a previous study that identified similar values of this aspect for overall dysphonia grade[15]. Thus, it is possible to verify that detection of dysphagia by voice variability is reliable in not indicating healthy individuals as individuals with disorders.

Although this study associates, for the first time in the literature, vocal production modification evaluated by the GRBAS scale with videofluoroscopy findings through test validity measures, it is worth noting that it presents some limitations. As previously discussed, the typology of dysphagia associated with its severity may have limited some outcomes, but showed good sensitivity indices and negative predictive values in both assessments. Moreover, the sample size was also small, which may have limited the scope of the analyses.

CONCLUSION

Postswallow voice data of the dysphagic individuals investigated in this study show significantly decreased dysphonia grade and asthenia and significantly increased strain, with no differences for the wet voice parameter. Regarding presence of stasis in the valleculae and piriform recesses, median test validity measures and negative predictive values were observed for the three parameters evaluated; however, good sensitivity results were identified, mainly with respect to phonation strain. Therefore, we conclude that postswallow vocal assessment presents good compatibility with videofluoroscopy findings.

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Author contributions

KWS, BS, ACM e MC contributed equally to the study design, collection and analysis of data, and writing of the manuscript.