Vocal Variability Post Swallowing in Individuals with and without Oropharyngeal Dysphagia

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Int Arch Otorhinolaryngol 2015;19:61–66.

Abstract

Introduction Voice modification after swallowing may indicate changes in the transit of the bolus.

Objective The aim of this study is to verify the use of perceptual voice analysis to detect oropharyngeal dysphagia.

Study Design Case series.

Methods Twenty-seven patients with dysphagia as diagnosed by videofluoroscopy and 25 without were evaluated. The sustained vowel /a/ was recorded before this exam and after swallowing different consistencies (pasty, liquid and solid). For the voice evaluation, the GRBAS scale (grade, roughness, breathiness, asthenia and strain) and the parameter "wet voice" were used. Three judges blinded to study group and time of emission performed voice analysis.

Results Individuals with dysphagia showed significant decrease in grade of voice and asthenia and increase in strain after swallowing pasty substances, differing from individuals without dysphagia who showed no modification of the parameters after swallowing. The wet voice parameter showed no difference after swallowing in both study groups.

Conclusion The decrease in grade and asthenia and increased strain are indicative of a swallowing disorder, indicating increased vocal strain to clean the vocal tract of food. The modification of vocal production after swallowing proved to be a trusted resource for detection of swallowing disorders.

Keywords
- deglutition disorders
- voice quality
- deglutition
- voice
- oropharyngeal dysphagia

Introduction

Swallowing, a stomatognathic function, is characterized by a complex mechanism that requires the involvement of many structures that must be coordinated to occur effectively. The main functional condition that needs to be considered is the ability to protect the lower airway through elevation, laryngeal closure and protective reflexes, such as coughing.[1] When starting the pharyngeal phase of swallowing, three events occur: laryngeal elevation through the contraction of the suprahyoid muscles; lowering of the epiglottis, which reduces the space of the laryngeal inlet; and vocal fold adduction, operating in glottal closure, which is an additional mechanism that reduces exposure of the lower airway.[1–3]

The main diagnostic method to evaluate swallowing dynamics is videofluoroscopy, also known as "videodeglutogram" or dynamic examination of swallowing. Considered the reference standard for evaluation and diagnosis of changes in this function, it consists of swallowing food with barium, allowing the visualization of the process by dynamic X-ray machine,

received
July 18, 2014
accepted after revision
September 5, 2014
published online
October 17, 2014

DOI http://dx.doi.org/10.1055/s-0034-1394129.
ISSN 1809-9777.

which shows the path traversed by the material swallowed. In this exam, the exact course taken by the food can be precisely identified, as well as the areas where the process does not occur efficiently; it is possible to view a deposit of contrasted material in places with changes in motility.[4,5]

Although videofluoroscopy is the standard for diagnosis, it is not easy to access for patients with swallowing disorders, besides having restrictions on its indication. Therefore, clinical evaluation is routinely used for detection of swallowing disorders and determination of treatment.[6,7] This method consists of several steps that, when taken together, describe the swallowing changes according to the characteristics presented by the patient, thus allowing the determination of therapeutics.[5,7,8]

One of the aspects considered in the clinical evaluation is laryngeal function, which requires assessment of the anatomical conditions of the region, evaluated by palpation and aspects of mobility and its functional capacity, evaluated by changes in vocal production after swallowing. Altered vocal production after swallowing has been considered a leading indicator of inefficiency of the process, because stasis of food in the laryngeal-pharyngeal cavity during swallowing is commonly observed in patients with dysphagia.[9,10] The presence of food in this region can alter the space of the vocal tract, modifying voice quality.[11] Although this parameter is routinely evaluated in clinical protocols, few studies have analyzed its reliability for detection of dysphagia, indicating possible bias of this method when indicating a change in swallowing. Moreover, studies do not compare voices of individuals with and without swallowing disorders, which could determine whether this modification can actually be attributed to a disturbance of this function or it occurs for all subjects immediately after swallowing.

This study aimed to: (1) investigate the reliability of the protocol used; (2) check whether significant change occurs in the perceptual assessment of voice after swallowing in individuals with oropharyngeal dysphagia; and (3) compare significant changes related to voice quality in the group with dysphagia compared with the control group.

Methods

Design and Sample

This study presents a descriptive cross-sectional prospective comparison between subjects with and subjects without oropharyngeal dysphagia aiming to verify changes of voice production after swallowing. The study was approved by the Ethics Research Committee under protocol 293.856.

Men and women 18 years or older capable of continuous voice production for at least 4 seconds and swallowing at least one of the consistencies in the evaluation (pasty, liquid and solid) were included. The study sample was divided into two groups: individuals with (G1) and individuals without (G2) oropharyngeal dysphagia. Subjects who were diagnosed with swallowing disorder by videofluoroscopy composed G1 and were stratified according to the score in the dysphagia severity scale from 1 to 5, signifying severe to discrete dysphagia. Individuals in G2 showed no swallowing disorders and scored 7 on the scale used, compatible with normality.[12] Pairing by sex and age was performed, with a difference of up to 5 years between pairs. Individuals with tracheostomy, organic-functional and organic vocal fold lesions, or injury of laryngeal nerves causing vocal fold paralysis were excluded. Subjects who had surgical removal of tumor and tissues involved in the swallowing process and all those individuals cognitively unable to respond to the protocol were also excluded.

Fifty-two individuals, 27 (14 men and 13 women) in G1 and 25 (12 men and 13 women) in G2, were evaluated, with mean ages of 71.07 for men and 76.69 for women in the first group and 68.05 and 78.53, respectively, in the second group. The evaluations performed yielded 201 vocal recordings, including 101 in G1 and 100 in G2. The difference in the number of recordings between groups was due the greater number of subjects in G1; the number of recordings was also less than expected due to the impossibility of evaluating some consistencies due to limitations of bolus preparation and oropharyngeal dysphagia.

Procedures

All study participants underwent evaluation of vocal production before and after a sequence of swallows during videofluoroscopy, using three consistencies of foods evaluated in the following order: pasty, liquid and solid. For the recording of vocal productions, the digital recorder DVR-Powerpack 576.BK (Powerpack, China) with external microphone was used. Before the exam, subjects were asked to perform a deep inspiration followed by emission of vowel /a/ in the usual tone of voice; if the emission lasted at least 4 seconds, it was considered valid. The same instructions were made for evaluations performed after swallowing each food consistency tested in the exam.

Videofluoroscopy

Videofluoroscopy examinations were performed with the Siemens Axion Iconos R100 fluoroscopy (Siemens, USA) model coupled to an image recording system in a computer, which allows further detailed analysis of the exam. During the examination, subjects remained seated and images were captured in the lateral and anteroposterior positions, with upper and lower limits ranging from the oral cavity to the stomach.

The examinations were performed by evaluating pasty, liquid and solid consistencies prepared, respectively, as follows: yogurt-type petit suisse with liquid barium (Bariogel®, Brazil) at a ratio of 1:1 (20 mL of yogurt to 20 mL of barium); distilled water with liquid barium (Bariogel®) at a ratio of 1:1 (40 mL of water to 40 mL of barium); and bread soaked in liquid barium (Bariogel®).

Based on the dysphagia severity scale,[12] the degree of dysphagia was determined on each subject and used to allocate subjects into their study groups. Individuals with functional swallowing (a score 6 on the scale) were excluded because they were considered to have neither normal swallowing nor dysphagia, which could compromise data analysis. The examination data were only used to include subjects in

Table 1 Compatibility between judges in the application of GRBAS scale and wet voice at each moment of evaluation

Moment of evaluation	Number of items evaluated	Cronbach's alpha
Before swallowing	6	0.898
After swallowing pasty food	6	0.882
After swallowing liquid food	6	0.872
After swallowing solid food	6	0.863

each study group and will not be described in detail here. Nevertheless, it should be noted that 18 (66.6%) subjects had grade 5 dysphagia, 5 (18.51%) had grade 4, 1 (3.70%) had grade 3, 3 (11%) had grade 2 and 0 (0%) had grade 1, demonstrating that the majority of the sample had mild to moderate oropharyngeal dysphagia.

Perceptual Analysis of Vocal Quality

At the end of data collection, voice recordings were given to three judges with clinical experience in voice analysis and evaluation of swallowing. The perceptual analysis was classified using the GRBAS scale (grade, roughness, breathiness, asthenia and strain).[13] The three judges received an instructional guide with the objectives and procedures of analysis to be performed. Values were assigned on a scale from 0 to 3 (no change, mild alteration, moderate alteration and severe alteration, respectively) to the parameters described in the protocol. In addition, the wet voice feature was included in perceptual assessment because it is commonly attributed to the vocal production of individuals with dysphagia after swallowing. The judges were blinded to the information and evaluation results of patients. Moreover, they were not informed about which recordings occurred before or after swallowing or to the subject's study group to maintain the reliability of the data and to not influence these aspects in the analysis. The recordings were sent in stages, with each stage not containing more than one recording of each subject, so evaluators could not compare samples.

Statistics

The data collected were analyzed using descriptive statistics and statistical tests, arranged in tables. The Kolmogorov-Smirnov test was used to test the normality of the data. To measure the reliability of the protocol used, we applied Cronbach's alpha to measure the correlation between judges. Moreover, the means of the results obtained from the judges for each variable evaluated were calculated. The comparison of the voice emission before and after swallowing of each consistency was performed using the *t* test for paired samples for variables with normal distribution and the Wilcoxon *U* test for variables with non-normal distribution. Maximum level of significance of 5% was adopted and the statistical software used for data analysis was SPSS version 20.0.

Results

►**Table 1** shows the reliability of the protocol used, GRBAS scale and wet voice in various stages of evaluation by the three judges. Cronbach's alpha coefficient demonstrated a good correlation between the answers provided by evaluators for all times.

►**Table 2** shows a significant decrease only in the voice grade after swallowing pasty food and ►**Table 3** demonstrates a significant decrease in the aspect of asthenia and increased strain after swallowing pasty food in individuals with oropharyngeal dysphagia.

►**Table 4** presents the data before and after swallowing on the G2 of variables with significant vocal change in the G1. Through the Wilcoxon *U* test, a statistical difference in voice modification after swallowing was not observed in G2.

Table 2 Emission before and after swallowing of each consistency in individuals with oropharyngeal dysphagia (Student *t* test)

	G		R		B	
	Mean	SD	Mean	SD	Mean	SD
Before swallowing	1.98	0.75	1.55	0.78	0.87	0.77
After swallowing pasty food ($n = 27$)	1.77	0.69	1.38	0.7	0.87	72
p	0.008[a]		0.134		> 0.999	
Before swallowing	1.94	0,074	1.51	0.77	0.84	0.73
After swallowing liquid food ($n = 26$)	1.8	0.54	1.61	0.52	0.84	0.65
p	0.146		0.439		> 0.999	
Before swallowing	1.93	0.68	1.44	0.74	0.84	0.74
After swallowing solid food ($n = 21$)	1.79	0.49	1.52	0.58	0.85	0.7
p	0.267		0.581		0.928	

Abbreviations: B, breathiness; G, grade; R, roughness; SD, standard deviation.
[a]$p < 0.05$.

Table 3 Emission before and after swallowing of each consistency in individuals with oropharyngeal dysphagia (Wilcoxon *U* test)

	A		S		Wet voice	
	Median	IR	Median	IR	Median	IR
Before swallowing	0.66	0–2.3	0.66	0–2	0.3	0–2
After swallowing pasty food ($n = 27$)	0	0–1.6	0.66	0–2.3	0.33	0–1.3
p	0.011[a]		0.028[a]		0.142	
Before swallowing	0.66	0–2.3	0.5	0–2	0.16	0–1.3
After swallowing liquid food ($n = 26$)	0	0–2	0.33	0–2.3	0.33	0–1.3
p	0.71		0.077		0.345	
Before swallowing	0	0–1	0.3	0–2	0.3	0–1.3
After swallowing solid food ($n = 21$)	0.33	0–2	0.33	0–2.6	0.33	0–1.3
p	0.428		0.586		0.444	

Abbreviations: A, asthenia; IR, interquartile range; S, strain.
[a]$p < 0.05$.

Discussion

The same anatomical structures are involved in phonation and swallowing, especially in the laryngeal region, which is responsible for the main execution of these functions [14]. Some studies have been conducted to identify vocal parameters that can contribute to detection of oropharyngeal dysphagia.[11,14–16]

Vocal production is initiated by the exhalation of air, which passes through the vocal folds in adduction position, producing a sound that is modified by the vocal tract that features the voice of each individual. The length and diameter of the vocal tract, ranging from the vocal folds to the nasal cavity, the placement of structures, such as the tongue and lips, as well as the permeability of the paranasal sinuses modify the sound produced by the vocal folds, making the voice of each person unique due to anatomical peculiarities.[17,18] Thus, anatomical or functional modifications in these structures, as well as the presence of food in the pharyngolaryngeal cavity in cases of oropharyngeal dysphagia, can lead to perceptual changes in the usual voice.[11,18]

The results of this study helped confirm that perceptual parameters commonly evaluated for vocal characterization may vary after swallowing in individuals with oropharyngeal dysphagia. This is not observed in subjects without this change, which is of fundamental importance in clinical applicability.[19] Furthermore, judges were compatible on the assignment of the observed features, as shown in ►**Table 1**. Perceptual analysis needs to have high compatibility in intra- and interevaluators so that the data are reliable compared with the real vocal production.[20] The scale used for perceptual analysis in this study is often by professionals that work in the voice area and has shown fairly consistent applicability by independent evaluators, allowing greater reliability between results obtained in this study.[13,21] A proviso should be made for the wet voice parameter added to the protocol in this study, which will be discussed later.

Voice grade depends on the perception of the evaluator and consequently, previous experiences in voice analysis is necessary to assign a gravity score based on a set of vocal characteristics perceived as variations of normality.[13,21] The

Table 4 Emission before and after swallowing of each consistency in group 2 (Wilcoxon *U* test)

	G		A		S	
	Median	IR	Median	IR	Median	IR
Before swallowing	0.66	0.3–2.3	0	0–1	0.33	0 to 2.3
After swallowing pasty food ($n = 25$)	1	0–2	0	0 to 0.6	0.33	0–2
p	0.357		0.803		0.101	
Before swallowing	0.6	0.3–2.3	0	0–1	0.3	0–2.3
After swallowing liquid food ($n = 25$)	1	0.3–2.3	0	0–1	0.3	0–2.3
p	0.406		0.167		0.439	
Before swallowing	0.6	0.3–2.3	0	0–1	0.3	0–2.3
After swallowing solid food ($n = 25$)	0.6	0.3–2	0	0–1	0.3	0–1.6
p	0.646		0.428		0.586	

Abbreviations: A, asthenia; G, grade; IR, interquartile range; S, strain.

use of this parameter in the evaluation of dysphagia allowed the identification of changes in the oropharyngeal transit of pasty food, with a decrease in severity of grade, even in a blinded analysis. It was noted that this modification only occurs for this consistency and was not modified for other consistencies evaluated. The viscosity of the pasty food permits it to adhere to the pharyngolaryngeal structures when there are changes in motility, as observed in imaging studies.[22,23] The presence of food in the pharyngolaryngeal cavity acts as a voice modifier and changes voice characteristics during the sound passage produced by the vocal folds over the vocal tract. The obstruction at any point in the vocal tract, as commonly accomplished by the lips and tongue during speech, changes the formants that compose the voice, giving more bass or treble according to the position of these structures.[18,24] Thus, the stasis of pasty food modified speech and decreased the aspects considered not normal and reduced the evaluator's perception of the grade of alteration, which can be associated with changes in the sound wave caused by the presence of food.[11] Nevertheless, the changes related to swallowing liquids and solids are not able to change this perception. The consumption of liquid is a beneficial resource for vocal production as it reduces the salivary viscosity and decreases dryness of the tract after long-term use, with little immediate benefits perceived aurally.[25] In case of change in motility for this consistency, no impact occurs on the voice after swallowing when there is no adherence of the material in the tract modifying the passage of sound. So as observed in a previous study, the use of liquid food for voice variability evaluation after swallowing shows little sensitivity because there is no immediately perceptible voice modification even in cases of tracheal aspiration.[16] In solid swallowing, it is believed that this change will not occur once the food causes a mechanical obstruction, leading to discomfort due to prolonged transit time of food, which affects effective breathing; phonation is performed only when there is clearance of the tract after conducting multiple swallows,[26,27] as observed in the tests performed.

Beyond the modification of voice grade, the parameters of vocal effort also changed after swallowing. During the perceptual analysis, the judges characterized the voice by assigning a marker of vocal effort, either asthenia or strain.[13,21] Individuals with vocal asthenia showed a decrease in this aspect after swallowing, consequently verifying higher strain; those who already had vocal strain had an increase of this parameter. The vocal strain is caused by the increased resistance of the vocal tract during passage of expiratory air, performed in an attempt to compensate for structural changes or a lack of balance between air and vocal muscle use during phonation, with excessive muscular effort during emission.[18,28] This effort also occurs during coughing, when the muscles contract abruptly to expel a foreign body.[29] When there is food residue in the tract, phonation occurs with more effort to keep the usual voice pattern, because the food causes obstruction, demonstrating that the increased vocal strain is associated with the attempt to maintain a normal pattern of speech and withdrawing food deposited in the tract.[11,14]

Although there is scarce literature about the use of voice modifications to evaluate dysphagia, it is based primarily on clinical identification of the presence of wet voice after swallowing.[30,31] Although commonly described as being a characteristic of voice in which there is a change in the usual pattern after swallowing, no features describe this variability in the literature, as opposed to the concepts of other vocal classifications observed.[11,16,21] This aspect complicates the standardization of analyses made by professionals in the area, because it involves subjective characterization with little scientific background. No significant change in this parameter before and after swallowing was observed in this study. As discussed in previous studies, this vocal characterization is sensitive and it is not always possible to identify individuals with alterations; the subjectivity and lack of standardization cause poor reproducibility between evaluators, reflecting a poor diagnostic prediction for dysphagia.[11,16]

Despite the important findings presented in this study, it is necessary to point out some limitations, among them, the sample size. Other authors who studied this method of evaluation also had this same difficulty concerning the limitations of the patients, because participation and integrity of oropharyngeal structures are necessary. In addition, the use of gold standard methods for evaluation are restricted to individuals who have conditions to accomplish such evaluation.[11,14–16] Even with this limitation, the results corroborate previous studies and demonstrate that this method of evaluation shows specificity to differentiate individuals without swallowing disorder.[16,31]

Further studies should be conducted to confirm our data to better standardize the use of voice assessment as a method of identification for oropharyngeal dysphagia. Other data obtained from this same sample demonstrating the use of parameters of vocal self-perception, acoustic voice analysis and comparison between voice modifications and videofluoroscopic examination will be presented in other publications to probe studies in this area.

Conclusion

Based on the data presented in this study, after swallowing pasty food, individuals with dysphagia decreased the grade of vocal alteration and increased strain, with no change in these vocal parameters for individuals without swallowing disorder, demonstrating its specificity for clinical use in the detection of oropharyngeal dysphagia. Nevertheless, the use of the wet voice parameter was not found to contribute to indicating this disorder, requiring further studies and standardization like other vocal parameters used in this study to allow a reliable evaluation for clinical applicability.

References

1 Pitts T, Rose MJ, Mortensen AN, et al. Coordination of cough and swallow: a meta-behavioral response to aspiration. Respir Physiol Neurobiol 2013;189(3):543–551

2 Hadley AJ, Kolb I, Tyler DJ. Laryngeal elevation by selective stimulation of the hypoglossal nerve. J Neural Eng 2013;10(4):046013
3 Pearson WG Jr, Hindson DF, Langmore SE, Zumwalt AC. Evaluating swallowing muscles essential for hyolaryngeal elevation by using muscle functional magnetic resonance imaging. Int J Radiat Oncol Biol Phys 2013;85(3):735–740
4 Wang J, Li WY, Zhang ZH, et al. [Assessment of dysphagia: report of 37 cases]. Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi 2012; 47(11):889–893
5 American Speech-Language-Hearing Association. Guidelines for speech-language pathologists performing videofluoroscopic swallowing studies. 2004. Available at: http://www.asha.org/policy/GL2004-00050/. Accessed April 28, 2014
6 Titsworth WL, Abram J, Fullerton A, et al. Prospective quality initiative to maximize dysphagia screening reduces hospital-acquired pneumonia prevalence in patients with stroke. Stroke 2013;44(11):3154–3160
7 Ko MJ, Kang MJ, Ko KJ, Ki YO, Chang HJ, Kwon JY. Clinical usefulness of Schedule for Oral-Motor Assessment (SOMA) in children with dysphagia. Ann Rehabil Med 2011;35(4):477–484
8 Kjaersgaard A, Nielsen LH, Sjölund BH. Randomized trial of two swallowing assessment approaches in patients with acquired brain injury: facial-oral tract therapy versus fibreoptic endoscopic evaluation of swallowing. Clin Rehabil 2014;28(3):243–253
9 Padovani AR, Moraes DP, Mangili LD, Andrade CRF. Protocolo Fonoaudiológico de Avaliação do Risco para Disfagia (PARD). Rev Soc Bras Fonoaudiol. 2007;2(3):199–205
10 Daniels SK, Anderson JA, Willson PC. Valid items for screening dysphagia risk in patients with stroke: a systematic review. Stroke 2012;43(3):892–897
11 Groves-Wright KJ, Boyce S, Kelchner L. Perception of wet vocal quality in identifying penetration/aspiration during swallowing. J Speech Lang Hear Res 2010;53(3):620–632
12 O'Neil KH, Purdy M, Falk J, Gallo L. The dysphagia outcome and severity scale. Dysphagia 1999;14(3):139–145
13 Hirano M. Clinical Examination of Voice. New York, NY: Springer-Verlag; 1981
14 Malandraki GA, Hind JA, Gangnon R, Logemann JA, Robbins J. The utility of pitch elevation in the evaluation of oropharyngeal dysphagia: preliminary findings. Am J Speech Lang Pathol 2011; 20(4):262–268
15 Warms T, Richards J. "Wet voice" as a predictor of penetration and aspiration in oropharyngeal dysphagia. Dysphagia 2000;15(2):84–88
16 Waito A, Bailey GL, Molfenter SM, Zoratto DC, Steele CM. Voice-quality abnormalities as a sign of dysphagia: validation against acoustic and videofluoroscopic data. Dysphagia 2011;26(2):125–134
17 Cleveland TF. A clearer view of singing voice production: 25 years of progress. J Voice 1994;8(1):18–23
18. Behlau M. Voz: o livro do especialista. Vol. 2. Rio de Janeiro, Brazil: Revinter; 2008
19 Rouquayrol MZ, Almeira N. Epidemiologia e Saúde. Rio de Janeiro, Brazil: Medsi; 2000
20 Kreiman J, Gerratt BR, Kempster GB, Erman A, Berke GS. Perceptual evaluation of voice quality: review, tutorial, and a framework for future research. J Speech Hear Res 1993;36(1):21–40
21. Behlau M. Voz: o livro do especialista. Vol. 1. Rio de Janeiro, Brazil: Revinter; 2001
22 Dantas RO, Dodds WJ. Influência da viscosidade do bolo alimentar deglutido na motilidade da faringe. Arq Gastroenterol 1990;27(4): 164–168
23 Prodomo LPV. Caracterização videofluoroscópica da fase faríngea da deglutição [dissertation]. Fundação Antonio Prudente: São Paulo; 2010
24 Sundberg J. Perception of singing. STL-QPSR 1979;20(1):1–48
25 Fujita R, Ferreira AE, Sarkovas C. Avaliação videoquimográfica da vibração de pregas vocais no pré e pós hidratação. Rev Bras Otorrinolaringol (Engl Ed) 2004;70(6):742–746
26 Vivone GP, Tavares MMM, Bartolomeu RS, Nemr K, Chiappetta ALML. Análise da consistência alimentar e tempo de deglutição em crianças com paralisia cerebral tetraplégica espástica. Rev CEFAC 2007;9(4):504–511
27 Moro ET. Prevenção da aspiração pulmonar do conteúdo gástrico. Rev Bras Anestesiol 2004;54(2):261–275
28 Koishi HU, Tsuji DH, Imamura R, Sennes LU. Variação da intensidade vocal: estudo da vibração das pregas vocais em seres humanos com videoquimografia. Rev Bras Otorrinolaringol (Engl Ed) 2003;69(4):464–470
29 Gibson PG, Vertigan AE. Speech pathology for chronic cough: a new approach. Pulm Pharmacol Ther 2009;22(2):159–162
30 Murugappan S, Boyce S, Khosla S, Kelchner L, Gutmark E. Acoustic characteristics of phonation in "wet voice" conditions. J Acoust Soc Am 2010;127(4):2578–2589
31 Ryu JS, Park SR, Choi KH. Prediction of laryngeal aspiration using voice analysis. Am J Phys Med Rehabil 2004;83(10):753–757