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ORIGINAL ARTICLE

Correlation Between Laryngeal Sensitivity and Penetration/Aspiration After Stroke

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Abstract Stroke is the most common neurological disease in adults that is associated with deglutition disorders. The presence of laryngeal sensitivity is very important in developing safe swallowing without risk of pulmonary complications. The aim of this study was to correlate laryngeal sensitivity with laryngeal penetration and tracheal aspiration after swallows of three food consistencies (puree, thickened liquid, and liquid) in poststroke individuals in the late phase. A cross-sectional clinical study was performed with 91 post-ischemic stroke individuals, with oropharyngeal dysphagia, who were in rehabilitation center treatment from 2009 to 2011. They had a mean age of 68.1 years and average time since injury was 22.6 months; 39 had injury to the right hemisphere and 52 had injury to the left hemisphere. All underwent fiberoptic endoscopic evaluation of swallowing and evaluation of laryngeal sensitivity by touching the tip of the endoscope to the arytenoids and aryepiglottic folds. The linear correlation coefficient of Spearman was applied to evaluate the correlation between laryngeal penetration and tracheal aspiration and the presence/absence of laryngeal sensitivity. There was a negative correlation between the observation of penetration and tracheal aspiration and laryngeal sensitivity, with all bolus consistencies ($p < 0.001$ for aspiration and $p \leq 0.01$ for penetration). The absence of laryngeal sensitivity determines the more frequent findings of penetration and tracheal aspiration. This sensory stimulus in the mucosa of the pharynx and larynx is an essential element for safe swallowing and its deficiency associated with altered motor activity can cause laryngeal penetration and aspiration in poststroke individuals regardless of food consistency.

Keywords Deglutition disorders · Stroke · Fiberoptic endoscopic evaluation of swallowing

Introduction

Oropharyngeal dysphagia is often present during the acute phase of stroke. Incidence varies from 22 to 70 %, and according to systematic review, it is around 55 % in the acute phase, causing an increased frequency of pneumonia in poststroke adults [1–4]. Incidence can vary depending on the criteria used to define dysphagia, such as assessment methods, size and location of the injury, and the time of disease involvement [1, 3, 5]. Swallowing disorders in poststroke individuals may disappear within days to weeks, but there are few studies and little information on those patients who have not shown spontaneous improvement of oropharyngeal dysphagia following the acute phase of stroke [1, 6, 7].

The accuracy of isolated clinical evaluation of dysphagia has been questioned due to the varied sensitivity and specificity data produced [8, 9]. Currently, two methods are used to accurately determine the presence of penetration or aspiration of food in the lower airways: videofluoroscopy, considered the gold standard in assessment, or fiberoptic

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endoscopic evaluation of swallowing (FEES), which, in addition to eliminating the exposure to radiation, is the only method that allows the evaluation of sensitivity in the pharynx and larynx.

The integrity of laryngeal sensitivity in the context of oropharyngeal swallowing was studied in healthy adults [10] and dysphagic individuals with diverse etiologies, confirming that there is more tracheal aspiration, laryngeal penetration, the presence of residues in the pharynx, and premature escape among those with severe sensitivity deficiency than in the moderate to no deficiency group [11, 12]. Moreover, specifically in acute poststroke patients, the authors observed deficiencies in unilateral or bilateral laryngeal sensitivity [13]. Despite studies showing changes in sensitivity in poststroke individuals, the evaluations generally are performed when the patient is in the acute phase of the disease and they are done from various brain regions, with no information on how the variation in sensitivity can interfere with penetration and aspiration. Moreover, the endoscope adapted with an air pulse is used to test the sensitivity [11], and such equipment is not always available in diagnostic and dysphagia rehabilitation centers.

The studies in the literature that have investigated laryngeal sensitivity in the acute stroke population do not show any data on these individuals after the acute phase. Our hypothesis is that sensory deficit continues even after the acute phase. Some individuals have not shown spontaneous improvement and this could contribute to penetration and aspiration independent of the motor component. Thus, to investigate the influence of laryngeal sensitivity in the swallowing of different food consistencies, this study aimed to correlate laryngeal sensitivity to laryngeal penetration and tracheal aspiration in poststroke individuals in the late phase.

Materials and Methods

Participants

The study gathered 91 supratentorial ischemic poststroke adults in treatment for oropharyngeal dysphagia in a rehabilitation center from 2009 to 2011. All had signs or symptoms of oropharyngeal dysphagia and the diagnosis of stroke from clinical and radiological imaging (computed tomography or magnetic resonance imaging). There were 41 females and 50 males, and the age range was 43–92 years (mean age = 68.1 years). The time of disease onset until assessment ranged from 2 to 192 months (mean = 22.6 months). Thirty-nine had injury to the right hemisphere and 52 had injury to the left hemisphere.

Individuals with brainstem stroke, other neurological diseases associated with stroke, diseases in the head and neck, and gastroenterological disorders that could affect swallowing, those using an orotracheal tube for mechanical ventilation, or those with a compromised level of consciousness that could jeopardize the procedures were excluded from the study. All participants agreed to and signed the consent form. The research protocol was approved by the Ethics Committee in Research Institution under protocol 0177/2009.

Data Collection

All patients underwent FEES administered by the same ENT doctor and accompanied by a speech language therapist. A Pentax® endoscope (model FNL 10RP3) coupled to a Pentax microcamera system (model PSV4000) and a Pentax light source (model LH-150 PC) was used. All examinations were stored on DVD media using a Samsung® DVD burner (model DVD R150). For the exam, the individual was instructed to sit upright in a chair or the ENT examination chair. The head was positioned in the anterior direction without flexion or rotation, as generally occurs in the act of eating. The endoscope was introduced via the more patent nostril; no topical anesthetic or vasoconstrictor was used in the nostrils or oropharynx to avoid changes in local sensitivity.

Laryngeal Assessment

Laryngeal sensitivity was tested by touching the distal tip of the endoscope to the arytenoids and bilateral aryepiglottic folds, as proposed by researchers [14]. This test was performed three times on each side on all individuals. The results of sensitivity analysis were classified as bilateral presence, unilateral presence, or bilateral absence.

A sensitivity analysis was performed after the exam by two evaluators: the ENT doctor that performed the exam and the speech language therapist with several years of experience in the area of dysphagia. They analyzed the images on the DVD individually and then compared their results. It is noteworthy that the evaluators at that time did not know the FEES test result. Only individuals whose exams the observers agreed upon were included. An intraobserver study was not conducted. Laryngeal sensitivity was considered present when cough reflex or vocal fold movement during adduction occurred on the side tested. There was a lack of sensitivity when neither of these two events occurred.

Swallowing Assessment

For the functional assessment of swallowing, 5-ml boluses of puree, thickened liquid, and liquid were used in this study. All subjects received the puree bolus. Thickened

liquid bolus was offered only when the patient did not aspirate the puree. Liquid consistency was offered only when there was the possibility of swallowing the thickened liquid.

Pear-flavored dietetic juice at room temperature and an instant food thickener, consisting of modified corn starch and maltodextrin containing (per 100 g) 373 kcal of calories, 92.6 g of carbohydrates, and 174 mg of sodium, were used to make the boluses. To prepare the thickened liquid, we used 1 tbsp. of thickener (4.5 g) in 100 ml of liquid, and for the puree we used 1.5 tbsp. (6.75 g) in 100 ml of liquid. Artificial blue food dye was added to the food to facilitate seeing the food in the pharyngeal region. There was laryngeal penetration when contrasted food was seen in the laryngeal vestibule region above the vocal folds, and there was tracheal aspiration when contrasted food was seen on and/or below the free edges of the vocal folds [10, 14, 15].

If an individual was using a feeding tube, the tube was not removed during the procedure.

Statistical Analysis

The agreement analysis of interobserver sensitivity was performed using the Kappa test, which measures the degree of agreement beyond what would be expected solely by chance. This measure of agreement ranges from 1 (complete agreement) to 0 (chance agreement). To study the correlation among the variables in laryngeal sensitivity, penetration, and aspiration with the three different food consistencies (puree, thickened liquid, and liquid), Spearman's linear correlation coefficient from STATISTICA software ver. 7.0 (StatSoft, Inc., Tulsa, OK) was used. The level of significance was 0.05.

Results

Interobserver sensitivity was observed in all but two individuals during evaluation so they were removed from the sample; the Kappa index was 0.969 and $p < 0.001$.

There were two cases of unilateral and left vocal fold paralysis. These individuals presented abnormal sensitivity of the larynx, one with unilateral change in sensitivity and the other with absence of bilateral sensitivity. It was observed that puree food was offered only in the absence of bilateral sensitivity, and because of aspiration, it was not possible to test other consistencies. The individual with unilateral alteration of sensitivity showed no penetration or aspiration with any consistency.

All 91 individuals received the puree bolus. Penetration was observed in 9/17 (52.9 %) individuals who had absence of bilateral sensitivity, in 6/27 (22.2 %) individuals with the presence of unilateral sensitivity, and in 4/47 (8.5 %) individuals with the presence of bilateral sensitivity. Aspiration was observed in 6/17 (35.3 %) individuals with absence of bilateral sensitivity, in 4/27 (14.8 %) individuals with the presence of unilateral sensitivity, and in only 2/47 (4.3 %) individuals with the presence of bilateral sensitivity. Laryngeal penetration and aspiration with the puree were seen more frequently when laryngeal sensitivity was worse, as demonstrated by negative and statistically significant values of Spearman's correlation ($p < 0.001$), according to Table 1.

In our sample, 86 (94.5 %) individuals received thickened liquid bolus. Penetration was observed in 9/14 (64.3 %) of the individuals with absence of bilateral sensitivity, in 5/25 (20 %) of the individuals with the presence of unilateral sensitivity, and in 6/47 (12.8 %) individuals with the presence of bilateral sensitivity. Aspiration was observed in 7/14 (50 %) of the individuals with absence of bilateral sensitivity, 3/25 (12 %) individuals with the presence of unilateral sensitivity, and only 2/47 (4.3 %) individuals with the presence of bilateral sensitivity. Laryngeal penetration and aspiration with the thickened liquid were seen more frequently when laryngeal sensitivity was worse, according to the negative and statistically significant values of Spearman's correlation ($p < 0.001$), as seen in Table 2.

Liquid bolus was offered to only 81 (89 %) individuals. Penetration was observed in 7/11 (63.6 %) individuals with absence of bilateral sensitivity, 6/23 (26 %) individuals with the presence of unilateral sensitivity, and 10/47 (21.3 %) individuals with the presence of bilateral sensitivity. Aspiration was observed in 7/11 (63.6 %) individuals with absence of bilateral sensitivity, 5/23 (21.7 %) individuals with the presence of unilateral sensitivity, and only 7/47 (14.9 %) individuals with the presence of bilateral sensitivity. Liquid bolus also correlated with negative and statistically significant values ($p = 0.01$ for penetration and $p < 0.001$ for aspiration) and, laryngeal penetration and tracheal aspiration with liquid were seen more frequently when laryngeal sensitivity was worse, as seen in Table 3.

The frequencies of penetration and aspiration in this study, according to the classification of sensitivity (bilateral presence, unilateral presence, and bilateral absence) with different food consistencies, are shown in Figs. 1 and 2.

Discussion

Swallowing is a process characterized by a succession of interrelated phenomena involving the activation of different neural circuits and the afferent and efferent pathways. During swallowing, there is the involvement of areas such as the cortex, brainstem, cerebellum, the nucleus ambiguus,

Table 1 Correlation between laryngeal sensitivity and penetration/aspiration in puree consistency ($n = 91$)

Findings	Sensitivity				p value
	Bilateral absence ($n = 17$)	Unilateral presence ($n = 27$)	Bilateral presence ($n = 47$)	Spearman's coefficient (r_s)	
Penetration	9 (52.9 %)	6 (22.2 %)	4 (8.5 %)	−0.39	<0.001
Aspiration	6 (35.3 %)	4 (14.8 %)	2 (4.3 %)	−0.34	<0.001

Table 2 Correlation between laryngeal sensitivity and penetration/aspiration in thickened liquid consistency ($n = 86$)

Endoscopic findings	Sensitivity				p value
	Bilateral absence ($n = 14$)	Unilateral presence ($n = 25$)	Bilateral presence ($n = 47$)	Spearman's coefficient (r_s)	
Penetration	9 (64.3 %)	5 (20 %)	6 (12.8 %)	−0.39	<0.001
Aspiration	7 (50 %)	3 (12 %)	2 (4.3 %)	−0.43	<0.001

Table 3 Correlation between laryngeal sensitivity and penetration/aspiration in liquid consistency ($n = 81$)

Endoscopic findings	Sensitivity				p value
	Bilateral absence ($n = 11$)	Unilateral presence ($n = 23$)	Bilateral presence ($n = 47$)	Spearman's coefficient (r_s)	
Penetration	7 (63.6 %)	6 (26 %)	10 (21.3 %)	−0.27	0.01
Aspiration	7 (63.6 %)	5 (21.7 %)	7 (14.9 %)	−0.34	<0.001

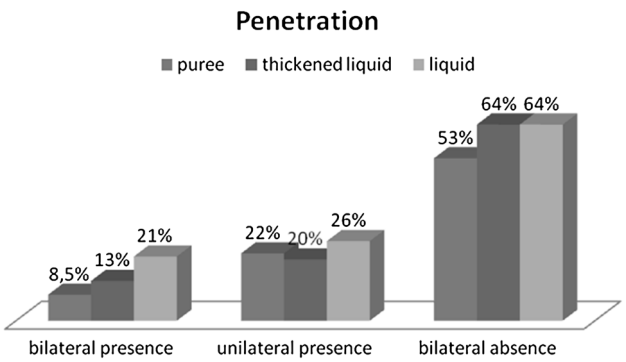

Fig. 1 Distribution of penetration frequency in relation to sensitivity in the diverse food consistencies offered

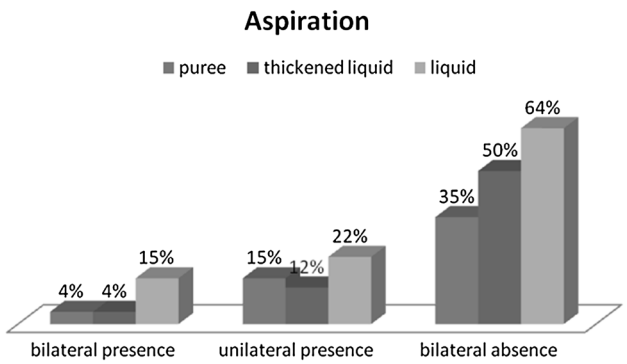

Fig. 2 Distribution of aspiration frequency in relation to sensitivity in the diverse food consistencies offered

the nucleus of the solitary tract, and reticular formation, which are essential for triggering this process synchronously [16, 17]. Human swallowing is a complex and coordinated function, highly dependent on afferent sensory information to start the process. A deficiency of information is one of the major causes of dysphagia in poststroke individuals [18].

Changes in the sensitivity of the oropharynx and larynx are easily evaluated by FEES, thus, not requiring specifically adapted endoscopes with an air pulse, as described in the literature [11]. Currently, the objective examination of swallowing varies among the services that work with dysphagic patients in centers that integrate multidisciplinary teams, especially those with otolaryngologists able to handle endoscopy.

This study was designed to investigate the possible correlation between laryngeal sensitivity and tracheal penetration/aspiration in those who experienced stroke that is no longer in its acute phase. In individuals who have a stroke, one or more of the above-mentioned circuits has been interfered with, resulting in alterations of sensory information and/or motor control structures involved in swallowing, thus characterizing the etiology of dysphagic framework.

According to our results it can be stated that a change in sensitivity determined a greater occurrence of tracheal

penetration and aspiration with all tested food types, but the presence of laryngeal sensitivity decreased the incidence of penetration and aspiration. The importance of sensitivity in swallowing has been thoroughly investigated by various authors. A previous study showed that moderate to severe laryngeal sensory impairment occurred in all dysphagic poststroke patients in the acute phase [13]. The sensitivity of the larynx may even remain impaired until the late phase of stroke, as observed in our sample.

FEES begins with the patient taking a puree bolus and the consistency and volume of the bolus increase in difficulty for the patient; thus, not all individuals receive all food consistencies, as in our study. Similar findings are cited by other authors who applied the minimal risk protocol [11, 19]. Increased consistency or viscosity of the bolus improves the swallowing function in patients with neurogenic dysphagia [20].

There is clinical evidence demonstrating that the decreased laryngeal sensitivity is relevant in the occurrence of penetration and aspiration. Individuals who have had their larynx topically anesthetized more often presented premature escape, residues, tracheal penetration, and aspiration with liquid and pureed consistencies [10]. However, it should be noted that dysfunction of oropharyngeal motor activities, such as the failure of laryngeal elevation, impaired contraction of the muscles of the pharynx, presence of residue, and insufficient opening of the upper esophageal sphincter, also contribute to the penetration and aspiration of food [21].

Among the studies on the sensitivity of the larynx, researchers have demonstrated that oropharyngeal anesthesia led to a sharp decrease of cortical sensorimotor activation of the bilateral hemispheres when compared to nonanesthetized groups [18]. This demonstrates that the pharyngeal phase of swallowing is highly dependent on the integrity of afferent sensory information, enabling cortical areas and those of the brainstem, and consequently triggering the motor response of swallowing. Therefore, without sensory information there will be no adequate activation of bilateral pharyngeal muscles, with greater tracheal penetration and aspiration.

In the two individuals from our sample who had paralysis of the vocal folds, only one presented aspiration with the puree; coincidentally, this individual had no bilateral sensitivity. The other subject did not show penetration and/or aspiration but showed integrity of sensitivity on at least one side.

This study investigated the correlation between the integrity of laryngeal sensitivity and the occurrence of penetration and aspiration in a sample of individuals with neurogenic dysphagia, specifically those who in late-stage stroke, a condition where there is no spontaneous recovery of swallowing without therapeutic intervention. A statistically significant and negative correlation was found between laryngeal sensitivity and penetration/aspiration, independent of the type of food swallowed, where the loss of sensitivity in the larynx results in the greater occurrence of penetration and aspiration, which may lead to clinical complications such as dehydration, malnutrition, and aspiration pneumonia.

The limitations of this study were the inclusion of different stages of poststroke, from 2 to 192 months. Some of these individuals received therapy for months and others for only a few weeks. We included patients with only supratentorial stroke, but in both hemispheres. We also included two cases of vocal fold paralysis in the sample, where the presence of aspiration is known to be more frequent in this group than in those that do not present these motor alterations. We did not evaluate other aspects such as motor pharyngeal weakness or changes in the upper esophageal sphincter.

Future research is needed to investigate there is a correlation between sensibility and pharyngeal weakness on penetration and aspiration in this specific population, perhaps by investigating whether the motor aspect or sensibility is more relevant in poststroke swallowing.

Conclusion

It is possible to conclude that worse sensitivity in the larynx presents a greater possibility of penetration and aspiration in late-phase poststroke individuals, regardless of the food consistency.

Conflict of interest The authors have no conflict of interest to declare.

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