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ORIGINAL ARTICLE

Relationship Between Laryngeal Sensory Deficits, Aspiration, and Pneumonia in Patients with Dysphagia

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Abstract The laryngeal adductor reflex (LAR) is an airway protective reflex that manifests as a brief vocal fold closure in response to laryngeal stimulation. This study examined if the absence of the LAR in response to touch delivered by a laryngoscope is associated with penetration/aspiration or pneumonia in patients with dysphagia. Inpatients at a teaching hospital with clinical symptoms of dysphagia were recruited upon referral to the otolaryngology clinic for a swallowing evaluation. Otolaryngologists observed the status of secretions and touched each arytenoid with the tip of the laryngoscope. The patients were then asked to swallow 3–5 mL grape gelatin and 3–5 mL colored water. All procedures were video-recorded. Two independent raters noted absence/presence of the LAR and penetration/aspiration of pharyngeal secretions, gelatin, and water on the recorded videos. A diagnosis of pneumonia during the patient's entire hospital stay was determined by a review of the hospital's medical records. Statistical analyses were performed using Fisher's exact test. Sixty-one patients were included. Twenty-one patients (34.5%) did not exhibit the LAR. No association was found between the absent LAR and penetration or aspiration. There was, however, a significant association between an absence of the LAR and pneumonia development. Patients with an absent LAR had 6.8 times the odds of developing pneumonia as compared to those with a present LAR (OR 6.75; 95% CI 1.76–25.96; $p < 0.01$). Using the LAR as a marker of laryngeal sensory function appears to be valuable for identifying patients at high risk of pneumonia.

Keywords Laryngeal sensory deficits · Dysphagia · Deglutition · Laryngeal adductor reflex · Aspiration · Pneumonia

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Introduction

Sensory input is vital to the oral, pharyngeal, and esophageal phases of swallowing. The afferent input arising from the laryngeal area is particularly important in triggering various reflexes, which protect the respiratory tract against the invasion of foreign materials. The afferent innervation of the human larynx is supplied by the internal branch of the superior laryngeal nerve. Mechanical or chemical stimulation of the laryngeal mucosa in the internal branch of the superior laryngeal nerve territory triggers the laryngeal adductor reflex (LAR) [1–5]. Loss of laryngeal sensation presented as depressed LAR has thus been considered as one of the risk factors associated with aspiration of food, liquids [6, 7], or oropharyngeal secretions [8–10].

Patients with dysphagia often demonstrate reduced laryngeal sensation, thus testing laryngeal sensation has been recommended as part of fiberoptic endoscopic

evaluation of swallowing (FEES) in order to identify patients at high risk for aspiration [11]. Clinicians test laryngeal sensation by applying light and brief touches to the laryngeal mucosa with the distal end of a flexible laryngoscope (the touch method). This direct mechanical stimulation to the laryngeal mucosa may elicit a cough, gag, swallow, or the LAR [12, 13]. If any of these reflexes are triggered in response to touch, laryngeal sensation is judged to be grossly intact [11]. Using this touch method, a previous study found a correlation between sensory deficits as determined by the absence/presence of either the LAR or the cough reflex and increased likelihood of penetration/aspiration in post stroke patients [6].

The clinical reliability of this simple technique, however, has been questioned [14]. Our preliminary investigation demonstrated that the pressure levels of the touches applied to the laryngeal mucosa varied a great deal [15], although all of them were above the threshold pressure of air pulses that evokes the LAR in healthy adults, identified by Aviv and others [16]. This finding suggests that patients may not elicit different reflexes consistently across trials. The study, however, found that only the LAR did consistently occur when the touches were applied to healthy adults, while cough, gag, and swallowing reflexes occurred in response to only some of the touches applied, suggesting that absence of cough, gag, or swallowing reflexes should not be interpreted as a sign of reduced laryngeal sensation. On the other hand, if a person does not demonstrate a LAR to the touch stimulus, sensory processing deficits are implicated.

The question remains whether or not an absent LAR is associated with penetration or aspiration in individuals with oropharyngeal dysphagia. It is also unknown if failure to trigger the LAR in response to touch is associated with increased risk of pneumonia. If the association between absent LAR and aspiration is observed, and if an absent LAR is associated with pneumonia, then patients with dysphagia who do not exhibit the LAR may warrant a more conservative approach for diet and other rehabilitation recommendations.

The aim of this study was to determine whether or not an absent LAR, as determined by the touch method, is associated with penetration/aspiration of food, liquid, or pharyngeal secretions in patients with dysphagia. The study also aimed to determine whether or not an absent LAR is associated with pneumonia in patients with swallowing disorders. We hypothesized that sensory deficits identified by the touch method would be associated with increased likelihood of penetration/aspiration and pneumonia in patients with dysphagia.

Methods

Setting

This study was conducted in the otolaryngology outpatient clinic of an urban teaching hospital in Tokyo, Japan. The study protocol was approved by the Institution Review Board (Ref No. 10781). Written informed consent was obtained from all participants or approved family members.

Participants

Inpatients with clinical symptoms of dysphagia, such as cough or wet voice on swallowing food or liquids, and/or sensation that food sticks in the throat were consecutively screened as they were referred to the Department of Otolaryngology for a swallowing evaluation from April 2015 through February 2016. Patients were excluded from the study if they had: (1) unstable state of consciousness as measured by Glasgow Coma Scale (GCS; GCS score <13 point [17, 18], (2) inability to sit upright and be transferred to the exam room of the otolaryngology clinic, (3) history of surgical removal of the arytenoids, (4) incomplete vocal fold closure identified during laryngoscopic evaluation, [19] (5) inability to understand the verbal instructions involved in endoscopic evaluation of swallowing with sensory testing, or (6) if they or their family did not provide the consent for participating the study. Patients with incomplete vocal fold closure were excluded because the LAR could not be evoked in those patients due to the impairment of the motor limb of the reflex, regardless the condition of the sensory limb of the reflex.

Equipment

Two different models of laryngoscopes (Olympus ENF VH and ENF-VQ: both with diameter = 3.9 mm; Olympus Medical Systems Corporation; Tokyo, Japan) were utilized for sensory and swallowing testing. FEES images were obtained using light sources (CLV-S40Pro, Olympus Medical System Corporation) and video recording and archiving systems (Olympus OTV-S7Pro, Olympus Medical System Corporation). The FEES videos were recorded at a rate of 30 frames per second.

Data Collection

The swallowing assessment was performed by one of three otolaryngologists as part of the standard care practices of the hospital. Examiners 1, 2, and 3 had 10, 13, and 9 years of prior experience using the touch method, respectively. Patients were seated upright in a chair or wheel chair.

Topical nasal vasoconstrictor (0.1 mL of 0.02% epinephrine) and anesthesia (0.2 mL of 4% lidocaine) were sprayed in the nostril that would be used. The scope was passed transnasally to the pharynx. Participants were prompted to vocalize a sustained "ee" for 2–3 s to assess vocal fold mobility. Pooling of oropharyngeal secretions in the pharynx and larynx was observed. [8, 9]

Then, the participants were instructed to close their eyes to be blinded to the monitor showing the endoscopic view. The otolaryngologist then lightly and briefly touched the mucosa over the left and right arytenoids with the tip of the laryngoscope. The patients rested for at least five seconds between touches.

Next, FEES was performed. The patients were then asked to swallow two trials each of (1) 3 mL grape gelatin (Otsuka Pharmaceutical Co., Ltd. Tokyo, Japan), (2) 5 mL grape gelatin, (3) 3 mL thin water, and (4) 5 mL thin water. All boluses were delivered using a syringe. Gelatin was used in FEES because it has been typically used for swallowing evaluation and rehabilitation in Japan. The Japanese Society of Dysphagia Rehabilitation has been recommending whether purée or jelly textures are safer or easier to swallow based on the most advanced classification for dysphagia diet by hardness, adhesiveness, and cohesiveness [20]. The water was colored purple with Pyoktanin for ease of visualization. When examiners observed that a patient aspirated or if the examiners were concerned that a patient would aspirate in upcoming trials, the second trial of that consistency (the larger volume) was not administered. If a cuffed tracheal tube was in place, the exam was done with the cuff inflated, as per hospital policy.

Two raters (a speech language pathologist and a physiatrist) who were not involved in the endoscopic evaluation independently analyzed the FEES videos by playing them frame-by-frame for determining (1) absence/presence of the LAR, (2) absence/presence of penetration/aspiration of gelatin and water, and (3) absence/presence of penetration/aspiration of secretions. If an adduction of the vocal folds was observed in response to touch on both sides, then the LAR was judged to be present. Absence/presence of the LAR was noted for the left and right arytenoids, or unknown if it could not be visualized on the video. When the LAR did not occur at one or both of the two test locations, the LAR was determined to be absent. Presence/absence of penetration/aspiration of 3 or 5 mL of gelatin, 3 or 5 mL of water, and pharyngeal secretions were noted. Penetration was defined as the invasion of test materials or pharyngeal secretions into the laryngeal vestibule above or to the level of the true vocal folds [21]. Aspiration was defined as the invasion of test materials or pharyngeal secretions below the true vocal folds [21]. Penetration or aspiration was determined to have occurred *before* the swallow, secondary to spillage into the hypopharynx before the swallow, or *after* the swallow, secondary to pharyngeal residue, or *during* the swallow if residue of material was observed in the laryngeal vestibule or below the vocal folds after the swallow [11].

The raters performed the rating for status of LAR, gelatin and water swallows, and status of secretions of participants on different days, in order to be blinded to their own judgments on the same participants. Disagreement on the judgments between the two raters was resolved by discussion to determine the final judgment of the patients' sensory and swallowing statuses.

Outcomes

The primary outcome of this study was penetration and aspiration of food, water, and secretions, as seen on the FEES. The secondary outcome for the study was pneumonia during the patients' hospital stay. Pneumonia was diagnosed by attending physicians based on clinical pneumonia symptoms and the evidence of an infiltrate on chest X-ray. Clinical pneumonia symptoms included fever, leukocytosis, or new onset or upper respiratory symptoms such as purulent sputum, increased respiratory secretions, cough, dyspnea, tachypnea, or worsening gas exchange [36]. Demographic characteristics and the record of pneumonia diagnosis were extracted from the hospital's electronic medical records.

Ninety-four inpatients met the inclusion criteria for this study. Of those, 61 patients (64.9%) completed both (1) sensory testing on both left and right arytenoids and (2) swallowing evaluation of 3 and/or 5 mL gelatin and 3 and/or 5 mL water, with high quality images obtained for judging the absence/presence of the LAR as well as swallowing status. The other thirty-three patients were not included for analysis: eleven of these patients did not complete the sensory testing due to examiner decision; eleven patients did not provide a clear view of the larynx for determining presence/absence of the LAR; five patients were not tested adequately (the raters judged that the tip of the scope did not contact the mucosa over the arytenoids), and six patients were not given gelatin or water for the swallowing evaluation for safety concern due to the presence of very severe dysphagia with reduced ability to clear the airway.

Data Analyses

Data normality was assessed using Shapiro–Wilk test. Continuous demographic variables were compared with the Wilcoxon rank sum test and categorical demographic variables were compared by Pearson's Chi square test or Fisher's exact test between patients with or without the

LAR. The association between presence or absence of the LAR and presence or absence of penetration and aspiration for gelatin, water, and pharyngeal secretions was examined with Fisher's exact test. The association between presence or absence of the LAR and the occurrence of pneumonia was also examined with Fisher's exact test. Statistical analyses were performed on SAS® for Windows (version 9.4; SAS Institute Inc. Cary, NC, USA). Alpha = 0.05 was employed for the analyses.

Results

Patient Demographics

Table 1 shows the demographic characteristics of 61 participants (35 males, mean age = 74.5 ± 16.3 years) by LAR status. Median length of hospital stay was 43.0 days (range 4–237). The univariate analyses showed that there was no statistically significant difference in any of the characteristics between the participants who had absence/presence LAR, suggesting that none of the demographic variables could have been a potential confounder of the association between LAR, penetration/aspiration, or pneumonia (Table 1).

The Association Between the Laryngeal Adductor Reflex and Penetration/Aspiration

Forty of the 61 participants (65.6%) demonstrated the LAR and 21 participants (34.4%) did not show the LAR. Of those 21 participants, five participants (23.8%) did not exhibit the LAR on either the left or right arytenoid, while 16 participants (76.2%) displayed the LAR on only one of the arytenoids.

Of the 61 participants, gelatin penetration occurred in nine participants (14.8%); water penetration was observed in 17 participants (27.8%); penetration of secretions was found in nine participants (14.8%, Table 2). No significant association was found between absence of LAR and penetration of gelatin (OR 0.50; 95% CI 0.09–2.64; $p = 0.48$) or water (OR 0.49; 95% CI 0.14–1.74; $p = 0.37$) or pharyngeal secretions (OR 1.65; 95% CI 0.40–6.93; $p = 0.70$).

Of the 61 participants, gelatin aspiration occurred in one participant (1.6%); water aspiration was observed in eight participants (13.1%); aspiration of secretions was found in four participants (6.5%, Table 3). No significant difference was found between absence of LAR and aspiration of gelatin (OR 0.98; 95% CI 0.93–1.02; $p = 1.00$) or water (OR 0.60; 95% CI 0.11–3.25; $p = 0.70$) or pharyngeal secretions (OR 0.62; 95% CI 0.06–6.32; $p = 1.00$).

The Association Between the Laryngeal Adductor Reflex and Pneumonia

Table 4 demonstrates the numbers of pneumonia cases by the LAR status. Thirteen of 61 patients (21.3%) developed pneumonia during their hospital stay. Of the 13 patients who developed pneumonia, nine patients (69.2%) did not exhibit the LAR, while four patients (30.8%) exhibited the LAR. There was a statistically significant difference in the number of pneumonia events between patients who had present the LAR and patients who had the absent LAR ($p < 0.01$). Patients without the LAR had a 6.8 times increase in odds of developing pneumonia as compared with the patients with the LAR (OR 6.75; 95% CI 1.76–25.96; $p < 0.01$).

Discussion

The aim of this research study was to determine whether or not an absent LAR elicited by pressure applied to the laryngeal mucosa with the tip of an endoscope was associated with an increased likelihood of penetration/aspiration in patients with dysphagia. Contrary to a previous study finding in stroke patients with dysphagia [6], no association was found between reduced laryngeal sensation and penetration/aspiration of food or liquid or pharyngeal secretions identified during FEES in this study sample. This study also aimed to determine whether or not an absent LAR was associated with pneumonia in patients with dysphagia. As hypothesized, an absence of the LAR was significantly associated with pneumonia in patients with swallowing disorders. The result supports the clinical utility of the LAR as a marker of laryngeal sensory function for identifying patients at high risk for pneumonia. When evaluating patients with dysphagia and making decisions in their care, a highly predictive measure for pneumonia, which could be simply assessed during the swallowing evaluation, would be valuable.

Unlike a previous report [6], the current study found no association between reduced laryngeal sensation identified with the touch method and penetration/aspiration of food or liquid materials or pharyngeal secretions. These inconsistent results may be related to the different methodologies of the studies. First, the previous report focused on poststroke patients with dysphagia, whereas our study examined patients with dysphagia due to heterogeneous etiologies. Sensory function in the larynx can be affected by various medical conditions, although the mechanism of the sensory deficits remains unclear [22]. For example, the mucosal sensory receptors can be altered by surgery or radiotherapy in the head and neck area [23, 24] or continuous chemical stimulation to the laryngeal surface such as

Table 1 Demographic characteristics

	Laryngeal adductor reflex ($n = 61$), n (%)		p value
	Present $n = 40$ (65.6)	Absent $n = 21$ (34.4)	
Age, median, years	70.0	74.0	0.31
Length of hospital stay (median, days)	43.5	40.0	0.62
Gender			0.79
Male	22 (62.9)	13 (37.1)	
Female	18 (69.2)	8 (30.8)	
Diagnosis			0.30*
Neurologic	22 (71.0)	9 (29.0)	
Respiratory	2 (40.0)	3 (60.0)	
Cardiac	4 (80.0)	1 (20.0)	
Dermatologic	2 (50.0)	2 (50.0)	
Gastroesophageal	1 (25.0)	3 (75.0)	
Other	9 (75.0)	3 (25.0)	
Diet level at evaluation			0.35
Nil per os	7 (53.8)	6 (42.6)	
Modified diet	16 (61.5)	10 (38.5)	
Normal diet	17 (77.3)	5 (22.7)	
Liquid intake			0.36
Not allowed to take liquids	6 (50.0)	6 (50.0)	
Thickened liquids	15 (75.0)	5 (25.0)	
Thin liquids	19 (65.5)	10 (35.5)	
Nasogastric tube			0.74*
Absent	33 (67.3)	16 (32.7)	
Present	7 (58.3)	5 (41.7)	
Tracheostomy			0.53*
Absent	37 (66.1)	19 (33.9)	
Cuffless-tracheostomy	3 (75.0)	1 (25.0)	
Cuffed-tracheostomy	0 (0)	1 (100.0)	
Number of patients examined by examiner			0.70*
Examiner 1	29 (67.4)	14 (32.6)	
Examiner 2	8 (66.7)	4 (33.3)	
Examiner 3	3 (50.0)	3 (50.0)	

* Fisher's exact test

Table 2 The laryngeal adductor reflex and penetration

Material	Penetration	Laryngeal adductor reflex			p value
		Present (%)	Absent (%)	Total	
Gelatin	Absent	33 (54.1)	19 (31.1)	52 (85.2)	0.48
	Present	7 (11.5)	2 (3.3)	9 (14.8)	
Water	Absent	27 (44.3)	17 (27.9)	44 (72.2)	0.37
	Present	13 (21.2)	4 (6.6)	17 (27.8)	
Secretions	Absent	35 (57.4)	17 (27.8)	52 (85.2)	0.70
	Present	5 (8.2)	4 (6.6)	9 (14.8)	

gastroesophageal reflex [25]. Neurological diseases, such as amyotrophic lateral sclerosis [26] or Parkinson's disease [27] have also been reported as possible causes for the impairment in the afferent pathway to the nucleus tractus solitarius in the medulla. The different pathophysiological conditions in this sample may have influenced the

Table 3 The laryngeal adductor reflex and aspiration

Material	Aspiration	Laryngeal adductor reflex			*p* value
		Present (%)	Absent (%)	Total	
Gelatin	Absent	39 (64.0)	21 (34.4)	60 (98.4)	1.00
	Present	1 (1.6)	0 (0.0)	1 (1.6)	
Water	Absent	34 (55.7)	19 (31.2)	53 (86.9)	0.70
	Present	6 (9.8)	2 (3.3)	8 (13.1)	
Secretions	Absent	37 (60.7)	20 (32.8)	57 (93.5)	1.00
	Present	3 (4.9)	1 (1.6)	4 (6.5)	

Table 4 The laryngeal adductor reflex and pneumonia

Pneumonia	Laryngeal adductor reflex		
	Present (%)	Absent (%)	Total
Absent	36 (90.0)	12 (57.1)	48 (78.7)
Present	4 (10.3)	9 (42.9)	13 (21.3)
Total	40	21	61

Fisher's exact test; $p < 0.01$

association between sensory deficits and penetration, aspiration, or pneumonia. A second reason for no association between reduced laryngeal sensation and penetration/aspiration is that the examiners of our study may have been deliberately conservative by not providing any test materials when they deemed the patients, all of which were in acute medical status, to be at high risk for aspiration and pneumonia. Thus, the current study likely excluded the potential aspirators from the study sample. These methodological differences may have resulted in the inconsistency regarding the value of the touch method for identifying penetration/aspiration risk in patients with dysphagia.

In contrast to the lack of association between aspiration and the LAR, this study did find that an absence of the LAR on either arytenoid was associated with pneumonia in patients with dysphagia. This finding was consistent with a previous study conducted by Sato and colleagues, which also found a link between reduced laryngeal sensation, as determined by the touch method, and the occurrence of pneumonia in individuals with dysphagia in a rehabilitation hospital [7]. However, it should be remembered that a body of literature has shown that aspiration of materials cannot be an independent predictor for pneumonia [28, 29]. Aside from laryngeal sensory deficits or aspiration of foreign materials, diseases-specific variables may have affected the pneumonia development in the patients in this study. For example, our study sample included patients with cardiovascular diseases and respiratory diseases, which are known to increase the risk for pneumonia. A population-based study demonstrated that patients with chronic heart disease had an almost two-times risk of nosocomial pneumonia [30]. Further, patients with cardiac diseases or respiratory diseases are likely to be older and have more chronic medical conditions, which compromise patients' defense mechanisms against lung infection and thus contribute to develop pneumonia [31]. These and other potential confounding factors should be controlled in multifactor analyses in a larger-scale study in order to predict the pneumonia development based on LAR status.

It may be argued that the use of topical anesthesia might have altered the results by depressing sensation. However, there is evidence to support that a limited dose of topical anesthesia the nasal cavity does not change laryngeal sensory thresholds in normal healthy adults significantly [32, 33]. Further, in our preliminary study, healthy participants always exhibited the LAR under the same level of topical anesthesia as we used in the current study (0.2 mL of 4% lidocaine hydrochloride) [15]. The study also demonstrated that pressures that were applied to the mucosa during the touch test were far stronger than the air pressures that have been reported to elicit an LAR, even with a nasal topical anesthesia present [31, 32]. Thus, we expect that supra-threshold stimuli applied by the touch test under nasal anesthetic condition would certainly elicit an LAR if sensory function were intact.

We acknowledge some potential limitations to this study. First, it is possible that the study failed to detect a significant difference in aspiration risk in patients with and without sensory deficits due to the low overall number of aspiration events. Previous studies have suggested that FEES protocols using small boluses [33] or limited

numbers of swallow trial [34] can underestimate the aspiration risk. Second, we used a referred population because patients in our hospital are not evaluated for swallowing disorders unless there are clinical symptoms. Thus, some potential selection biases may have been inherent in the study population. For example, patients with mild dysphagia who could have passed the screening test for dysphagia may not have been referred to the otolaryngologists for instrumental evaluation. On the contrary, patients with severe medical conditions who were not able to sit upright were excluded from the study. The study also could not accommodate patients who presented with a poor laryngeal view during FEES or individuals who could not tolerate the touch method due to discomfort. Subjects who were judged to be at high risk for aspiration were not given larger boluses, which clearly limited the possible number of positive aspirators found in the evaluation. The potential selection bias might have affected the results of the current study. Third, one of our study outcomes, pneumonia, was diagnosed by attending physicians based on clinical pneumonia symptoms and the evidence of an infiltrate on chest x-ray. Accuracy of pneumonia diagnosis could have been improved by using the diagnosis on the CDC/NHSN surveillance definitions [35]. Finally, due to the limited sample size, further analyses on the data were not possible such as stratifying by etiologies, demographics, or LAR status (i.e. unilateral or bilateral absence). Future research is warranted for testing the association between sensory deficits, oropharyngeal dysphagia, and airway complications, accounting for demographic variables, and LAR status.

Conclusion

The current study demonstrated no association between absence of the LAR, as determined by the touch method, and penetration/aspiration of gelatin or liquid or pharyngeal secretions in patients with dysphagia. However, there was a significant association between an absent LAR and pneumonia in patients with swallowing disorders.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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