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Relationship Between Laryngeal Sensation, Length of Intubation, and Aspiration in Patients with Acute Respiratory Failure

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Abstract

Background: Dysphagia is common in hospitalized patients post-extubation and associated with poor outcomes. Laryngeal sensation is critical for airway protection and safe swallowing.

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Informed Consent: Informed consent was obtained from all participants prior to enrollment in this research study.

However, current understanding of the relationship between laryngeal sensation and aspiration in post-extubation populations is limited.

Methods: Acute respiratory failure patients requiring intensive care unit admission and mechanical ventilation received a Flexible Endoscopic Evaluation of Swallowing (FEES) within 72 hours of extubation. Univariate and multivariable analyses were performed to examine the relationship between laryngeal sensation, length of intubation, and aspiration. Secondary outcomes included pharyngolaryngeal secretions, pneumonia, and diet recommendations.

Results: One-hundred and three patients met inclusion criteria. Fifty-one patients demonstrated an absent laryngeal adductor reflex (LAR). Altered laryngeal sensation correlated with the presence of secretions ($p = 0.004$). There was a significant interaction between the LAR, aspiration, and duration of mechanical ventilation. Altered laryngeal sensation was significantly associated with aspiration on FEES only in patients with a shorter length of intubation ($p = 0.008$). Patients with altered laryngeal sensation were prescribed significantly more restricted liquid ($p = 0.03$) and solid ($p = 0.001$) diets. No relationship was found between laryngeal sensation and pneumonia.

Conclusions: There is a high prevalence of laryngeal sensory deficits in mechanically ventilated patients post-extubation. Altered laryngeal sensation was associated with secretions, aspiration, and modified diet recommendations especially in those patients with a shorter length of mechanical ventilation. These results demonstrate that laryngeal sensory abnormalities impact the development of post-extubation dysphagia.

Keywords

Deglutition; Deglutition Disorders; Laryngeal Sensation; FEES; Acute Respiratory Failure; Critical Illness

Background

Acute respiratory failure (ARF) is a common, heterogeneous disorder requiring invasive mechanical ventilation and admission to an intensive care unit (ICU) (1). Dysphagia post-extubation occurs in up to 62% of patients (2) and can result in aspiration, which is associated with increased rates of pneumonia, re-intubation, mortality, and hospital length of stay (3). Dysphagia symptoms can persist up to six months after hospital discharge (4). Multiple mechanisms may contribute to the development of post-extubation dysphagia including neuromyopathy (5), impaired mentation (6), gastroesophageal reflux (7), disrupted coordination of breathing and swallowing (8, 9), direct trauma to laryngeal structures including edema, erythema, ulceration, and granulation tissue (10, 11), and reduced oropharyngeal (12) and laryngeal sensation (12, 13). The role of laryngeal sensation in the development of post-extubation dysphagia, however, is relatively unknown.

Laryngeal sensation is critical for airway protection and is tested through elicitation of the laryngeal adductor reflex (LAR) during Flexible Endoscopic Evaluation of Swallowing (FEES) (14). In healthy adults, tactile stimulation of each arytenoid with the tip of the endoscope triggers a brainstem-mediated LAR, as evidenced by a brief adduction of the true vocal folds (15). Afferent input from the internal branch of the superior laryngeal nerve

provides sensory feedback to central neural circuits to ensure timely glottic closure (16, 17). Reduced laryngeal sensation can place patients at greater risk for aspiration of food and liquids (13, 18, 19), as well as pneumonia (20). To date, only one study has reported laryngeal sensory impairments in post-extubation populations. Scheel et al. (11) found no relationship between laryngeal sensory deficits and aspiration; however, this study was limited due to a relatively small sample size.

Despite the impact of aspiration on health outcomes in critically ill patients, little is known about the relationship between laryngeal sensory deficits and aspiration. We sought to examine this relationship, as well as the effect of length of intubation, in a large cohort of post-extubated ARF patients. Secondary outcomes investigated included pharyngolaryngeal secretions, pneumonia, and diet recommendations. Our hypothesis was that laryngeal sensory deficits would be associated with higher rates of aspiration, secretions, pneumonia, and modified diet recommendations.

Methods

Study Design

This study was part of a National Institutes of Health (NIH) funded, prospective, multi-site cohort study examining aspiration in ARF patients. Patients were eligible if they were at least 18 years old, admitted to an ICU, and mechanically ventilated with an endotracheal tube for longer than 48 hours. Exclusionary criteria included contraindications to enteral nutrition, pre-existing or acute primary, central, or peripheral neuromuscular disorder, pre-existing history of dysphagia or head and neck cancer or surgery, presence of a tracheostomy, coagulopathy resulting in uncontrolled nasal or pharyngeal bleeding, and altered mentation. Patients found to have vocal fold immobility during FEES were excluded from this sub-study analysis since the LAR would not be present due to impairment of the motor limb of the reflex (20).

Data Collection

Experienced speech-language pathologists (SLPs) performed FEES on all patients within 72 hours of extubation. Both fiberoptic and distal chip endoscopes were used across study sites. FEES is standard of care at two of the four study sites. All boluses were dyed green and additional white food coloring was added to thin liquid bolus trials. Boluses were administered in the following order: ½ and full teaspoon of ice chips; 5 ml, 15 ml, and 2 oz nectar-thick liquid (Thick & Easy®, Hormel Health Labs, Austin, MN); 5 ml and 10 ml puree; 5 ml, 15 ml, and 2 oz thin liquid; ¼ piece of graham cracker; 3 oz water swallow test. If aspiration was visualized on a small bolus (i.e., 5 ml), then the larger bolus within that consistency was skipped and the next consistency was presented. The 3 oz water swallow test was not performed if aspiration was visualized on any prior thin liquid bolus. Bolus presentations were stopped if the clinician perceived significant risk to the patient. Stopping rules for each bolus consistency and for the entire study optimized both the delivery of diverse bolus consistencies and patient safety. Following PO trials, the clinician assessed laryngeal sensation by advancing the endoscope tip to briefly contact each arytenoid. If the

laryngeal adductor reflex was not readily apparent on one side, a second attempt was made. Dietary recommendations were made by the SLP upon the conclusion of the FEES.

Data & Statistical Analysis

An independent rater with 30 years of experience rating FEES judged airway safety on the penetration–aspiration scale (PAS) (21) and the presence or absence of secretions and the LAR. Aspiration was defined as a PAS score of 6 or greater on any consistency (21). Presence of the LAR was defined as adduction of the vocal folds or arytenoids. Absent LAR was defined as a unilateral or bilateral absent reflex. Secretions were grouped into four categories: no secretions, secretions pooled outside the laryngeal vestibule, secretions pooled inside the laryngeal vestibule, and secretions pooled both inside and outside the laryngeal vestibule. All incidences of hospital-acquired pneumonia, as diagnosed by the medical team, were recorded. An independent otolaryngologist assessed vocal fold mobility during a speech task (“eee-sniff”), which elicited vocal fold abduction and adduction.

Categorical variables were compared with Pearson’s chi-square test. Cramer’s V was used to examine the strength of associations for chi-squared analyses. In order to examine demographic predictors of laryngeal sensory deficits, a multivariable logistic regression was performed. Variables included age, gender, and baseline demographic characteristics that were statistically significantly associated with laryngeal sensation in univariate analyses, including race, history of myocardial infarction, and history of diabetes mellitus. To examine the effects of duration of mechanical ventilation on the relationship between altered laryngeal sensation and aspiration, a second multivariable logistic regression adjusting for gender, endotracheal tube size, and duration of mechanical ventilation (log normalized) was performed. In subsequent univariate analyses, patients were categorized into four groups based on length of mechanical ventilation (long/short) and LAR (absent/present). Length of mechanical ventilation was stratified by $<$ or $\geq$ 100 hours. Alpha was set at 0.05 for all analyses.

Results

Patient Characteristics

A total of 141 patients were enrolled in the study. Laryngeal sensation was performed on 110 patients (bilateral testing on 97; unilateral testing on 13). Seven of these patients were excluded: six patients presented with vocal fold immobility and one did not provide adequate visibility during FEES. Therefore, 103 patients met inclusion criteria and were included in the analysis.

Univariate analyses revealed no statistically significant difference in baseline characteristics of patients who did and did not have laryngeal sensation testing performed (Table 1). Intact bilateral LAR was present in 52 of the 103 patients (50.5%). In the 51 patients who exhibited LAR deficits, 23 demonstrated a unilateral absent LAR (45%), and 28 patients demonstrated bilaterally absent LAR (55%). In univariate analyses, history of myocardial infarction ($\chi^2 = 3.21$, $p = 0.04$, $V = 0.18$), diabetes mellitus ($\chi^2 = 4.64$, $p = 0.04$, $V = 0.15$), and non-white race ($\chi^2 = 9.37$, $p = 0.001$, $V = 0.30$) were statistically significantly

associated with an absent LAR (Table 2). In a multivariable logistic regression, race was the only variable that remained statistically significantly associated with an absent LAR (p = 0.02, OR = 2.06, 95% CI: 1.21 – 7.22).

Laryngeal Sensation and Aspiration

A significant relationship was found between absent LAR and aspiration (χ^2 = 5.50, p = 0.01, V = 0.25). Forty-seven percent of patients who demonstrated laryngeal sensory deficits aspirated on their FEES examination, compared to 23% of patients with an intact LAR. Aspiration occurred in 39% of patients with a bilaterally absent LAR compared to 57% of patients with a unilateral absent LAR, though there were no statistically significant differences between patients with a unilateral and bilaterally absent LAR (χ^2 = 1.51, p = 0.22, V = 0.17). Of the 35 patients who aspirated, 91% aspirated thin liquid and 29% aspirated without a sensory response. Silent aspiration occurred in 16% of patients with an absent LAR compared to 6% with an intact LAR. An absent LAR was not associated with higher rates of silent aspiration compared to patients with an intact LAR (χ^2 = 1.71, p = 0.19, V = 0.16). A significant interaction between duration of mechanical ventilation and the LAR response and their associations with aspiration was found (p = 0.01). In a stratified analysis of those patients with a shorter duration of mechanical ventilation, an absent LAR was significantly associated with aspiration. Specifically, 47% (8/17) of patients with an absent LAR aspirated compared to only 9% (2/23) in patients with a present LAR (p = 0.005). For those patients with a longer duration of mechanical ventilation, an absent LAR was not associated with aspiration. Specifically, 47% (16/34) of patients with an absent LAR aspirated compared to 35% (10/29) in those patients with a present LAR (p = 0.31; Figure 1).

Laryngeal Sensation and Secretions, Pneumonia, and Diet Recommendations

Absent LAR was significantly associated with the presence of secretions, (χ^2 = 8.32, p = 0.004, V = 0.29; Table 3), whereas the length of mechanical ventilation did not reach significance, (χ^2 = 1.08, p = 0.30, V = 0.10). Absent LAR was not associated with hospital-acquired pneumonia after FEES, (χ^2 = 0.10, p = 0.75, V = 0.02). The absence of an LAR was also associated with modified liquid (χ^2 = 9.02, p = 0.03, V = 0.17) and solid (χ^2 = 16.10, p = 0.001, V = 0.28) diet recommendations. Furthermore, patients with longer durations of mechanical ventilation were significantly more likely to have modified liquid (χ^2 = 5.96, p = 0.02, V = 0.24) and solid (χ^2 = 5.84, p = 0.02, V = 0.24) diet recommendations.

Discussion

Though dysphagia post-extubation is common and associated with poor health outcomes, current understanding of its underlying mechanisms is limited. Laryngeal sensation is critical for airway protection and safe swallowing, but its relationship with aspiration post-extubation is unknown. The primary aim of this prospective study was to examine the relationship between laryngeal sensation and aspiration in a large cohort of patients with ARF. Secondary aims included examining secretions, pneumonia, and diet recommendations, as well as the effect of duration of mechanical ventilation.

Laryngeal sensory deficits were prevalent within 72 hours after extubation and associated with aspiration. This finding is consistent with prior studies demonstrating a relationship between laryngeal sensory impairments and aspiration in stroke, chronic obstructive pulmonary disease, and other heterogeneous populations (13, 18, 22). Though studies have predominantly focused on aspiration, there are multiple changes in swallowing physiology that may contribute to dysphagia after extubation. An increased length of time to achieve laryngeal closure and reopening after the swallow has been observed, which could be caused by altered laryngeal sensation (23). These results suggest that routine assessment of laryngeal sensation post-extubation could be of clinical benefit when determining aspiration risk.

Several studies have suggested a relationship between length of mechanical ventilation and dysphagia (3, 24-30), though other analyses have not shown this relationship (11, 31-34). There are likely many methodological factors that contribute to this discrepancy, including sample size, timing of evaluation, and lack of objective instrumental evaluations. Studies have yet to examine the role of laryngeal sensation in the relationship between length of intubation and aspiration risk. Interestingly, our results showed that altered laryngeal sensation has a more profound effect on aspiration risk in patients with a short length of mechanical ventilation (< 100 hours). In patients with a longer duration of mechanical ventilation, laryngeal sensory deficits alone do not seem to influence the risk of aspiration. It is likely that there are other underlying mechanisms and types of dysfunction related to their critical illness that contribute to a patient's aspiration risk if they are intubated for a prolonged length of time. These patients are likely sicker at baseline, resulting in deconditioning, neuromyopathy, impaired mentation, and disrupted coordination of breathing and swallowing. Alternatively, patients with a shorter duration of mechanical ventilation are less critically ill and not subjected to these types of dysfunction known to contribute to dysphagia in this patient population. Altered laryngeal sensation resulting from the local impact of an endotracheal tube affects swallowing physiology in these patients, increasing their risk of aspiration. The underlying pathophysiology is complex and multifaceted, underscoring the importance of accounting for multiple, interacting sensory and motoric mechanisms when evaluating and treating this population.

An absent LAR was not associated with silent aspiration in our cohort, though this might be suspected due to separate innervations of the vagus nerve. Supraglottic sensation is mediated by the internal branch of the superior laryngeal nerve, whereas subglottic sensation is mediated by the recurrent laryngeal nerve. However, the lack of statistical significance observed may be due to low power. Larger studies will be necessary to further determine if there is an association between supraglottic and subglottic sensation in patients post-extubation.

Altered laryngeal sensation was associated with the presence of pharyngolaryngeal secretions. Though we were unable to examine differences in secretion severity due to insufficient sample size, patients with an intact LAR were less likely to have pooling inside the laryngeal vestibule, emphasizing the importance of laryngeal sensation to inform a motoric response and effectively manage secretions. Length of mechanical ventilation, however, was not related to the presence of secretions. Contrary to a prior study examining a

heterogeneous group of patients with dysphagia (20), we found no association between hospital-acquired pneumonia and reduced laryngeal sensation. This lack of association might be due to inconsistent diagnostic criteria for pneumonia across sites, a small sample size, or insufficient follow-up after discharge. Furthermore, SLP intervention, including diet modifications, feeding strategies, and oral hygiene, might have minimized the incidence of pneumonia in this population, limiting our ability to detect an effect. Future research studies examining the effect of altered laryngeal sensation on pneumonia in a larger sample are warranted. In our cohort, non-white patients were more likely to have altered laryngeal sensation. This result was unexpected as there is no research, to our knowledge, that would suggest an association. Future studies will be necessary to determine the significance of this finding. Finally, patients with altered laryngeal sensation received more restrictive liquid and solid diet recommendations compared to patients with intact sensation, highlighting the clinical implications of changes in laryngeal sensation post-extubation.

We acknowledge that our study has several limitations. First, the FEES rater was not blinded to laryngeal sensation, aspiration, or secretions, but was an independent rater who did not participate in any of the primary data collection. Furthermore, explicit and objective definitions of each outcome were utilized to minimize bias. Secondly, inter- and intra-rater reliability was not reported. However, variable reliability has been previously reported with the touch method of laryngeal sensation testing (35); so to avoid the problem with variable rating secondary to differing levels of expertise, we chose to use the ratings of a clinician who is the foremost expert in FEES as the “best possible” answer. Thirdly, the present study used the ‘touch method’ of laryngeal sensation testing, which has demonstrated variability in pressures compared to the air pulse method (35, 36). However, the air pulse method has been shown to identify sensory impairments with greater frequency compared to the touch method, though the clinical significance is unclear as these sensory impairments were not associated with penetration or aspiration (37).

An area of interest that we were unable to study is the effect of a bilaterally absent LAR on the development of pneumonia, compared to a unilateral presentation. In our cohort, the pattern was nearly equally divided between unilateral and bilateral presentations. However, insufficient sample size limited our ability to examine this research question. Future studies should continue to explore the underlying mechanisms contributing to post-extubation dysphagia and further identify risk factors for altered laryngeal sensation. Doing so would be important to develop optimal treatment for this complex patient population.

Conclusion

This prospective, multi-site study reports a high prevalence of laryngeal sensory deficits in mechanically ventilated patients post-extubation. Altered laryngeal sensation was associated with aspiration and shown to have a more profound effect on aspiration risk in patients with a short length of mechanical ventilation. The presence of secretions and modified diet recommendations were also correlated with altered laryngeal sensation. These results demonstrate that laryngeal sensory abnormalities impact the development of post-extubation dysphagia and underscore the importance of routine assessment of laryngeal sensation in this patient population.

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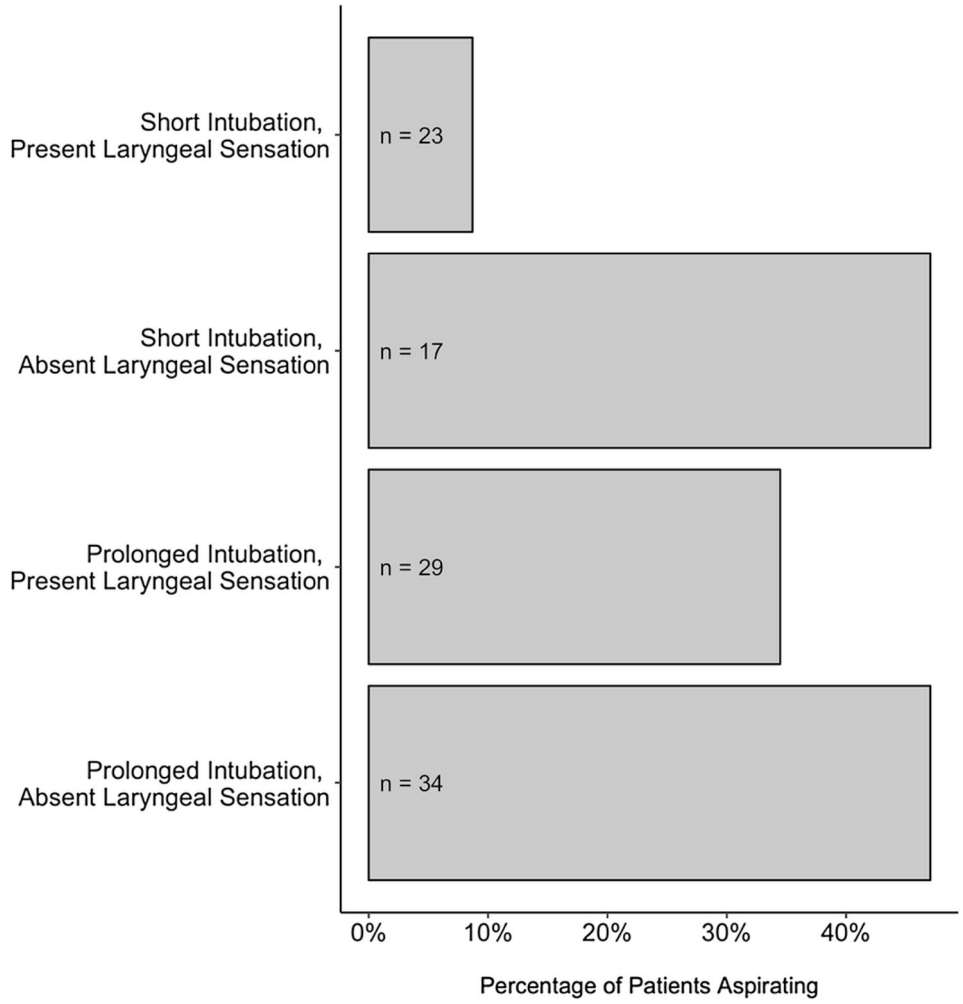

Figure 1:
Laryngeal Sensation, Length of Intubation, and Aspiration

Table 1:

Baseline Characteristics Between Patients With and Without Laryngeal Sensory Testing

	LAR performed (n = 110)	**LAR not performed (n = 31)**	***p* value**
Age	56.2 ± 15	61.1 ± 15	0.11
Gender (% male)	65%	59%	0.58
Service (% MICU)	72%	81%	0.43
Length of intubation (hours)	147 ± 92	153 ± 86	0.76
Frequency of aspiration	36%	46%	0.36

LAR = laryngeal adductor reflex; MICU = medical intensive care unit

Table 2:

Demographic Characteristics

	LAR present (n = 52)	LAR absent (n =51)	*p* value
Age (years)	54 ± 14	57 ± 16	0.30
Gender (% male)	65%	51%	0.14
Race (% Caucasian)	71%	29%	0.001
Height (in)	67 ± 4	66 ± 4	0.22
Weight (kg)	85 ± 24	92 ± 32	0.23
Primary service (% MICU)	81%	63%	0.04
Length of time from admission to intubation (hours)	7.5 [0.25 – 57]	20 [0 – 72]	0.54
Length of intubation (hours)	116 [70 – 187]	153 [72 – 216]	0.23
Length of time from extubation to FEES (hours)	36 [1 – 73]	36 [3 – 71]	0.91
Re-intubation			0.99
None	79%	78%	
Elective	8%	8%	
Urgent	13%	14%	
History of Myocardial Infarction	12%	27%	0.04
History of Congestive Heart Failure	19%	24%	0.59
History of Peripheral Vascular Disease	8%	12%	0.49
History of COPD	29%	27%	0.87
History of Connective Tissue Disease	2%	6%	0.30
History of Liver Disease	21%	27%	0.46
History of Diabetes Mellitus	19%	37%	0.04
History of Renal Disease	21%	20%	0.85
History of Solid Tumor	6%	6%	0.98

LAR = laryngeal adductor reflex; in = inches; kg = kilograms; MICU = medical intensive care unit; ETT = endotracheal tube; FEES = flexible endoscopic evaluation of swallowing

Table 3:

Laryngeal Sensation and Secretions, Pneumonia, and Diet Recommendations

	LAR present (n = 52)	LAR absent (n =51)	*p* value
Secretions			0.02
Normal/No excess	67%	38%	
Outside laryngeal vestibule	25%	48%	
Inside laryngeal vestibule	0%	8%	
Inside & outside laryngeal vestibule	8%	6%	
Hospital-Acquired Pneumonia	10%	8%	0.75
FEES liquid diet recommendations			0.03
NPO	10%	12%	
Honey-thick	0%	6%	
Nectar-thick	25%	43%	
Thin	65%	39%	
FEES solid diet recommendations			0.001
NPO	10%	12%	
Puree	8%	22%	
Mechanical soft	21%	43%	
Regular	61%	23%	

FEES = flexible endoscopic evaluation of swallowing; NPO = nothing by mouth