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Neurophysiology and Clinical Implications of the Laryngeal Adductor Reflex

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Abstract

The laryngeal adductor reflex (LAR) is an involuntary protective response to stimuli in the larynx. The superior laryngeal nerve (SLN) acts as the afferent limb and the recurrent laryngeal nerve (RLN) as the efferent limb of this reflex, which is modulated by the central nervous system. Perhaps the most clinically significant application of the LAR is its use in laryngopharyngeal (LP) sensory discrimination testing. Importantly, aberrations in the LAR may predict dysphagia or portend clinical phenotypes of chronic cough, vocal cord dysfunction or pediatric apneas. LP sensation is a potential target for interventions addressing the aforementioned conditions though currently remains an area of active investigation.

Keywords

LAR; glottic closure reflex; superior laryngeal nerve; laryngeal sensory testing; laryngopharyngeal sensation

Introduction

In humans, the LP complex serves three principle functions: airway protection, respiration and voice production. To accomplish and coordinate these fundamental tasks, we rely on a dynamic and efficient physiologic process generated from interactions of specialized

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Conflict of Interest

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anatomic components. To perform properly, the motor functions of the laryngopharynx are matched in importance by sensory contributions such as those producing the LAR. The primitive, protective function of the LAR to prevent against aspiration has been underscored by the finding that normal individuals maintain the reflex during various vocal tasks¹.

Definition

The laryngeal adductor reflex, also called the glottic closure reflex, is a mechanism of laryngeal protection, preventing material from inappropriately entering the upper airway. Mechanically, it is the bilateral thyroarytenoid (TA) muscle response to mechanical or chemical irritation of the laryngeal mucosa.

Review of Anatomy & Neural Circuitry

The LAR is a brainstem-mediated, involuntary reflex arc providing airway protection from ingested material². Mechanoreceptors and chemoreceptors in the LP mucosa receive innervation from the internal branch of the SLN, which serves as the afferent component of the LAR³. Sensory information is then transduced through the central nervous system via the nucleus tractus solitaries to the ipsilateral nucleus ambiguus in the medulla of the brainstem. The motor neurons within the nucleus ambiguus then project to the recurrent laryngeal nerve (RLN), the efferent component. In response to a unilateral stimulus, a discrete and rapid bilateral contraction of the TA muscles is produced.

Though brief, the neuronal mechanics responsible for this critical reflex are quite complex and have been extensively studied in humans as well as animal models. Much of our modern understanding of the neurophysiology behind the glottic closure reflex is a product of extensive work done in felines and canines by Sasaki and Suzuki during the late 1970's⁴⁻⁶. More recently, using a porcine model, Sasaki reported the important finding that the ipsilateral LAR is maintained but the contralateral LAR is extinguished in states of altered consciousness⁷. Contemporary investigations in rodents by Sun and colleagues have suggested that variable ipsilateral and contralateral efferent neuronal activity may be important for the coordination of breathing with the other LP behaviors of swallowing and cough⁸.

LAR Testing

The addition of sensory testing to flexible endoscopic evaluation of swallowing (FEES) is termed flexible endoscopic evaluation of swallowing with sensory testing (FEESST). FEESST directly evaluates LP sensation by assessing the ability of a tactile stimulus to elicit the LAR⁹⁻¹¹. Sensory testing may be grossly performed with the tip of the flexible endoscope or formally quantified with a LP air-pulse stimulator. A pulse of air is delivered to the supraglottic mucosa through a side-channel on the flexible endoscope. Each side is tested individually and is expected to elicit a bilateral response in persons with intact supraglottic sensation.

The pressure of the air-pulse delivered through the endoscope (mmHg) may be varied to quantify the amount of stimulus required to elicit the LAR^{9,12}. Aviv and colleagues

described normative sensory thresholds to calibrated pulses of air¹³. An individual with normal LP sensation manifests LAR at a pulse pressure of less than 4mmHg. Those requiring greater pressure are identified as having moderate (4 to 6mmHg) or severe sensory impairment (greater than 6mmHg). These thresholds correlate with psychophysical testing, or patient-reported sensation of delivered air pulses^{14,15}. Among normal individuals, the average threshold for eliciting the LAR is 2.60mmHg; this value differs significantly between age groups with an average threshold of 2.06mmHg in those less than 41 years and 2.97mmHg in those older than 60 years¹⁶.

A known limitation of LP sensory discrimination testing is poor interobserver agreement between endoscopists, but it is particularly useful in individuals with impaired cognition who are unable to participate in the subjective task of recognizing and confirming the presence of a palpable air pulse^{10,17}. Additionally, it has been shown that nasal anesthetic of either 0.05% oxymetazoline or 4% cocaine does not alter laryngeal sensory testing during FEEST¹⁸.

Other means of assessing the integrity of SLN function include traditional electromyography¹⁹ or less invasive, external electrodes that detect surface-evoked laryngeal action potentials²⁰. However, the utility and application of such methods continue to be defined and they have yet to be adopted into routine clinical practice.

Clinical Implications

Individuals with a diminished or absent LAR may be at risk for significant clinical consequences. In adults, increased LP sensory thresholds have been observed in those with prolonged tracheostomy, gastroesophageal reflux (GER), obstructive sleep apnea, chronic obstructive pulmonary disease, neurodegenerative disorders and advanced age^{16,21–25}. In these populations, sensory impairment may contribute to the development of dysphagia and aspiration. Furthermore, abnormal LAR thresholds may play a role in the spectrum of laryngeal hypersensitivity disorders such as chronic cough and vocal cord dysfunction²¹. The deleterious effects of altered LP sensation in adult and pediatric patients are reviewed in more detail below.

Dysphagia

In adults, altered LP sensation, especially when bilateral, is a risk for impaired and possibly unsafe swallowing. Aviv and colleagues reported a strong association between pharyngeal motor dysfunction, or abnormal pharyngeal squeeze maneuver (PSM), and decreased LP sensation among patients with dysphagia²⁶. They found that isolated pharyngeal motor dysfunction with intact LP sensation predicted penetration and aspiration with pureed consistencies whereas an isolated LP sensory deficit with an intact PSM predicted penetration and aspiration with thin liquids. Furthermore, nearly all patients with an absent LAR and PSM aspirated both thin liquids and purees^{27,28}. In a prospective study of 20 adults with cerebral strokes, Aviv found that an abnormal FEEST, even in the presence of a normal modified barium swallow, was associated with later development of pneumonia²⁹. This prompted the author's recommendation to consider sensory testing as an adjunct in guiding post-stroke dietary management in this population.

Other populations with LP sensory deficits manifested by abnormal LAR may be at particular risk for dysphagia. A study by Tabae and colleagues reviewed a cohort of individuals with unilateral vocal fold immobility of myriad etiologies. They found that 83% had abnormal SLN function on FEEST and over one-third with an absent LAR. Such deficits were associated with significantly higher rates of penetration and aspiration during trials of purees³⁰. Work by Phua and Aviv and their colleagues has shown that individuals with GER or chronic cough have, on average, elevated LAR thresholds and postulate that, as a consequence, may be at a higher risk of swallowing dysfunction^{21,31}.

Chronic Cough & Vocal Cord Dysfunction

It has been proposed that enhanced LP sensitivity may result from neural plasticity in the central nervous system which alters sensorimotor pathways including the LAR³². The clinical manifestations of these neurosensory changes have been termed the 'irritable larynx,' which is suggested to represent of spectrum of disorders including chronic cough, paradoxical vocal cord motion or vocal cord dysfunction, throat clearing, dysphonia and laryngospasm³². Heightened laryngeal sensitivity and decreased LAR thresholds have been reported as sequelae of viral upper respiratory infection³³, irritant exposure³⁴, GER, psychogenic conditions and tissue injury. Abnormal LAR testing in this population of patients may discriminate individuals with altered sensory thresholds from those who experience exposure to more stimuli or irritants.

Pediatrics

Thompson and colleagues have investigate LP sensation in populations of infants and children. In pediatric patients, they reported that increased LP sensory thresholds, or diminished LAR, resulted in a significantly higher likelihood of laryngeal reflux penetration and aspiration³⁵. Furthermore, infants with a history of apneas have been reported to have higher LAR thresholds than their age-matched counterparts³. The investigators propose that decreased LP sensitivity results in prolonged and excessive secretion exposure thereby inducing apnea among these infants. In turn, prolonged secretion exposure may promote LP edema, which could further increase LAR thresholds in these infants. Such consequences may represent a potential mechanism for the development of sudden infant death syndrome (SIDS) similar to neonates found to be at high risk for SIDS from apneas secondary to GER³⁶. Work in animal models lends support to these clinical observations³⁷ however the cause of SIDS remains speculative.

Interventions

Surgical, medical and behavioral therapies have been proposed for rehabilitation of the impaired LAR. In 1997, Aviv and colleagues reported restoration of normal LAR in two individuals with altered LP sensation following brainstem strokes by performing a neural anastomosis between the great auricular nerve and the superior laryngeal nerve¹². In a subsequent study, Aviv noted improved LP sensation, measured by LAR thresholds, in patients with laryngopharyngeal reflux (LPR) following the use of a proton pump inhibitor (PPI)³¹. Similar findings were also described in a pediatric population whose LP sensation improved with PPI treatment or Nissen fundoplication³⁸.

In individuals with primary complaints of cough, symptoms of GER or LPR, or vocal cord dysfunction, a significantly decreased LP sensory threshold was appreciated with the use of PPI and behavioral therapy including respiratory retraining³⁹. Also, gabapentin, a neuromodulator, has shown to be effective in some individuals with refractory chronic cough or throat clearing^{40–42}. Behavioral cough therapy, generally performed by trained speech language pathologists, has demonstrated decreased cough sensitivity, decreased urge to cough and increased cough threshold^{43,44}.

Conclusion

Our knowledge of LP sensation and the LAR continues to evolve, and our current understanding of its neuronal circuitry as well as its critical contribution to safe deglutition has influenced clinical application of the LAR, particularly as it is used in FEEST. Efficient and reproducible sensory testing using LAR has enabled implementation of preventative and therapeutic interventions to avoid deleterious consequences of LP sensory dysfunction. In addition to its relationship to dysphagia, impaired LAR is involved in the development and potentiation of chronic cough, vocal cord dysfunction and laryngospasm. Targeting LP sensory contributions to these conditions relies significantly on behavioral therapy and remains an area of active investigation.

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