Upper Airway Stimulation Therapy

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KEYWORDS

- Obstructive sleep apnea • Sleep surgery • Hypoglossal nerve
- Cranial nerve stimulation

KEY POINTS

- Obstructive sleep apnea (OSA) in adults is often a multifactorial process, with both mechanical and physiologic processes contributing to airway collapse during sleep.
- Contraction of the base of tongue provides support and stabilization of the posterior oropharynx through a complex interaction with the palate and oropharyngeal constrictors. This assists in maintaining a patent airway.
- Muscle tone during sleep is influenced by the loss of tonic muscle activity to the upper airway with sleep onset, CO_2-mediated ventilatory instability, and an inadequate activation of phasic genioglossus muscle reflex.
- Traditional surgical interventions for OSA address the mechanical (anatomic) contributions to OSA by altering soft tissue. The Inspire II implant is the first surgical intervention to address the physiologic processes that contribute to OSA.
- In a multicenter, prospective cohort study, patients were implanted with the Inspire II system and followed for 12 months. Apnea Hypopnea Index (AHI) decreased by 68% after implant, and 63% of patients had a postimplant AHI of less than 15 events per hour.

INTRODUCTION

Upper airway stimulation acts to reduce or eliminate upper airway collapse and resultant obstructive sleep apnea (OSA) by augmenting genioglossus muscle tone during sleep. It is unique among surgical interventions in that it does not attempt to reconstruct the structure of the upper airway, but rather augments mechanisms of physiologic compensation to prevent OSA. A novel approach warrants an understanding of these processes.

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MECHANISMS OF UPPER AIRWAY COLLAPSE AND PHYSIOLOGY OBSTRUCTIVE SLEEP APNEA

Overview

Airway collapse in OSA is the result of a complex interaction of both upper airway structural characteristics and ventilatory physiology during sleep. It is an imbalance between a structurally smaller (and therefore at-risk) upper airway and physiologic mechanisms that sustain breathing during sleep. The contribution of these 2 processes is highly variable between individuals and results in vast differences in the underlying physiologic disturbance responsible for an individual's OSA. But the consequence of this imbalance is an upper airway that is unable to maintain adequate ventilation to sustain life.

Anatomic Considerations

Multiple anatomic features contribute to the abnormal upper airway in OSA in adults. It is the common scenario that when combined they all contribute to a small upper airway, which when exposed to the stress of sleep onset and ventilatory (loop gain) instability leads to obstruction. Multiple structural phenotypes may exist that contribute to the risk of OSA.

Tongue anatomy

The tongue is a vital muscle that is responsible for a variety of functions, from speech and mastication, to maintenance of a patent airway and pharyngeal stability. The anterior tongue is responsible for speech and mastication, while the posterior tongue is responsible for maintaining pharyngeal stability. In people, the posterior tongue anatomically is not in the oral cavity but is the anterior wall of the pharynx. The differences in these functions are highlighted by distinct differences in both the anatomy and physiology of the anterior and posterior tongue musculature.

The human tongue is comprised of 8 pairs of skeletal muscles: 4 paired extrinsic muscles (with a bony attachment to anchor the tongue and movements) and 4 paired intrinsic muscles, with no bony attachments. Extrinsic muscle fibers originate from external bony attachments and terminate in the tongue, whereas intrinsic muscles both originate and terminate within the tongue. As a general rule, whole-tongue movements are attributed to extrinsic muscle function, whereas lingual-shaped changes are attributed to intrinsic musculature. The posterior tongue muscles are significantly more fatigue resistant than those of the anterior fibers because of a higher percentage of slow-twitch type I fibers. This is similar to the fatigue-resistant composition of cardiac and diaphragmatic muscle fiber composition, which are designed to withstand fatigue and constant, sustained activity. The high ratio of fatigue-resistant fibers is critical for functions requiring sustained, tonic contractions, as is seen in swallowing and maintaining airway stability.

Tongue-palate-oropharynx interaction

The anatomic and functional relationships between the tongue base and the superior pharyngeal constrictor and the tongue base and palate are key to understanding the potential benefit in using hypoglossal nerve stimulation to improve airway stability. The central third (the anterior wall) of the oropharynx is formed by the posterior aspect of the tongue. The superior pharyngeal constrictor muscle forms the muscular ring of the hypopharynx. Studies have shown that movements of the tongue create a forward mechanical drag on the superior constrictor muscle, which makes the pharyngeal wall stiffer and less compliant, therefore less prone to collapse. The stability of the oropharynx is not only dependent on the stiffness of the constrictor muscles