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CLINICAL REVIEW

Sleep, breathing and the nose

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Summary During sleep there is a discrete fall in minute ventilation and an associated increase in upper airway resistance. In normal subjects, the nasal part of the upper airway contributes only little to the elevation of the total resistance, which is mainly the consequence of pharyngeal narrowing. Yet, swelling of the nasal mucosa due to congestion of the submucosal capacitance vessels may significantly affect nasal airflow. In many healthy subjects an alternating pattern of congestion and decongestion of the nasal passages is observed. Some individuals demonstrate congestion of the ipsilateral half of the nasal cavity when lying down on the side. Nasal diseases, including structural anomalies and various forms of rhinitis, tend to increase nasal resistance, which typically impairs breathing via the nasal route in recumbency and during sleep. A role of nasal obstruction in the pathogenesis of sleep-disordered breathing has been implicated by many authors. While it proves difficult to show a relationship between the degree of nasal obstruction and the number of disturbed breathing events, the presence of nasal obstruction will most likely have an impact on the severity of sleep-disordered breathing. Identification of nasal obstruction is important in the diagnostic work-up of patients suffering from snoring and sleep apnea.

Abbreviations AHI, apnea–hypopnea-index (number of apneas plus hypopneas per hour of sleep); BMI, body mass index (weight in kilograms divided by height in meters squared); CPAP, continuous positive airway pressure, applied via nose- or facemask; CT, computerized tomography; ctrls, healthy control subjects; ENT, ear-nose-throat; FVLs, flow-volume loops; MP-H, mandibular plane to hyoid distance; MS, Mallampati score: clinical score used to evaluate accessibility for intubation; NARES, non-allergic rhinitis with eosinophilia syndrome; NO, nasal obstruction; NV, nasal ventilation; NR, nasal resistance; NREM, non-rapid eye movement sleep; NSD, nasal septum deviation; OSA, obstructive sleep apnea; PAS, posterior airway space; REM, rapid eye movement sleep; Sn-I, snoring index (count of snores per hour sleep); TVC, topical vasoconstrictor.

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Introduction

Breathing is a vital function based on the conduction of air through a system of branching tubes, that taper off and eventually connect to the alveoli. These are the functional respiratory units within the lungs. The primary function of the lungs is gas exchange: transporting oxygen from the environment into the blood and eliminating carbon dioxide from the blood to meet the metabolic demands of the body. The nose is the natural gateway for the air entering the body. Although the resistance to airflow is lower when the respiration follows the oral route, most individuals are habitual nose breathers. Indeed, the nose is physiologically fit

for priming the ambient air before it is conveyed to the distal respiratory tissues. It serves as an integrated system for air filtering, heating and humidification.

Sleep is known to alter the function of the respiratory system. The ventilation decreases in correspondence with the decline in metabolic demand, as the body turns to a state of rest. In addition, sleep resets the activity of the central nervous system in a way that voluntary control over breathing is lost. The disappearance of the state of wakefulness directly affects the control of breathing, making the respiratory neurons in the brainstem less responsive to afferent stimuli. Overall, there is a net hypoventilation during sleep as a consequence of a decreased respiratory drive and an increased respiratory resistance.

The nose is affected by sleep in several ways. Recumbency is the preferred sleeping posture in man. Nasal resistance is prone to increase in this body position. Moreover, the naturally occurring pattern of cyclical and alternating mucosal congestion in the nasal passages may be altered. These effects may be aggravated in certain pathologic nasal conditions. Finally, the nasal route of breathing may be switched to oro-nasal respiration in sleep.

The aim of this article is to review the current state of scientific knowledge regarding the relationship between nasal function, breathing and sleep, including:

- the effect of sleep on breathing
- nasal anatomy and function
- physiological adaptations of the nose to sleep
- the effect of nasal pathology on breathing during sleep
- the role of nasal obstruction in snoring and sleep-disordered breathing

The discussion of current treatment options is a different matter, for which the reader is referred to other available sources.

Normal nasal conditions

Sleep and breathing

The effects of sleep on spontaneous breathing in humans are well-established and have been extensively reviewed by Krieger.[1] To provide a detailed description of the sleep-related respiratory changes is beyond the scope of this article. Briefly, it has been shown that during drowsiness and light non-rapid eye movement (NREM) sleep an oscillating breathing pattern and an overall moderate decrease in ventilation may appear in many normal subjects.[2] The observed periodicity of breathing seems to be due to a combination of unsteady sleep and instability of the central respiratory drive. Because the ventilatory system is controlled by negative feedback, it is prone to cyclical instability. Most often, the respiratory periodicity parallels the variations in the level of vigilance. In deep NREM sleep, however, the pattern of breathing is regular and the tendency to hypoventilate even more pronounced.[2,3] This hypoventilation seems to be the result of both decreased ventilatory drive and increased upper airway resistance.[4] In contrast with the wake state, small increases in resistance to airflow are not compensated for by increased work of breathing during steady NREM sleep.[5] Rapid eye movement (REM) sleep is characterized by irregular and shallow breathing. The erratic appearance of the breathing pattern is due to sudden changes in both amplitude and frequency of the respiratory cycle.[2] Bouts of irregular and decreased breathing are often synchronous with REM bursts.[2,6] This phenomenon is most probably of central origin and related to REM sleep processes .

The nose and breathing

The nose and paranasal sinuses constitute a complex system of interconnecting cavities. This functional complex, which is the interface between the ambient air and the lower airways, serves many physiologic purposes, including air filtering, humidifying and warming. As such, the nose is the only means of bringing appropriately conditioned air into the lungs. In addition, it is the initial platform for launching immunologic responses against potentially noxious agents. Finally, contact between the inspired air and the olfactory nerves, located in the roof of the nasal cavity, provides the sense of smell, which is closely associated with the taste sensation. In their recent article, Van Cauwenberge et al. provide a detailed review of the nasal anatomy and physiology.[7]

Anatomy of the nose

Paired nasal bones and upper and lower lateral cartilages are the supporting parts of the external nose (Fig. 1). The internal nasal cavity is split into a right and left half by the nasal septum (Fig. 2). The nasal cavity extends from the nares anteriorly to the choanae posteriorly. The choanae separate the nasal cavity from the nasopharynx. From both lateral nasal walls an inferior, a middle and occasionally a superior turbinate project medially and inferiorly into the nasal cavity. The portion of