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Nasal physiology in children

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Although the function of the nasal airway in the child is the same as in the adult (Table 1), there are several unique features of the nasal airway in childhood which require consideration to understand the effect of nasal dysfunction in children.

Table 1. Functions of the nose

1. Air passage for breathing
2. Warms and humidifies inspired air
3. Removes particulates and vapors from inspired air
4. Immunologic monitoring of inspired air
5. Olfaction

The most obvious difference between the nasal airway in childhood and in the adult are its dimensions (Livingstone, 1932). The nasal airway in the newborn is obviously smaller than in the adult. This is reflected in the resistance to airflow. Although there are no systematic studies of the changes in nasal resistance from newborn to adult, a composite graph using data obtained from several sources demonstrates a decrease in nasal resistance from newborn to adult (Figure 1).

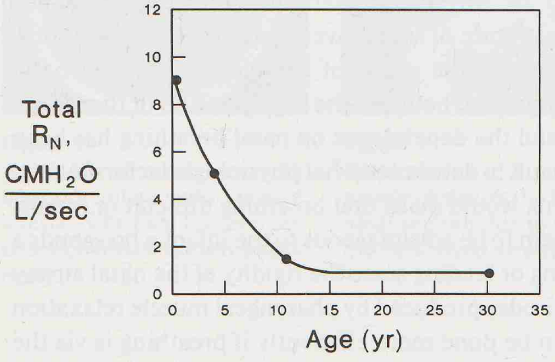

Figure 1.
Graph showing the decrease in nasal resistance with increasing age from infancy to adulthood. See text for sources of data.

The resistance to airflow in the newborn is approximately four times that in the adult and the variability in resistance is much greater (Lacourt and Polgar, 1971). This variability in resistance may suggest an immaturity in the vasomotor control of the nasal mucosa in the child. This immaturity is further suggested by the ap-

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parent lack of an established nasal cycle of alternate congestion of the nasal airways (Van Cauwenberge and Deleye, 1984). Van Cauwenberge and Deleye studied 26 children, age three to six years, using anterior passive rhinomanometry and found no evidence of an alternating fluctuation of nasal resistance (Van Cauwenberge and Deleye, 1984). There was variation in nasal resistance noted but these changes occurred simultaneously in both nasal passages. Instead of producing a stabilization of total nasal resistance as in the adult, this type of solitary cycling produces a variation in the total nasal resistance in the child throughout the day. This variability makes it difficult to establish absolute values for nasal resistance in children. The presence of a true nasal cycle has not been investigated in detail in the newborn; however, the data of Lacourt and Polgar do suggest that nasal resistance in the newborn does fluctuate in the solitary fashion described by Van Cauwenberge in older children; that is, both right and left nostrils change resistance together in most cases (Lacourt and Polgar, 1971; Van Cauwenberge and Deleye, 1984). These observations of greater variability in nasal resistance and the absence of a normal nasal cycle in children imply immaturity of the vasomotor control of the nasal mucosa.

A unique feature of the nasal airway in children is the dependence of the newborn on nasal breathing. It is apparent to those who manage rhinologic problems in infants that bilateral nasal obstruction in the newborn produces significant distress, intermittent cyanosis, apnea and major feeding problems. Complete unilateral nasal obstruction, while it does not produce severe respiratory distress in infants, can produce significant feeding problems if the contralateral nasal airway intermittently becomes obstructed by physiologic variation in nasal resistance (Masing and Horbaschk, 1969). In spite of some investigations, it has been difficult to determine which factors are the cause of this dependence on nasal breathing in the infant. The correlation between the high position of the larynx and epiglottis in the newborn and the dependence on nasal breathing has been made, although it has been difficult to determine what physiologic factors related to this high position of the larynx would make oral breathing difficult or impossible. Nasal breathing would seem to be advantageous to the infant who spends a large portion of the time sleeping or feeding since the rigidity of the nasal airway would minimize obstructive episodes produced by pharyngeal muscle relaxation during sleep. Also, suckling can be done more efficiently if breathing is via the nasal airway. Although these suggestions may in part justify the fact of obligatory nasal breathing in childhood, it does not provide evidence of the mechanism for this dependence on nasal breathing.

Laçourt and Polgar (1971) found that there are reciprocal changes in nasal and pulmonary resistance in the newborn. Changes observed in nasal resistance were in opposite direction to pulmonary resistance changes resulting in a stabilization of total airway resistance. This may be more important in the respiratory regula-

tion of the newborn since similar changes have not been consistently observed in the adult airway.

Several pathologic conditions illustrate the dependence of the newborn on nasal respiration. Total obstruction of the nasal airway as a result of choanal atresia (Figure 2) or the presence of large intranasal masses either congenital, such as a glioma (Figure 3), or acquired, such as polyps, may cause respiratory distress in a newborn. This degree of obstruction is sufficient to produce feeding problems, delayed physical and mental development, and respiratory distress. Relief of the obstruction, preferably by early repair of atresia or removal of the obstructing mass reverses these pathologic changes. Alternatively, maintenance of an oral airway and gastric tube feedings may be necessary until repair can be accomplished.

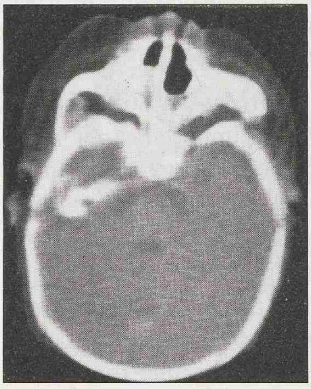

Figure 2.
Axial CT of nasal airway in newborn infant with choanal atresia. Note total bilateral obstruction of nasal airway posteriorly.

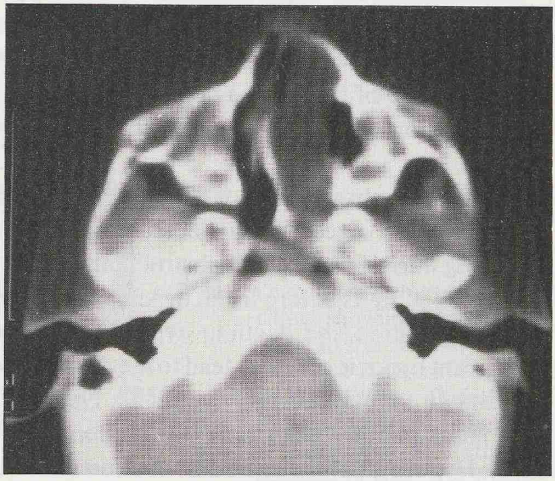

Figure 3.
Nasal glioma in 8 month old child. The glioma completely obstructs the left nasal airway. Deformity of the nasal septum due to the large intranasal mass narrows the right nasal airway.

The problems associated with nasal airway obstruction in the older child are less dramatic than those in the newborn. In the older child, acquired diseases such as rhinitis, either allergic or vasomotor, and nasal polyps or adenoid hypertrophy replace the congenital problems more prevalent in a newborn as the cause of obstruction. Prolonged increased nasal resistance in the older child may lead to chronic mouth breathing. This posture of the open mouth may alter the forces molding the upper dental arch and result in a high-arch palate, a narrow dental

arch with malocclusion and the characteristic adenoid facies. The adenoid facies is characterized by a nose that appears to be flattened with a small underdeveloped nostrils, a short upper lip and an open mouth. Three etiologic mechanisms have been proposed to explain how nasal obstruction with resultant mouth breathing can influence craniofacial and dentofacial development (Bushey, 1979).

1. The compression theory proposes that narrowing of the upper alveolar arch results from unbalanced muscular forces due to the low tongue position with compression of the maxilla by excessive facial muscle and soft tissue tension due to the open mouth posture.
2. The disuse atrophy theory proposes that nasal obstruction causes atrophy of the nasal passages with resultant elevation of the palatal vault and associated narrowing of the upper dental arch.
3. Finally, abnormal aerodynamic forces and decreased nasal respiration may influence dentofacial form. It is probable that some combination of these factors is the cause of the altered dentofacial growth in children with chronic nasal obstruction.

More recently, observations of sleep apnea in children with nasal obstruction and with oral pharyngeal airway obstruction indicate the importance of nasal breathing during sleep. Nasal obstruction can produce intermittent hypercapnea and hypoxia. In its severe form, hypercapnea or hypoxia during sleep can cause sleep deprivation and daytime hypersomnolence (Guilleminault et al., 1976). Significant hypoxia also may lead to the development of pulmonary hypertension resulting in cor pulmonale (Levey et al., 1967) Although this is usually seen with both nasal and oro-pharyngeal obstruction, it can occur with nasal obstruction alone. Hypoventilation with nasal obstruction alone may occur since the oral airway, unlike the nasal airway, is not rigidly supported by bone or cartilage. During inspiration, the negative airway pressure as a result of a high nasal resistance can cause collapse of the oropharyngeal airway with resulting increased resistance and possibly total obstruction. Documented symptomatology of sleep apnea in children includes excessive daytime sleepiness, snoring, nocturnal enuresis, decreased school performance, morning headaches, mood and personality changes, weight problems and hypertension.

The mucociliary system functions to maintain a continuously renewed mucous blanket on exposed nasal mucosal surfaces. This provides for warming and humidification of inspired air and removal of gaseous and particulate irritants from the air stream. Dysfunction of the mucociliary system in childhood may result in sinusitis and in cases in which there is generalized ciliary dysfunction, bronchiectasis or chronic pulmonary infection may result.

Inflammatory changes in the nasal mucosa as a result of viral or allergic rhinitis

may transiently alter the physical properties and quantity of nasal mucous and ciliary function. Persistant alterations in nasal function, however, are rare. But two congenital diseases should be discussed with respect to their effect on nasal mucociliary function.

In 1933 Kartagener reported a triad of sinusitis versus, situs inversus, and bronchiectasis. It was not until 1976 that Afzelius identified the cause of the defect. He found that a genetic defect produces immotile cilia and spermatozoa. Viewed under the electron microscope, spermatozoan tails and cilia were relatively normal except that dynein arms were not present (Figure 4). These structures are necessary for generating the movements of cilia and spermatozoan tails (Inbrie, 1981).

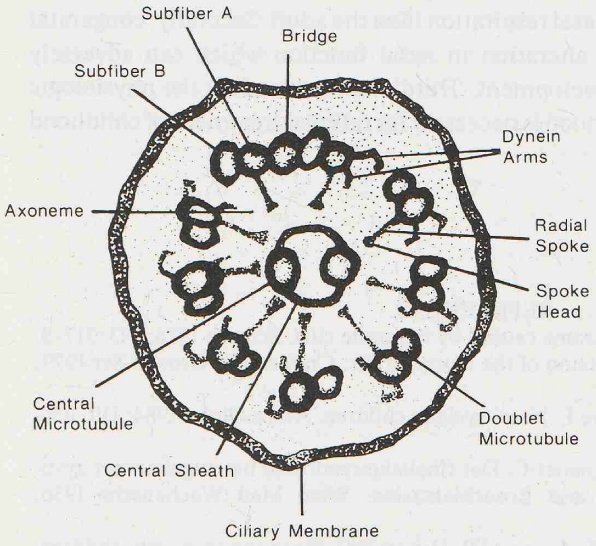

Figure 4.
Diagram of a cross section of a cilium showing component parts. In the immotile cilia syndrome the dynein arms are absent. (From J. D. Imbrie. Kartagener's syndrome: A genetic defect affecting the function of cilia. Am J Otolaryngol 2:215–222, 1981).

Patients with immotile cilia syndrome may have variable manifestations in both the upper and lower respiratory tract. The triad of cough, sinusitis and otitis is a consistent findings while situs inversus is seen in only one-half the patients. Nasal polyps are a frequent finding in these patients and because of the relative rarity of nasal polyps in children, the presence of polyps should suggest a differential diagnosis of this syndrome. The nasal clearance test using sacharine applied to the tip of the inferior turbinate will be negative in these patients. Definitive diagnosis is based on ultrastructural examination of respiratory mucosa from the nose.

Another congenital disorder which may alter nasal mucociliary function in children is cystic fibrosis. The disease was originally reported by Franconi et al. in

1936. This disorder is a hereditary disease transmitted as a mendelian recessive trait. It is a generalized disease involving eccrine and mucous secretory glands producing an increase viscosity of mucous. Although multiple organ systems are affected, most deaths are due to chronic pulmonary infections. Chronic sinus infection occurs in most patients. The patients develop nasal polyps as early as two years of age. This disorder, like the immotile cilia syndrome is one of the rare causes of nasal polyps in childhood. The altered physical properties of the nasal mucosa associated with chronic infection is the most likely etiology for the sinusitis and polyps which occur in this disease.

In conclusion, there are several unique features of the nasal airway in childhood which take on special importance in normal growth and development. Firstly, the child is more dependent on nasal respiration than the adult. Secondly, congenital abnormalities may produce alteration in nasal function which can adversely effect normal growth and development. Thirdly, understanding the physiologic functions of the nose in childhood is necessary for rational treatment of childhood nasal disorders.

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