DEVELOPMENT, STRUCTURE AND FUNCTION OF THE UPPER AIRWAYS.

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Introduction
The upper airways (UAW) are more and more understood as an integral part of the airconducting system. The concept of “united airways” with all its implications for clinical medicine increases the importance of understanding the structure and function of the upper airways. The upper airways include the airways from the nose down to the thoracic inlet including all the adjacent spaces, such as paranasal sinuses. The structure and function of the UAW have significant influence upon the conduction of the air to the lower airways, not only due to the anatomical structure but also due to the function of the mucosa, neural and lymphatic tissues. The main function of the upper airways is cleaning and conditioning of the air conducted into the lower airways. The upper airways protect the lower airways and participate in the phonation. The nose works as a sensory organ hosting the phylogenetically oldest sense – olfaction.

Development of the upper airways
The development of the upper airways is determined by the development of the skeletal system of the head but is also closely related to the development of the gastrointestinal system.

The development of the skull occurs in two major phases: The development of neurocranium, the protective case for the brain, and viscerocranium forming the skeletal part of the face. Most of the structures of the face and neck originate from the pharyngeal arches. Pharyngeal arches consist of an outer layer of ectodermal tissue and an inner layer of epithelium of endodermal origin, both enclosing the core of mesenchymal tissue. Mesenchyme for the formation of the cranial structures is from paraaxial and lateral plate mesoderm, together with a substantial part of neural crest cells. Neural crest cells contribute to the skeletal components of the face. The mesodermal component of the pharyngeal arches forms the muscular tissue of the face and neck [1]. The neural crest cells represent a particularly vulnerable cell population and are rather sensitive to the effects of toxic or teratogenic agents. Therefore, various craniofacial defects and abnormalities are rather frequent among all birth defects. The development of the nasal cavity dates into the sixth post-conceptual week. From the original nasal pits forms the primitive nasal cavity separated from the primitive oral cavity by the oronasal membrane. Primitive choanae connect the nasal and oral cavities immediately behind the primary palate. With the development of the secondary palate, the final choanae form at the junction of nasal cavity and pharynx. At the same time, the nasal conchae (upper, middle and lower) develop, emerging from the lateral wall of the nasal cavity. The nasal septum forms from the fused nasal processes and grows caudally, finally merging with the palatine shelves. Ectodermal layer located on the ceiling of the nasal cavity transforms into olfactory epithelium, with some of the cells differentiating into olfactory receptors (neurons) whose axons form the olfactory nerves. Axons of these neurons grow into the olfactory bulb in the anterior brain [2].
The development of the face and all the structures of the viscerocranium are influenced by the development of the paranasal sinuses. With the development of air sinuses the face obtains its final shape. At birth, the maxillary sinus is about 8 mm deep, 4 mm wide and about 3 mm high. The growth continues after birth and the development is finished only at early adulthood. The frontal and sphenoidal sinuses are not detectable at birth, and their main development begins at approximately 2 years of age. Frontal sinuses can usually be detected on the x-ray only at an age of about 7 years.

**Larynx**

The development of the larynx is associated with the development of lower airways. At the post-conceptual age of 4 weeks, a bud outgrows from the ventral part of the foregut forming the respiratory diverticulum which communicates widely with the foregut. Later on, trachea and oesophagus separate by the formation of oesophagotracheal septum. Cartilaginous tissues from the fourth and sixth pharyngeal arches fuse and form the arytenoid, thyroid, cricoid, corniculate and cuneiform cartilages. The laryngeal cartilages, including the epiglottis, originate from the mesenchymal tissue. The muscles originating from the fourth arch (cricothyroid, levator palatine, pharyngeal constrictors) are innervated by the superior laryngeal nerve, whereas the laryngeal muscles (with exception of the cricothyroid) are supplied by the nerve from the sixth arch, the laryngeal recurrent nerve. At about 6 weeks of gestational age rapid proliferation of the laryngeal epithelium leads to temporary occlusion of the lumen. After recanalisation at about the age of 10 weeks, there remains a pair of lateral recesses (laryngeal ventricles). Around them, both true and false vocal cords differentiate. Within a further 6 weeks, the larynx develops almost its definitive appearance with the formation of thyroid, cricoid and arytenoid cartilages from the mesenchyme, and further differentiation of epiglottis and arytenoids [2]. The growth of the larynx is accelerated during the first 3 years of postnatal life and gradually the epiglottis achieves its final shape. Major postnatal changes occur in the first year of life and then during the pubertal growth spurt. The hyo-laryngeal complex descends during postnatal life mainly relative to the jaw, face and cranial base. Its position relative to the vertebral column remains relatively stable from the end of the second year of life. The descent of hyoid-laryngeal complex together with the mobility of the tongue allows formation of a wide range of sounds [3].

**Lymphatic tissue**

The upper airways are equipped with well-developed defence structures represented by a system of lymphatic tissue. This is known as Waldeyer ring and consists of the lymphoid tissue in the nasopharynx (pharyngeal tonsil or adenoid tissue), lymphatic tissue at the base of the tongue (lingual tonsil) and the two faucial tonsils. The main task of this lymphatic system is to serve as defence against infection. It has been documented that the size of the adenoid tissue depends on the development of the whole nasal cavity and the palate. Accelerated growth of this tissue may predispose to upper airway obstruction. This usually results in converting nasal breathing to mouth breathing, thus leading to exclusion of the positive influence of the nasal mucosa and secretions upon the inspired air. Enlarged adenoids, together with enlarged tonsils, are the most frequent cause of the paediatric obstructive sleep apnoea syndrome.

**Functional aspects of the upper airways**

The upper airways are mainly involved in the conduction and conditioning of the air to the lower airways. The nose regulates the air stream, prewarms, cleans and humidifies inhaled air. Nasal mucus can hold up to about 70% of passing dust particles. Soluble particles get dissolved in the mucus, non-soluble particles are held by the outer mucus layer and moved
towards the nasopharynx by the ciliary activity. The frequency of ciliary beating in the nose is between 4 and 10 beats per second (Hz) and is influenced by temperature, viscosity of the mucus and osmotic properties. The direction of the ciliary movement on the respiratory epithelium in the paranasal sinuses is always towards the ostium, thus bringing the secretions from the sinuses to the nasal passage. The same system of ‘mucociliary elevator’ also works in the lower airways. The frequency of ciliary beating in the lower airways is higher, and the direction of the co-ordinated movement is towards the pharynx. The activity of respiratory cilia may be negatively influenced viral infections or environmental agents (e.g. cigarette smoke or air pollution) leading to impairment of mucociliary clearance. Primary defects of ciliary function are mostly caused by congenital defects of the structure of the cilia. Primary ciliary dyskinesia leads to permanent insufficient clearing of secretions from upper and lower airways. This results in recurrent and chronic infections and in the gradually developing severe damage of the whole respiratory tract. Chronic sinusitis, otitis and bronchitis with the development of bronchiectasis are the main problems and damage of lung parenchyma by chronic bacterial infections determines the prognosis [4].

The functional co-ordination of the upper airways during breathing is a very complex event. The pharyngeal airway is not sufficiently supported by bony or cartilaginous structures and tends to collapse when exposed to negative pressure during inspiration. This is compensated by a co-ordinated neuromuscular activity during inspiration. The equilibrium of the negative pressure generating muscles and the airway dilating muscles guarantees patency of the upper airways. Discoordination may lead to increased collapsibility of the pharyngeal airway during inspirium. During sleep, the activity of the airway dilating muscles is usually diminished. If combined with some anatomical factors that lead to narrowing of the upper airway, a marked collapsibility can develop. This obstruction of the airways during sleep can lead to breathing disturbances of various severity – from simple snoring to severe apneic episodes with severe hyposaturations [5].

**Conclusion**

The upper airways play an important role in the respiratory function. The interrelation between respiratory and gastrointestinal systems and the need of proper coordination of both systems during breathing and swallowing impose high requirements on structure and function of both systems. Evaluation of the structure and function of the upper airways should be included into diagnostic processes in patients with respiratory problems. In many diseases of the lower respiratory tract, treatment cannot be successful unless a concomitant pathology of the upper airways is under control.

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**References**