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Anatomy of the Upper Airway and Its Growth in Childhood

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Abstract

Because several craniofacial anomalies are related to the narrow upper airway, for example narrow maxilla or retruded mandible, orthodontists and oral and maxillofacial surgeons are involving diagnosis and treatment of paediatric obstructive sleep apnoea. The knowledge of anatomy of the upper airway and its growth change in childhood is crucial for both clinical and research purposes.

Keywords: Anatomy; Upper airway; Childhood; Nasopharynx; Oropharynx

Introduction

Anatomy of the upper airway

The upper airway is also called the upper respiratory tract [1,2]. It includes the nose, nasal cavity, sinuses and pharynx [2]. If using the boundary of the chest cavity, it can include larynx and upper trachea [1]. In studies investigating obstructive sleep apnoea (OSA) or sleep-disordered breathing (SDB), which focus on the potential obstruction of the upper airway, the term 'upper airway' typically refers to the 'pharynx and its surrounding structures' [3].

The pharynx is a muscular tube posterior to the nasal cavity, oral cavity and larynx, and anterior to the cervical vertebrae [1,2]. It lies from the skull base to the lower border of the cricoid cartilage. For descriptive purposes, the pharynx is typically divided into three anatomic parts: the nasopharynx, oropharynx and laryngopharynx (hypopharynx) [4].

The nasopharynx is located above the soft palate, and communicates anteriorly with the nasal cavity. The adenoid (pharyngeal tonsil) is a collection of nodular lymphoid tissue located on the superoposterior roof of the nasopharynx. It also extends laterally into the pharyngeal recess [5].

The oropharynx is located above the soft palate, and under the upper border of the epiglottis. It communicates anteriorly with the oral cavity, and has the posterior one-third of the tongue and soft palate as its anterior border. The posterior wall of the oropharynx comprises the superior, middle, and inferior constrictor muscles. The lateral oropharyngeal walls are formed by muscles, lateral parapharyngeal fat pads and lymphoid tissues (primarily the palatine tonsils). In the midsagittal view, the oropharynx can be subdivided into retropalatal part and retroglossal parts [3].

The retropalatal part of the oropharynx is bounded by the level of the hard palate to the caudal margin of the soft palate. The soft palate is the removable posterior third of the palate, and does not contain a bony framework. The end of the soft palate is a midline pendulous projection, which is called the 'uvula'. Two arches support the soft palate (i.e. the palatoglossal and palatopharyngeal arches). The palatine tonsils are rounded lymphoid tissues which are located in the triangular interval between the anterior and posterior arches [5].

The retroglossal part of the oropharynx is bounded by the caudal margin of the soft palate and the tip of the epiglottis. The dorsum of the posterior third of the tongue comprises the anterior border of the retroglossal oropharynx. It contains numerous mucous-producing glands and lingual tonsils (lymph follicles). The hyoid bone is a floating bone that lies below the mandible and at a level opposite the lower portion of the third and upper portion of the fourth vertebrae. It provides attachments to the tongue muscles [3,4].

The laryngopharynx is posterior to the larynx, and extends from the superior surface of the hyoid bone and inferior to the lower border of the cricoid cartilage, where it becomes continuous with the oesophagus [3,4].

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Growth of the upper airway in childhood: Growth of the nasopharynx: Scheerer et al. [6] used a special impression technique, and found the volume of the nasopharynx increased from 3 years until to maturity. Using a computed tomography (CT) scan, Li et al. [7] recently reported that the volume of the nasopharynx increased from 6 to 18 years of age. However, whether this increase is steady remains controversial.

A longitudinal study by Jeans et al. [8] showed that the area of the nasopharyngeal airway decreased slightly from 3 to 5 years of age because of the nasopharyngeal soft tissue growing more rapidly than the nasopharynx airway. After 5 years of age, the soft tissue area remained relatively constant; hence, the nasopharyngeal airway enlarged steadily up to 9 years of age. Afterward, a more rapid increase occurred until the age of 13 years, followed by a slow increase until 19 years. However, Arens et al. [9] found that the nasopharyngeal airway dimension was maintained proportionally to the skeletal structures between 1 year and 11 years of age.

The adenoids form the major part of the nasopharyngeal soft tissues [8] and the size of the adenoids increases from birth until its peak between 7 years and 10 years of age before steadily decreasing throughout adulthood [10]. That the dimensions of the nasopharyngeal airway do not follow the size change of the adenoids may be due to the balance between the adenoids and the bulk of the muscles [8].

The main growth direction of the nasopharynx is vertical. Its vertical height increases continuously until maturity (in boys until 18 years of age or later, and in girls until approximately 13 years of age) [11]. The depth of the nasopharynx is established early in life. The dimension from the atlas to the posterior nasal spine is stable after 1 or 2 years of age. The bihamular width of the nasopharynx remains stable as well after 2 years of age, but the choanal width of the nasopharynx increases moderately until maturity [8,11].

Growth of the oropharynx: The volume and area of the upper airway increases continuously from childhood into adulthood [7,12], but the types of the increase differ in its 3D directions.

In the sagittal direction: The increase in the sagittal direction (i.e. the depth) exhibits the least growth. Mislik et al. [13] investigated the lateral cephalograms of 880 children aged 6-17 years, and found the distance 'p' (shortest distance between the soft palate and posterior pharyngeal wall) and 't' (shortest distance between the tongue and posterior pharyngeal wall) increased slightly from 6 to 17 years of age. The change in 'p' was from 8.1 to 9.2 mm, whereas that of 't' was from 10.6 to 11.2 mm. Therefore, they concluded that the upper airway dimensions were established in early childhood and remained stable thereafter.

However Taylor et al. [14] investigated the longitudinal cephalograms of 32 children (16 boys and 16 females) aged 6 to 18 years, and reported that the oropharynx was still growing throughout the observational period. Moreover, two periods of accelerated changes were found (6-9 years and 12-15 years), in addition to two periods of quiescent changes (9-12 years and 15-18 years).

Examining the 3D CT scans of 281 Chinese children aged 6 to 18 years also showed small changes in the depths of the oropharynx [7]. Another study on lateral cephalograms from 239 Taiwanese participants aged 7 to 27 years also revealed that the depth of the oropharyngeal airway increased significantly from childhood into adulthood [15].

In the vertical direction: Chiang et al. [12] and Ronen et al. [16] have reported on a significant pharyngeal length increase and gender differences. Chiang et al. [12] indicated that the length of the airway increases up to 15 years of age, and remained stable in females, but continued to increase in males. Ronen et al. [16] found that, in the prepubertal period, the airway length was similar in boys and girls. After puberty, however, the airway length was significantly greater in boys than in girls.

In the transverse direction: Only 3D techniques can be used to measure the width of the upper airway. Extant data are scant. The data obtained by Li et al. [7] showed that the width of the oropharyngeal airway increased more than its depth from 6 to 18 years of age.

Growth of the surrounding structures of the oropharynx

The growth in the length of the soft palate is most rapid early in life (1.5 to 2 years of age). Soon after, there is little to no increase from 1.5 to 4 or 5 years of age. After this period, the growth resumes steadily, increasing until late adolescence or early adulthood [17]. The most rapid increase in the thickness of the soft palate occurs during the first year of life, after which the increment is minor. Maximum thickness is reached by 14 to 16 years of age. The inclination of the soft palate (angle formed between the soft and hard palates) becomes progressively more acute with age.

The palatine tonsils are large during the childhood and begin to atrophy at the onset of puberty [5].

The tongue grows until maturity in relation to the intermaxillary space with age. The tongue concurrently descends in the oral cavity, which compensates for the increase in bulk, and maintains tongue function during growth [18].

During the growth period, the hyoid bone descends with the mandible and the vertebrae, and its relatively stable superioinferior position between the third and the fourth vertebrae is maintained [19]. The hyoid bone may move forward slightly during puberty in relation to the cervical vertebrae [20].

Growth of the hypopharynx: Measured from the level of the epiglottis, the increase in the depth of the hypopharynx is greater than that of the oropharynx. Males exhibit a greater increase compared with females in the depth of the hypopharynx after the per-pubertal period [7,15].

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