Chapter 1

Anatomic consideration for airway management

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Introduction

Surface structures of the head and neck that are relevant for airway management include the nose, mouth, and the cricothyroid area. These structures represent access points to the airway for mask ventilation, elective intubation, and emergent access for airway control (Figure 1.1). For most of the population, the nose, mouth, and oropharynx are easily identified. Identifying the cricothyroid membrane requires knowledge of the anterior neck and the skill set necessary for locating it. Ultrasound has improved the ability to identify the cricothyroid membrane.[1,2]

The nose and mouth, located on the anterior face, are easily accessed unless congenital anomalies, trauma, radiation, or prior surgery have complicated the anatomy. The cricothyroid membrane is located below the surface of the anterior neck.

This chapter will review the anatomy of the airway while highlighting surface and functional anatomy. The respiratory and digestive systems will also be discussed in regard to how they may impact airway management.

Nose

The nose participates in a number of functions – olfaction, phonation, humidification, respiration, and filtration.[3] The anatomy of the nose can be divided into two sections, the external nose and the nasal cavity including the septum.[4]

The upper one-third of the bony external nose connects the nasion to the forehead. The lower two-thirds is cartilaginous, consisting of two alar cartilages. The tip consists of fibrocartilage that helps to maintain the shape of the nose.

The nasal cavity encompasses the vestibule anteriorly and stretches to the nasopharynx posteriorly. This cavity is divided by the midline septum, which is composed of both cartilage and bone. The septum comprises the ethmoid bone descending from the cribriform plate, vomer, and septal cartilage. The lateral walls of the nasal cavity are composed of a series of turbinates – superior, middle, and inferior. The turbinates divide the nasal fossae into meatuses. The turbinates are lined by ciliated columnar epithelium, which aids in filtration and protection. The inferior turbinate determines the size of the endotracheal tube that may be passed nasally (Figure 1.2).

The end branches of the carotid arteries, both internal and external, supply the nose. The area above the middle turbinate is supplied by the anterior ethmoidal arteries. The remaining

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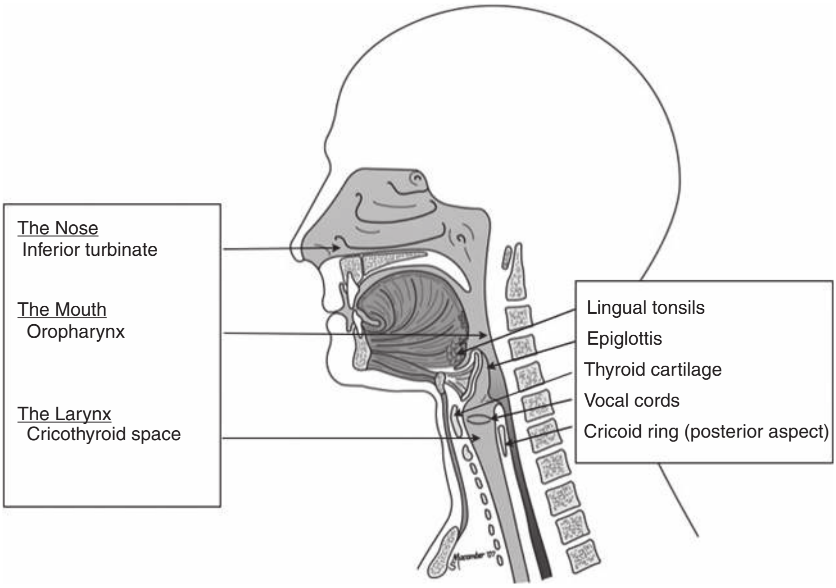

Figure 1.1 The nose, the mouth, and the cricothyroid area are three potential access points for airway management. The cricothyroid membrane is not shown in this figure

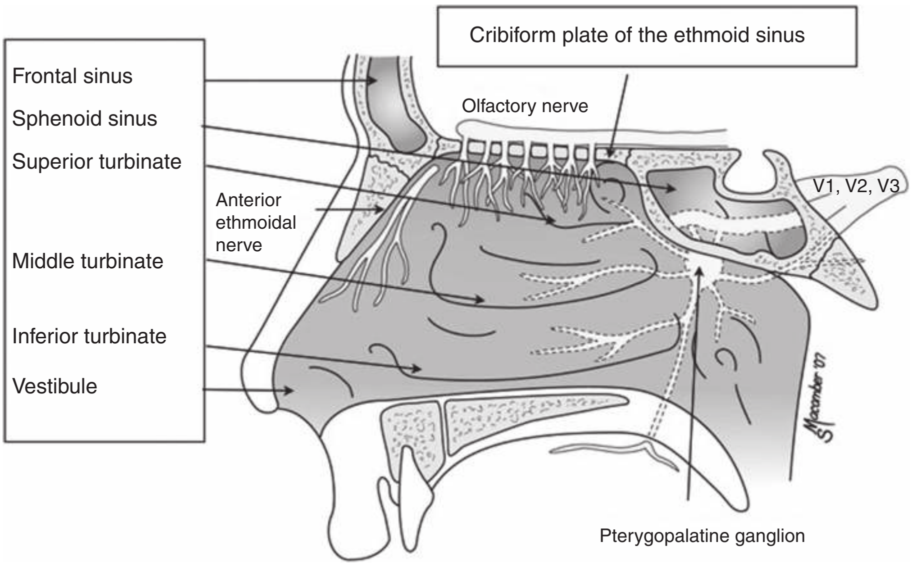

Figure 1.2 Lateral view and innervation of the nasopharynx

regions are supplied by the sphenopalatine, palatine, and labial arteries. This extremely vascular area, known as Kiesselbach's plexus, is the source of epistaxis and hemorrhage.

Non-olfactory areas of the nose are innervated primarily by the maxillary division of the trigeminal nerve – anterior ethmoid and sphenopalatine (pterygopalatine) nerves

(Figure 1.2). The vidian nerve supplies the secretory glands, and the parasympathetic and sympathetic systems supply the nasal vasculature.

The paranasal sinuses – maxillary, frontal, ethmoid, and sphenoid – drain into the nasal cavity. They are paired, pneumatic spaces that extend from the nasal cavity into the skull. The frontal sinus is not present at birth and, when it is fully developed, the anterior cranial fossa and the orbit border the frontal sinus.

The maxillary sinus continues to develop until the third decade. Structures bordering the maxillary sinus include orbit, cheek, nasal cavity, and teeth. The extremely thin walls of the ethmoid sinus are located in the superior and lateral aspects of the nose. The thin walls allow for easy spread of infection and tumor. The sphenoid sinus abuts several significant structures – optic nerve, internal carotid artery, pituitary fossa, and the cavernous sinus. The cavernous sinus contains branches of the trigeminal, oculomotor, abducens, and trochlear nerves.[4]

Nasal intubations can have serious complications. Severe facial trauma, such as Leforte fractures II and III, and basilar skull fractures are contraindications to nasal intubation. Nasal intubations in patients with these conditions may penetrate the brain via the orbit and cribriform plate. The cribriform plate is a part of the ethmoid bone, which separates the brain from the nasal cavity. It attaches to the frontal bone of the skull known as the ethmoidal notch. The roof of this structure also connects to the nasal cavities in the skull.[5] Nasal intubation, if attempted in patients with skull and facial fractures, is safest with fiberoptic assistance.[6]

Mouth

The mouth is involved with deglutition and speech articulation. It is functionally divided into two continuous areas: the oral cavity and the oropharynx (Figure 1.3).[7] Anatomically, the oral cavity starts at the lips, with the vermillion-skin borders extending posteriorly, and

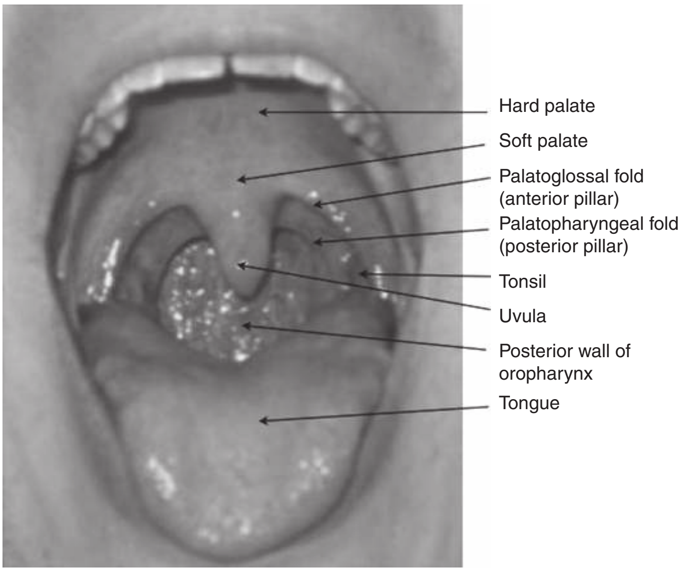

Figure 1.3 Structures of the oral cavity and oropharynx

ends superiorly at the soft palate. Inferiorly, it includes the anterior two-thirds of the tongue. The oral cavity is, therefore, bounded superiorly by the hard palate, posteriorly by the oropharynx, inferiorly by the tongue, and anteriorly by the lips, with the maxillary and mandibular alveolar ridges/teeth and gingivae extending laterally and including the buccal mucosa and retromolar trigone (Figure 1.3).

Tongue

The tongue is involved with speech articulation and deglutition.[7] The anterior two-thirds of the tongue resides in the oral cavity, and the posterior third resides in the oropharynx. The intrinsic muscles of the tongue control its movement and the shape while the extrinsic muscles fix the tongue to bony landmarks for support. The following extrinsic muscles attach the tongue to the mandible (genioglossus), the hyoid (hyoglossus), the styloid process (styloglossus), and the soft palate (palatoglossus). When a supine patient loses consciousness, these muscles relax the tongue into the oropharynx and may produce airway obstruction. Applying the simple airway maneuver of a jaw thrust pulls the tongue forward by the action of the genioglossus muscle, which is attached to the symphysis menti of the mandible.[8] As a result, the pathway opens for airflow into the oropharynx. The tongue musculature is innervated by the hypoglossal nerve (CN XII), and taste to the anterior two-thirds of the tongue is provided by the lingual nerve (CN V_3).

Pharynx

The pharynx is a continuous and dynamic structure, conceptualized as a musculofascial distensible tube connecting the nasal and oral cavities with the lower larynx and esophagus.[8] The pharynx serves as a conduit for air and food while providing protection from pathogens and preventing entrance by foreign bodies. The adult pharynx is approximately 12–15 cm in length. It is functionally divided into three parts: nasopharynx, oropharynx, and hypopharynx (Figure 1.4).

The nasopharynx serves an important role in the respiratory system by warming and humidifying incoming air. The nasopharynx is located posterior to the nasal septum and extends to the level of the soft palate. The nasal choanae, eustachian tubes, and oropharynx converge into the nasopharynx. In this area, a ring of lymphoid tissue (palatine, lingual, tubal, and nasopharyngeal tonsils (adenoids)) is known as the Ring of Waldeyer. Suspended inhaled particles enter through the nose, reach the tonsils, and become sequestered. The tonsils serve as a defense against pathogens entering the body. As the lymphoid tissues enlarge, particularly the palatine tonsils, they may impede passage of air during mask ventilation or placement of a nasopharyngeal airway or endotracheal tube.[5] The lingual tonsils are located between the tongue and epiglottis, thereby precluding detection under routine airway examination (Figure 1.1). Enlarged lingual tonsils are often asymptomatic and have been a source for unanticipated difficult intubation and reported death during induction of anesthesia.[9]

The oropharynx has a role in both the digestive and respiratory systems. It is located between the soft palate superiorly and ends at the superior edge of the epiglottis. Functionally, it prevents food from entering the larynx.

The hypopharynx is situated behind the larynx and often is referred to as the laryngopharynx. It begins at the cervical vertebra C4 and ends at C6. It includes the epiglottis and extends to the inferior border of the cricoid cartilage, becoming continuous with the

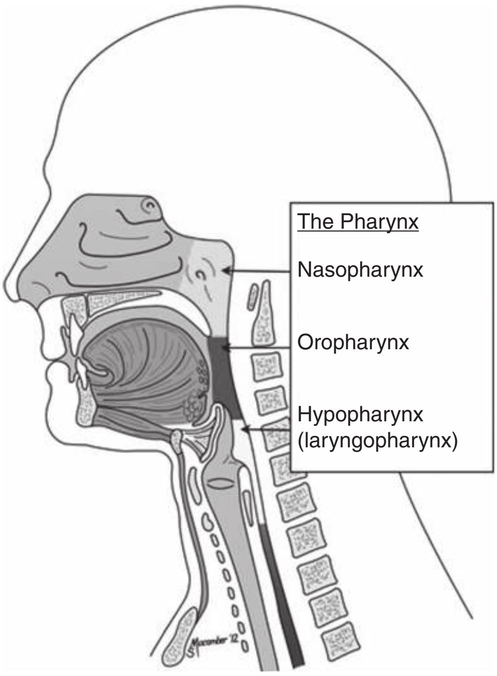

Figure 1.4 Lateral view of the pharynx

esophagus. The role of the hypopharynx is to channel air to the trachea and food to the esophagus.

Larynx

The larynx starts at the base of the tongue and ends at the trachea.[4,7,8] The U-shaped hyoid bone suspends and anchors the larynx during respiration and phonation. The laryngeal skeletal framework is formed by three unpaired cartilages (thyroid, cricoid, and epiglottis) and three paired cartilages (arytenoid, corniculate, cuneiform), which are joined by membranes, synovial joints, and ligaments. The ligaments are covered with mucous membranes and referred to as folds. The thyroid cartilage is the largest of the laryngeal structures and is embryologically fused in the midline, forming a V-shaped shield in the anterior neck. The laryngeal prominence in men is referred to as the "Adam's apple," whereas in women it is less prominent. On the inside of the thyroid laminae are the vestibular ligaments and below that, the vocal ligaments. The cricoid cartilage is the lower limit of the larynx and connects to the trachea.

Two membranes attach to the thyroid: the thyrohyoid membrane and cricothyroid membrane. The thyrohyoid membrane connects the thyroid cartilage to the hyoid bone whereas the cricothyroid membrane connects the cricoid to the thyroid cartilage (Figure 1.5).

The cricoid cartilage is a signet-shaped ring with the anterior side shorter (5–7 mm) and posterior side taller (2–3 cm); it is the only complete cartilaginous ring in the airway.[8] It serves several functions: anatomically, it provides posterior support of the larynx; clinically, it is used as a landmark to identify the cricothyroid membrane for emergency airway access. Cricoid pressure is used during emergency placement of an endotracheal tube in patients with a high risk of aspiration. The action of pressing the cricoid ring downward, thereby

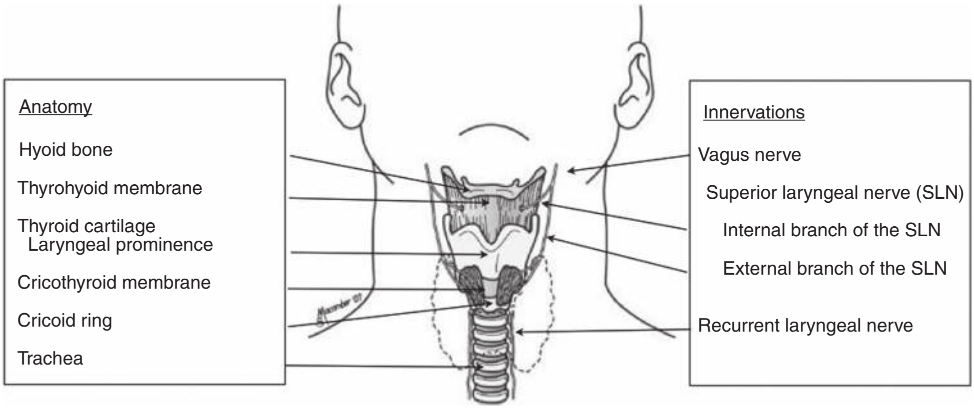

Figure 1.5 Anterior view of larynx with landmarks and innervation of the larynx

compressing the esophagus against the cervical vertebrae, is thought to prevent passive regurgitation without creating airway obstruction. Particularly in an airway emergency, the cricothyroid membrane is an important landmark to identify.

When other points of entry to the airway are not available, the cricothyroid membrane serves as a window and allows entry into the respiratory tract below the glottis.[10,11] The cricothyroid membrane is located superficially below the skin in the anterior neck and is situated between the thyroid cartilage and cricoid ring. It covers the cricothyroid space, which averages 9 mm in height and 3 cm in width in adults. The cricothyroid space is palpable as an indentation or soft spot at the inferior edge of the thyroid cartilage (particularly in men) and/or superior to the cricoid cartilage (in women).[7] The vocal cords, which are protected by the thyroid cartilage, are located approximately a centimeter above the cricothyroid space (Figure 1.1).

During endoscopy, the larynx can be seen beginning at the base of the tongue. The initial view is of the epiglottis, which is a flexible, fibroelastic, omega-shaped cartilage. The epiglottis serves as a protective structure and acts to guide food away from the larynx. The epiglottis is attached to the tongue by the medial glossoepiglottic fold and lateral glossoepiglottic folds. The area between these folds is termed the valleculae. The tip of the Macintosh blade is placed at this site for direct laryngoscopy. The paired arytenoids articulate with the posterior aspect of the cricoid cartilage. This is a synovial joint that can be affected by rheumatoid arthritis. The arytenoids control the vocal cord movement. The vocal cords (folds) project from the arytenoids in a posterior to anterior plane and attach to the inner surface of the thyroid cartilage. The epiglottis is also connected to the arytenoids laterally by the aryepiglottic ligaments and folds. Within these folds, paired fibroelastic cartilages – the cuneiform and the corniculate – reinforce the support of the aryepiglottic fold and aid arytenoid movement. The glottic opening is bounded by the epiglottis, the aryepiglottic fold, and the corniculate cartilages (Figure 1.6).

Two muscle groups control movement of the larynx. The extrinsic muscle group modifies the larynx position by its attachment to the hyoid bone and other anatomic structures. The extrinsic muscles include the sternohyoid, sternothyroid, thyrohyoid, thyroepiglottic, stylopharyngeus, and inferior pharyngeal constrictor. The intrinsic muscles directly affect the glottic movement by facilitating movement of the laryngeal cartilages.

Table 1.1 The larynx intrinsic muscles: action and innervation

Muscle	Action	Innervation
Transverse arytenoid	Adducts arytenoids	Recurrent laryngeal nerve
Lateral cricoarytenoids	Adducts arytenoids, closes glottis	Recurrent laryngeal nerve
Posterior arytenoids	Abducts vocal cords	Recurrent laryngeal nerve
Thyroarytenoids	Relaxes tension on vocal cords	Recurrent laryngeal nerve
Vocalis	Relaxes vocal cord	Recurrent laryngeal nerve
Oblique arytenoid	Closes the glottis	Recurrent laryngeal nerve
Aryepiglottic	Closes the glottis	Recurrent laryngeal nerve
Cricothyroid	Tensor of the vocal cords	External branch of the superior laryngeal nerve

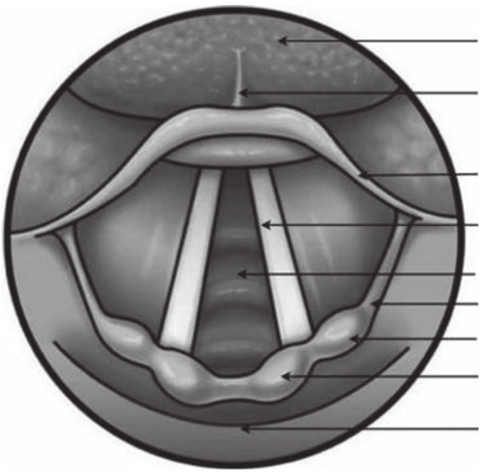

Figure 1.6 Endoscopic view of the larynx

The intrinsic muscles include posterior cricoarytenoid, lateral cricoarytenoid, transverse arytenoid, oblique arytenoid, aryepiglottic, vocalis, thyroarytenoid, and cricothyroid muscles. The intrinsic muscles coordinate movement of the vocal cords to facilitate respiration, deglutition, and phonation (Table 1.1).[4]

The vagus nerve (CN X) and its branches innervate the larynx (Figure 1.5). Just inferior to the hyoid bone, the vagus nerve branches into the superior laryngeal nerve, which further bifurcates into external and internal branches. The internal branch pierces the thyrohyoid membrane, carrying sensory input from the laryngeal mucosa to the area above the vocal cords. The recurrent laryngeal nerve, a branch of the vagus, supplies sensory input to the larynx below the vocal cords and motor innervation to all intrinsic muscles of the larynx except the cricothyroid muscle. The external branch of the vagus supplies motor innervation to the cricothyroid muscle. The laryngeal branches of the superior and inferior thyroid arteries supply the larynx. Clinically, injury to one recurrent laryngeal nerve may present asymptomatically or as a slight change in voice quality. Damage to both recurrent laryngeal

Table 1.2 Comparative airway anatomy

Anatomic location	Infant	Adult	Clinical impact
Head	Large occiput to body ratio	Proportional occiput to body	Adults require blankets to achieve sniffing position for intubation; infants naturally in sniffing position, no blankets required
Tongue	Relatively large related to submandibular space	Usually proportionate to submandibular space	Infants are obligate nasal breathers until 6 months
Epiglottis	Increased vagal tone Floppy, long, omega- or U-shaped	Normal vagal tone Flexible, tear-drop shape	In infants, bradycardia more likely to occur compared to adults In infants, better view of vocal cords with Miller blade
Larynx			
Position	C2–C3 until age 6 years	C4–C5	Airway obstruction more likely in children
Shape	Funnel shape	Cylinder shape	
Vocal cord	Angled	Horizontal	
Narrowest part	Cricoid cartilage	Level of the vocal cords	Use uncuffed endotracheal tubes in infants

nerves presents as a dire emergency due to total airway obstruction since the vocal cords cannot abduct and allow passage of air into the lungs.

The pediatric airway

Pediatric patients are more prone to airway obstruction than adults due to the size, shape, and position of the anatomic parts of the airway. The tonsils are small in newborns and become adult size by ages 4 to 7 years old, which may make mask ventilation difficult as well as obscure the view of the larynx.[12–14] In an unconscious child, the tongue falls back in the oropharynx blocking the flow of air.

Infants desaturate faster than adults with upper airway obstruction due to smaller lung volumes and a more compliant chest wall. The pediatric airway has several distinctive features. The larynx is positioned more rostrally in children than in adults, making the tongue size relatively large in relation to the oropharynx. The vocal cords are angled and protected by a posterior angled U-shaped epiglottis. Most important, the narrowest part of the airway is at the level of the cricoid cartilage, and the diameter of the trachea is smaller and shorter than that of adults. Table 1.2 describes the differences between the infant and adult airway and highlights the effect on clinical practice.

Conclusion

The nose, mouth, pharynx, and larynx comprise a complex array of structures designed to give us the "human airway." These highly integrated structures permit breathing, protect the airway from foreign bodies, protect the body from pathogens, enable taste and phonation, and assist in food intake and emergency airway access. Mastery of the anatomy and understanding the function and innervation of the "human airway" facilitates an approach for safe elective and emergent airway management.

References

1. Elliott DSJ, Baker PA, Scott MR, Birch CW, Thompson JMD. Accuracy of surface landmark identification for cannula cricothyroidotomy. *Anaesthesia*. 2010;**65**:889–94.
2. Kristensen MS. Ultrasonography in the management of the airway. *Acta Anaesthesiol. Scand.* 2011;**55**:1160–61. PubMed PMID: 22092121.
3. Dhillon RS, East CA, *Nose and Paranasal Sinuses, Ear, Nose and Throat and Head and Neck Surgery*, Elsevier, 2013, pp. 29–54.
4. Krohner R, Ramanathan S. Functional anatomy of the airway. In Hagberg C, editor, *Benumof's Airway Management*, 2nd edn., Mosby Elsevier, 2007, pp. 3–21.
5. Hall CE, Shutt LE. Nasotracheal intubation for head and neck surgery. *Anaesthesia*. 2003;**58**:249–56.
6. Hagberg C, Rainer G, Krier C. Complications of managing the airway. In Hagberg C, editor, *Benumof's Airway Management*, 2nd edn., Mosby Elsevier, 2007, p. 1193.
7. Fowler N, Scharpf J. Clinical head and neck anatomy for the anesthesiologist. In Abdelmalak B, Doyle D, editors, *Anesthesia for Otolaryngologic Surgery*, Cambridge University Press, 2013, pp. 1–10.
8. Redden R. Anatomic airway considerations in anesthesia. In Hagberg C, editor, *Handbook of Difficult Airway Management*, Churchill Livingstone, 2000, pp. 1–13.
9. Ovassapian A, Glassenberg R, Randel GI, Klock A, Mesnick PS, Klafta JM. The unexpected difficult airway and lingual tonsil hyperplasia: a case series and a review of the literature. *Anesthesiology*. 2002;**97**:124–32.
10. Goumas P, Kokkinis K, Petrocheilos J, Naxakis S, Mochloulis G. Cricothyroidotomy and the anatomy of the cricothyroid space. An autopsy study. *J. Laryngol. Otol.* 1997;**111**:354–6.
11. Melker R, Florete F. Cricothyrotomy review and debate. *Anesthesiol. Clin. N. Am.* 1995;**13**:565–83.
12. Rabb M, Szmuk P. The difficult pediatric airway. In Hagberg C, editor, *Benumof's Airway Management*, 2nd edn, Mosby Elsevier, 2007, pp. 783–5.
13. Wheeler M. The difficult pediatric airway. In Hagberg C, editor, *Handbook of Difficult Airway Management*, Churchill Livingstone, 2000, pp. 257–300.
14. Sunder RA, Haile DT, Farrell PT, Sharma A. Pediatric airway management: current practices and future directions. *Paediatr. Anaesth.* 2012;**22**:1008–15. PubMed PMID: 22967160. Epub 2012/09/13.