Developmental anatomy of the airway

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Abstract

The airway develops from the primitive foregut at four weeks' gestation. Congenital anomalies may result when this process is abnormal. The anatomy of the airway at birth is uniquely different from older children and adults with a large tongue, long floppy epiglottis, large occiput and cephalad larynx. These features affect the technique required for face-mask ventilation, supraglottic airway use and endotracheal intubation. A neutral head position and straight bladed laryngoscope are usually used for intubation. Neonates are also obligate nasal breathers and simultaneously suckle and breathe. Minute volume is rate-dependent and the highly compliant chest easily displays sternal and intercostal recession during respiratory distress, and early onset of fatigue. From the neonatal period onwards the anatomy gradually begins to resemble that of adults. The cricoid descends caudally, the epiglottis becomes firmer and shorter, and the relatively large occiput recedes. The conventional wisdom of the cricoid ring being the narrowest part of the paediatric airway is not supported by contemporary investigation. The consequence of these findings on endotracheal tube selection and the rationale for increasing use of cuffed endotracheal tubes in children is discussed.

Keywords Airway; anaesthesia; anatomy; larynx; paediatric; trachea endotracheal tube

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Learning objectives

After reading this article, you should be able to:

- describe the changes in airway anatomy from neonate to older child
- understand how the more common congenital abnormalities of the airway arise
- understand how the developmental anatomy from neonate to older child might influence paediatric airway management
- appreciate how contemporary studies of laryngeal anatomy in children challenge established dogma
- correctly size paediatric uncuffed and cuffed endotracheal tubes

Embryonic and fetal development

Development of the human airway starts at week 4 of gestation. Most of the structures of the face and neck originate from the pharyngeal (branchial) arches. These develop as paired structures lateral to the developing foregut and laryngotracheal groove. The first three pharyngeal arches give rise to the maxilla, mandible and hyoid bone with their accompanying nerves and muscles, whereas arches 4–6 give rise to the laryngeal cartilages with their associated muscles and are supplied by branches of the vagus nerve. The tonsils arise from the second pharyngeal pouch. Disruption of the neural crest cell development results in craniofacial abnormalities. Interruption of mandibular development leads to micrognathia and retrodisplacement of the tongue. This may manifest as Treacher Collins syndrome (mandibulofacial dysostosis) or Robin sequence (micrognathia, cleft palate and glossoptosis).

The anterior two-thirds of the tongue is derived mostly from the first arch and the posterior one-third from the third and fourth arches. The epiglottis also develops from the third and fourth pharyngeal arches via the hypopharyngeal eminence. The primary palate begins at week 5 fusing to become the nasal tip and upper lip, followed by the secondary palate at week 7 forming the soft and hard palate. The palate is formed from lateral palatine processes which project medially on each side of the tongue and fuse with the nasal septum. Cleft lips and palates result from failure of this process.

The larynx, trachea and bronchi originate from the median laryngotracheal groove. As the groove deepens, its lips fuse forming a tube lined with endoderm, which becomes the epithelial lining of the respiratory tract. The cranial end of the tube becomes the larynx, mid-section the trachea, and the caudal end bifurcates into two buds – the bronchi and lungs. This process starts by week 7 with the alveolar ducts and primitive alveoli being completed by 27 weeks. Incomplete fusion or abnormality of the tracheo-oesophageal septum may result in laryngeal cleft or tracheo-oesophageal fistula.

The airway at birth

The neonate has a large head, short neck, and prominent occiput. The mandible is underdeveloped and when combined with a prominent mid-face, results in a degree of relative micrognathia. Most of the tongue lies within the oral cavity at birth. The arrangement of the larynx (epiglottis-hyoid-glottis-cricoid complex) at birth is more cephalad and more compressed than later in life (Figure 1). The tip of the epiglottis is at the mid-level of C1, the glottis at mid C3 and the cricoid at the superior border of C4 at birth.[1] These structures may be up to half a vertebral body more cephalad in premature neonates.

The epiglottis is intimately related to the base of the tongue superiorly. Inferiorly it is attached to the thyroid cartilage by the thyro-epiglottic ligament and suspended from the hyoid bone by

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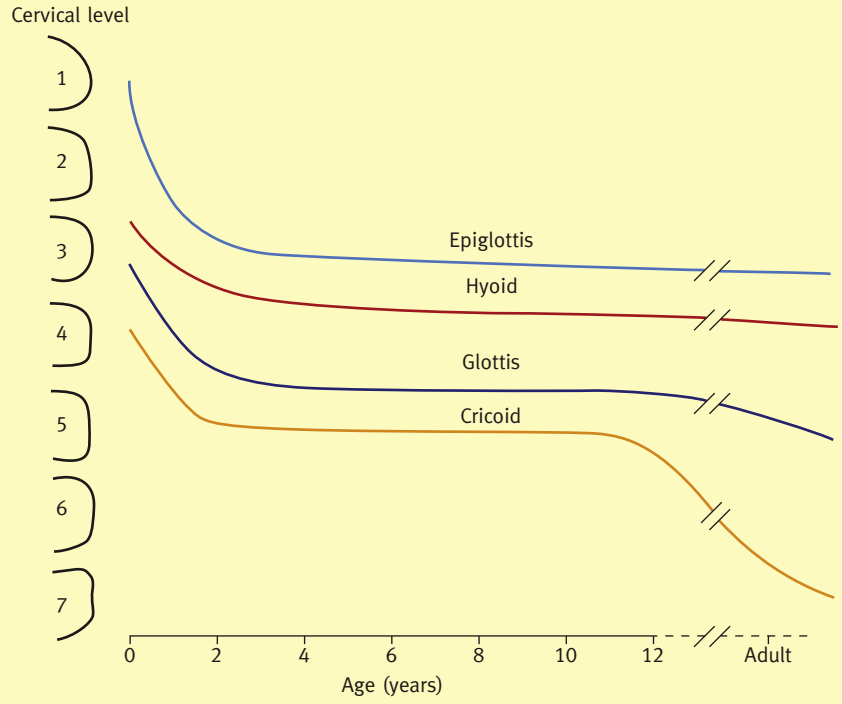
The change in level of laryngeal and related structures relative to the cervical spine with age.



From Westhorpe RN. The position of the larynx in children and its relationship to the ease of intubation. *Anaesth Intens Care*, 1987; 15: 384–8.

Figure 1

the hyo-epiglottic ligament that initially attaches close to the base of the epiglottis (Figure 2). Together this explains the 'down-folded' position of the epiglottis that projects at approximately 45° to the vertical. The tip of the epiglottis makes contact with the soft palate and when supine touches the posterior pharyngeal wall. Although this may cause problems with visualizing the larynx at intubation, the apposition of the epiglottis and uvula in the midline effectively separates a midline pathway into the trachea for air (neonates are nasal breathers) and two lateral channels (piriform fossae) leading into the oesophagus for milk; allowing swallowing and breathing at the same time. Another feature of the epiglottis at birth is its attachment to the arytaenoid cartilages by relatively prominent and fleshy ary-epiglottic folds. This gives rise to an omega or inverted U-shaped complex. This further protects against aspiration while breathing during suckling. Active, synchronized muscle tone during the respiratory cycle is required for patency of the upper airway and larynx. Lack of maturation leads to the most common upper airway problems in early infancy — laryngomalacia and vocal cord paresis.

The large occiput, relative micrognathia, large tongue and downfolded epiglottis can make mask ventilation and endotracheal intubation challenging. Supporting the shoulders and maintaining a neutral head position may counter this. The 'downfolded' position of the epiglottis makes it susceptible to being pushed against the laryngeal inlet if too long an oral airway is used. When using a laryngeal mask airway (LMA) in a neonate or infant, meticulous care needs to be taken with positioning. Frequently the epiglottis will be visible if a flexible laryngoscope is passed through an LMA. During spontaneous ventilation this reflects the normal position, but will require the epiglottis to be lifted if the LMA is being used as a conduit for intubation.

The cephalad position of the larynx creates an acute angle with the base of tongue, making it appear *anterior* at direct laryngoscopy (Figure 2). Furthermore the relative inferior attachment of the hyo-epiglottic ligament makes for an inefficient lever if a laryngoscope is inserted into the vallecula (as with a MacIntosh blade in adults). For these reasons, a straight bladed laryngoscope inserted lateral to the tongue (to counter the extreme angle) with the tip positioned under the epiglottis, is preferred by many paediatric anaesthetists. The laryngeal inlet and inferior surface of the epiglottis are innervated by the vagus nerve, which may be stimulated by this technique. Video-laryngoscopy may improve visualization particularly with micrognathic syndromes, abolishing the need to displace the tongue into the submandibular space.

Weak intercostal and diaphragmatic muscles (lack of type 1 fibres), horizontal ribs and a protuberant abdomen results in earlier onset of fatigue and less efficient ventilation. Minute volume is rate-dependent, and a gas filled over-distended stomach easily splints the diaphragm. Chest wall-specific compliance is higher, and intercostal or sternal recession is readily visible with increased respiratory effort or airway obstruction.