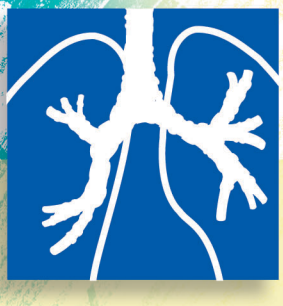
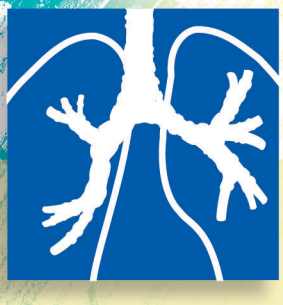


The Respiratory System



2 The Upper and Lower Airway and Associated Structures

Chapter Outline

THE NOSE

Pupillodilatation

A vasoconstrictor sprayed into the nasal vestibule can ascend in the nasolacrimal duct to the conjunctival sac, where it is absorbed, and may produce pupillodilatation.

Examination of the Nasal Cavity

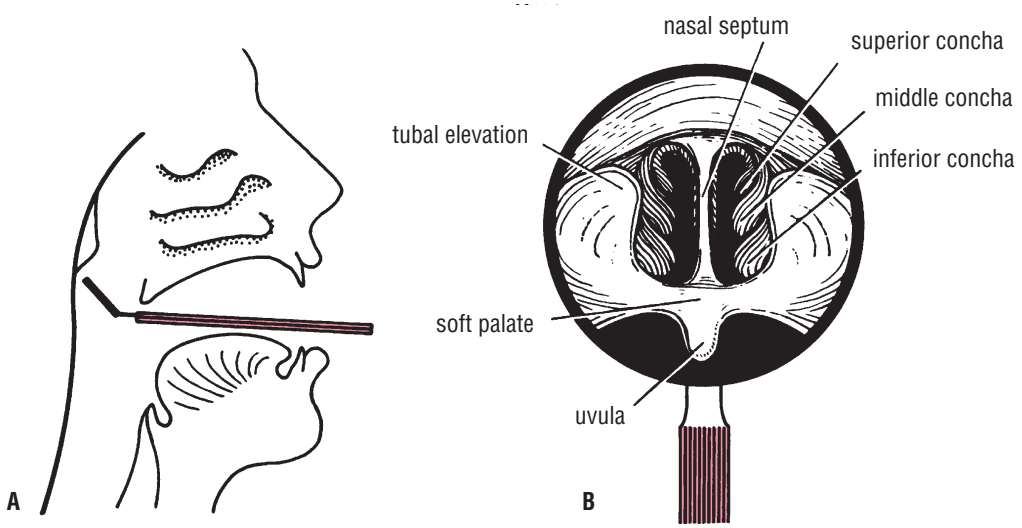
Examination of the nasal cavity may be carried out by inserting a speculum through the external nares or by means of a mirror in the pharynx. In the latter case, the choanae and the posterior border of the septum can be visualized (CD Fig. 2-1). It should be remembered that the nasal septum is rarely situated in the midline. A severely deviated septum may interfere with drainage of the nose and the paranasal sinuses.

Infection of the Nasal Cavity

Infection of the nasal cavity can spread in a variety of directions. The paranasal sinuses are especially prone to infection. Organisms may spread via the nasal part of the pharynx and the auditory tube to the middle ear. It is possible for organisms to ascend to the meninges of the anterior cranial fossa, along the sheaths of the olfactory nerves through the cribriform plate, and produce meningitis.

Epistaxis, or bleeding from the nose, is a frequent condition. The most common cause is nose picking. The bleeding may be arterial or venous, and most episodes occur on the anteroinferior portion of the septum and involve the septal branches of the sphenopalatine and facial vessels.

Beware of bilateral cauterization of the septal mucous membrane. It could compromise the blood supply to the perichondrium and cause necrosis of the cartilaginous part of the septum.



CD Figure 2-1 **A.** Position of the mirror in posterior rhinoscopy. **B.** Structures seen in posterior rhinoscopy.

Nasal Obstruction

Nasal obstruction can be caused by edema of the mucous membrane secondary to infection, or by foreign bodies lodged between the conchae. The shelf-like conchae make impaction and retention of balloons, peas, and small toys relatively easy in children. Other causes include tumors, polyps, and septal abscesses.

Deflection of the nasal septum is common. It is believed to occur most commonly in males because of trauma in childhood.

The most voluminous part of the nasal cavity is close to the floor, and it is usually possible to pass a well-lubricated tube through the nostril along the inferior meatus into the nasopharynx.

Trauma to the Nose

Nasal Fractures

Fractures involving the nasal bones are common. Blows directed from the front may cause one or both nasal bones to be displaced downward and inward.

Lateral fractures also occur in which one nasal bone is driven inward and the other outward; the nasal septum is usually involved.

Skin Lacerations

Lacerations are sutured in the usual way. Remember, however, that there is very little excess of skin so that the vascularity may be compromised if too much tension is placed on the sutures. Avoid making incisions across depressed areas on the side of the nose or at the junction of the nose and the lip, or across the lower eyelid, since future scars tend to contract and distort the depression.

CONGENITAL ANOMALIES OF THE NOSE

Median Nasal Furrow

In median nasal furrow, the nasal septum is split, separating the two halves of the nose (CD Fig. 2-2A).

Lateral Proboscis

In lateral proboscis, a skin-covered process develops, usually with a dimple at its lower end (CD Fig. 2-2B).

THE PARANASAL SINUSES

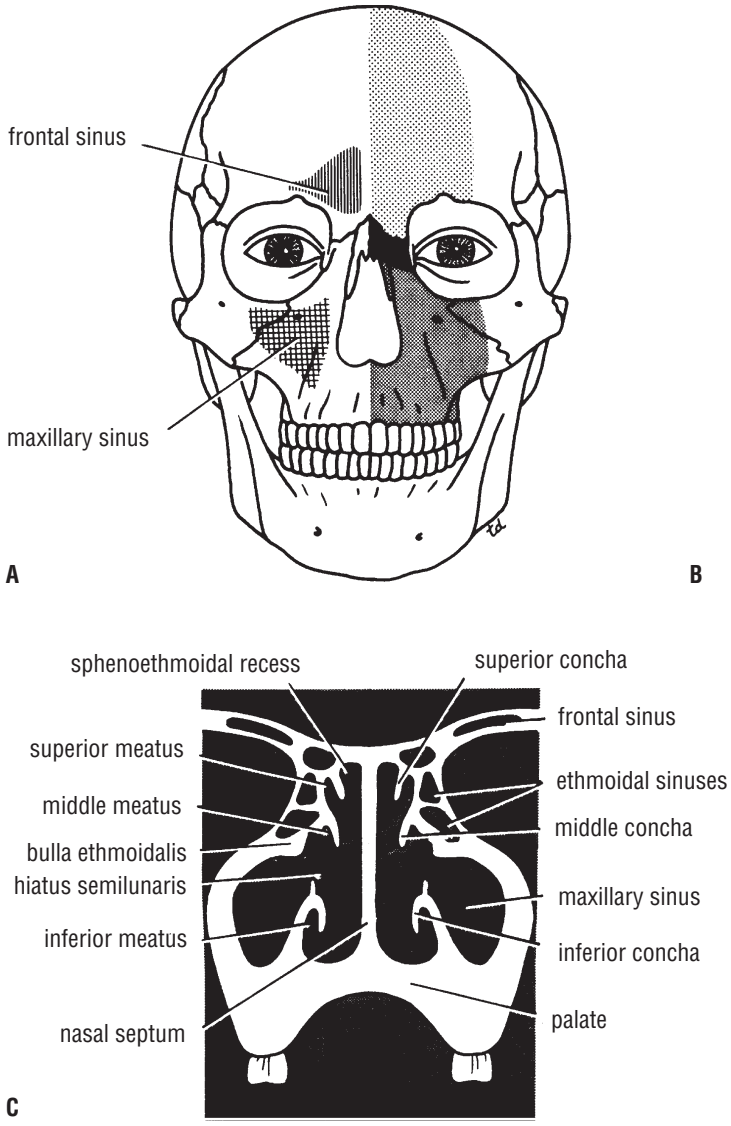
Sinusitis and the Examination of the Paranasal Sinuses

Infection of the paranasal sinuses is a common complication of nasal infections. Rarely, the cause of maxillary sinusitis is

A

B

CD Figure 2-2 **A.** Median nasal furrow in which the nasal septum has completely split, separating the two halves of the nose. Note that the external nares are separated by a wide furrow. (Courtesy of L Thompson.) **B.** Lateral proboscis.



CD Figure 2-3 **A.** Bones of the face showing the positions of the frontal and maxillary sinuses. **B.** Regions where pain is experienced in sinusitis (lightly dotted area in frontal sinusitis; solid area in sphenoethmoidal sinusitis; and heavily dotted area in maxillary sinusitis). **C.** Coronal section through the nasal cavity showing the frontal, ethmoidal, and maxillary sinuses.

extension from an apical dental abscess. The extreme thinness of the medial wall of the orbit relative to the ethmoidal air cells must be emphasized. Ethmoidal sinusitis is the most common cause of orbital cellulitis. The infection can easily spread through the paper-thin bone.

The frontal, ethmoidal, and maxillary sinuses can be palpated clinically for areas of tenderness (CD Fig. 2-3). The frontal sinus can be examined by pressing the finger upward beneath the medial end of the superior orbital margin. Here the floor of the frontal sinus is closest to the surface.

The ethmoidal sinuses can be palpated by pressing the finger medially against the medial wall of the orbit. The maxillary sinus can be examined for tenderness by pressing the finger against the anterior wall of the maxilla below the inferior orbital margin; pressure over the infraorbital nerve may reveal increased sensitivity.

The frontal sinus is supplied by the supraorbital nerve, which also supplies the skin of the forehead and scalp. It is not surprising, therefore, that patients with frontal sinusitis have pain referred over this area (see CD Fig. 2-3). The maxillary sinus is innervated by the infraorbital nerve and, in this case, pain is referred to the upper jaw, including the teeth (see CD Fig. 2-3).

THE MOUTH

Examination of the Mouth

The mouth is one of the most important areas of the body that the medical professional is called on to examine. Needless to say, the health professional must be able to recognize all the structures visible in the mouth and be familiar with the normal variations in the color of the mucous membrane covering the underlying structures. The sensory nerve supply and lymph drainage of the mouth cavity should be known. The close relation of the lingual nerve to the lower

third molar tooth should be remembered. The close relation of the submandibular duct to the floor of the mouth may enable one to palpate a calculus in cases of periodic swelling of the submandibular salivary gland.

Lips and Vestibule and Facial Paralysis

Asymmetry of the lips and paralysis of the buccinator with a tendency to accumulate saliva and food in the vestibule indicate a lesion of the facial nerve on that side.

Ranula

Ranula is a cystic swelling arising in a distended mucous gland of the mucous membrane. It commonly occurs in the floor of the mouth, and because of its transparent covering, it resembles frog skin.

THE TONGUE

Laceration of the Tongue

A wound of the tongue is often caused by the patient's teeth following a blow on the chin when the tongue is partly protruded from the mouth. It can also occur when a patient accidentally bites the tongue while eating, during recovery from an anesthetic, or during an epileptic attack. Bleeding is halted by grasping the tongue between the finger and thumb posterior to the laceration, thus occluding the branches of the lingual artery.

Tongue and Airway Obstruction

In an unconscious patient, there is a tendency for the tongue to fall backward and obstruct the laryngeal opening. This is caused by the loss of tone of the extrinsic muscles and, unless quickly corrected "with a jaw thrust or chin lift maneuver," will lead to all of the signs and symptoms of airway obstruction.

Anatomy of Procedures

Pulling the Tongue Forward in Airway Obstruction

The head should be extended at the atlantooccipital joint and the neck flexed at the C4 to C7 joints. The extended head stretches the fascia and muscles of the front of the neck and causes a forward and downward movement of the mandible that is correctable by placing a finger below the symphysis menti and pulling the mandible forward and up. Sometimes this is inadequate to relieve the obstruction and should be supplemented by placing the fingers behind the angles of the mandible and exerting forward pressure. This moves the mandible forward, causing displacement of the tongue away from the laryngeal opening, since the mandible is attached to the tongue by the genioglossus muscles.

Oral Endotracheal Intubation

Total visualization of the glottis with a laryngoscope is not necessary for endotracheal intubation. If the epiglottis is visible, the tube is laid on the laryngeal side of the epiglottis and advanced along its surface. Often this procedure alone will allow the tube to go into the trachea. If only the esophagus is visible and not the vocal cords, the endotracheal tube can be placed "blindly" just anterior to the esophageal opening. Occasionally when the tube is caught at the anterior glottic constriction, the head should be flexed slightly, allowing the pressure of the tongue to displace the endotracheal tube posteriorly and hence move it into the opening of the glottis. Frequently this maneuver has to be supplemented by turning the head slightly to one side or another. The use of styleted endotracheal tubes also may help in this situation. "Trigger tubes" may be used, which allow the tip to be manipulated from above.

When oral endotracheal intubation is impossible in the above situations, nasotracheal intubation may be successful, since the tube approaches the glottis slightly more posteriorly and is directed more toward it.

Oral Endotracheal Intubation and the Incisor Teeth

Interference with endotracheal intubation may be caused by the presence of protruding incisor teeth, often making it necessary to put the endotracheal tube in an extreme lateral position to approach the glottis.

Oral Endotracheal Intubation and the Small Mandible

Patients with receding jaws, secondary to a small mandible, often make intubation difficult, and in some cases the nasal route or a lighted stylet or digital intubation must be used. However, since this anatomic configuration approaches the picture seen in younger children, many times a small straight blade such as a Miller no. 2 or Miller no. 3 can overcome the visual difficulties noted when a curved blade of the Macintosh type is used.

THE PALATE

Angioedema of the Uvula (Quincke's Uvula)

The uvula has a core of voluntary muscle, the musculus uvulae, that is attached to the posterior border of the hard

palate. Surrounding the muscle is the loose connective tissue of the submucosa that is responsible for the great swelling of this structure secondary to angioedema.

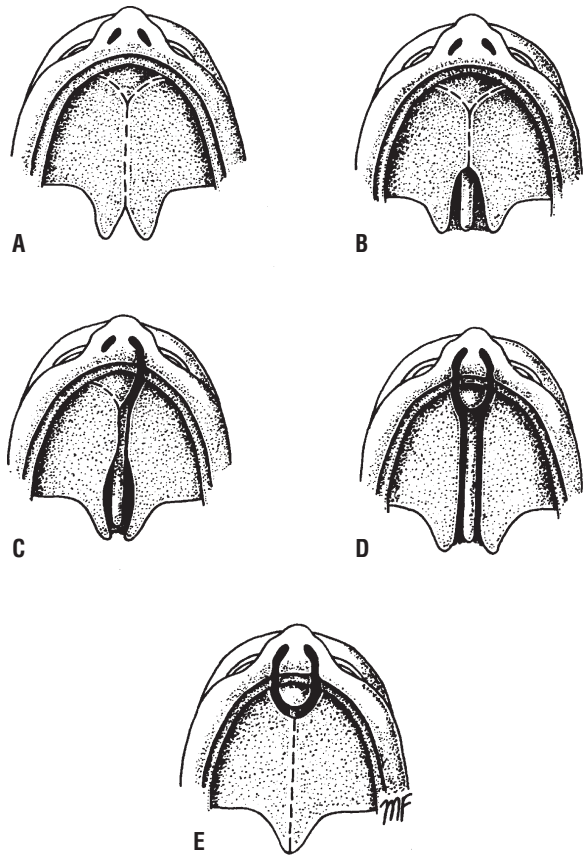
CONGENITAL ANOMALIES OF THE PALATE

Cleft Palate

Cleft palate is commonly associated with cleft upper lip. All degrees of cleft palate occur and are caused by failure of the palatal processes of the maxilla to fuse with each other in the midline; in severe cases, these processes also fail to fuse with the primary palate (premaxilla) (CD Figs. 2-4 and 2-5). The first degree of severity is cleft uvula, and the second degree is ununited palatal processes. The third degree is ununited palatal processes and a cleft on one side of the primary palate. This type is usually associated with unilateral cleft lip. The fourth degree of severity, which is rare, consists of ununited palatal processes and a cleft on both sides of the primary palate. This type is usually associated with bilateral cleft lip. A rare form may occur in which a bilateral cleft lip and failure of the primary palate to fuse with the palatal processes of the maxilla on each side are present.

A baby born with a severe cleft palate presents a difficult feeding problem, since he or she is unable to suck efficiently. Such a baby often receives in the mouth some milk, which then is regurgitated through the nose or aspirated into the lungs, leading to respiratory infection. For this reason, careful artificial feeding is required until the baby is strong enough to undergo surgery. Plastic surgery is recommended usually between 1 and 2 years of age, before improper speech habits have been acquired.

CD Figure 2-4 Cleft hard and soft palate.



CD Figure 2-5 Different forms of cleft palate: cleft uvula (**A**), cleft soft and hard palate (**B**), total unilateral cleft palate and cleft lip (**C**), total bilateral cleft palate and cleft lip (**D**), and bilateral cleft lip and jaw (**E**).

THE SALIVARY GLANDS

Parotid Salivary Gland and Lesions of the Facial Nerve

The facial nerve lies in the interval between the superficial and deep parts of the gland. A benign parotid tumor rarely, if ever, causes facial palsy. A malignant tumor of the parotid is usually highly invasive and quickly involves the facial nerve, causing unilateral facial paralysis.

Parotid Gland Infections

The parotid gland may become acutely inflamed as a result of retrograde bacterial infection from the mouth via the parotid duct. The gland may also become infected via the bloodstream, as in mumps.

Parotid Duct and Facial Injuries

The parotid duct, which is a comparatively superficial structure on the face, runs forward from the parotid gland one fingerbreadth below the zygomatic arch (see text Fig. 2-18). It is about 2 in. (5 cm) long and can be rolled beneath the examining finger at the anterior border of the masseter as it turns medially and pierces the buccinator muscle; it then opens into the mouth opposite the upper second molar tooth (see text Fig. 2-8).

The parotid duct may be damaged in injuries to the face or may be inadvertently cut during surgical operations on the face. The integrity of the parotid duct can be established by wiping the inside of the cheek dry and then pressing on the parotid gland. Look for a drop of viscid saliva to appear on the tip of the papilla in the mouth.

Submandibular Gland: Calculus Formation

The submandibular salivary gland is a common site of calculus formation. The presence of a tense swelling below the body of the mandible, which is greatest before or during a meal and is reduced in size or absent between meals, is diagnostic of the condition. Examination of the floor of the mouth will reveal absence of ejection of saliva from the orifice of the duct of the affected gland. Frequently, the stone can be palpated in the duct, which lies below the mucous membrane of the floor of the mouth.

Sublingual Gland and Cyst Formation

Blockage of one of the ducts of the sublingual gland may cause cysts under the tongue.

THE PHARYNX

The Killian's Dehiscence and Foreign Bodies

Inverted foreign bodies tend to get snared in the region of Killian's dehiscence.

The Piriform Fossa and Foreign Bodies

The piriform fossa is a common site for fish bones or other foreign bodies to become lodged.

THE PROCESS OF SWALLOWING (DEGLUTITION)

Swallowing in Unconscious Individuals

During swallowing in conscious individuals, food and fluid cross naturally from the mouth to the esophagus, and movements of air from the nose to the larynx is momentarily stopped. In unconscious individuals, when the reflex mechanisms are not functioning, it is possible for food and fluid to enter the bronchial tree or air to enter the stomach. Moreover, should vomiting occur, the regurgitated gastric contents may be inhaled into the lungs (see below).

Pharyngeal Obstruction of the Upper Airway

This condition frequently occurs in patients during cardiopulmonary arrest or in the decreased level of consciousness that accompanies a major cerebrovascular accident or drug overdose. The obstruction is caused when the atonic tongue falls back and the pharyngeal wall caves in due to loss of tone of the pharyngeal muscles. The obstruction may clear if the patient is placed in the lateral decubitus position, with the neck extended and the jaw pulled forward (which pulls the tongue forward). If the patient must lie in a supine position, an oropharyngeal or nasopharyngeal airway may have to be inserted to counteract the flaccid pharyngeal walls.

Loss of the Gag Reflex

In conscious patients the airway is protected by a number of important reflexes, including the gag reflex, the laryngeal reflex, and the cough reflex. The gag or swallowing reflex occurs in response to stimulation of the pharyngeal mucous membrane, which is innervated by the glossopharyngeal nerve. The laryngeal and cough reflexes (trachea and bronchi) are mediated by the vagus nerve. These protective reflexes are lost in descending order as the patient becomes less and less responsive. In these circumstances the airway may be blocked by aspiration of vomit and gastric and pharyngeal secretions.

PALATINE TONSILS

Examination of the Tonsils

With the mouth wide open and with a good light shining into the mouth, the tongue is depressed with a spatula. The tonsils can be clearly seen on each side of the oral pharynx in the depression between the palatoglossal and palatopharyngeal folds. Note the size and color of the tonsil; a reddened tonsil covered with mucus or pus is a clear indication of tonsillitis.

Tonsillitis

The palatine tonsils reach their maximum normal size in early childhood. After puberty, together with other lymphoid tissues in the body, they gradually atrophy. The palatine tonsils are a common site of infection, producing the characteristic sore throat and pyrexia. The deep cervical lymph node situated below and behind the angle of the mandible, which drains lymph from this organ, is usually enlarged and tender.

Tonsillectomy, which is often the treatment for recurrent episodes of tonsillitis, is sometimes accompanied by troublesome postoperative bleeding from the external palatine vein.

Quinsy

A peritonsillar abscess, or quinsy, is caused by spread of infection from the palatine tonsil to the loose connective tissue outside the capsule (see text Fig. 2-24).

Adenoids

Adenoids are enlarged nasopharyngeal tonsils usually associated with infection. Excessive enlargement blocks the posterior nasal openings and causes the patient to snore loudly at night and to breathe through the open mouth. The close relationship of the infected lymphoid tissue to the auditory tube may be the cause of deafness and recurrent otitis media.

THE LARYNX

The Cricoid Cartilage and the Sellick Maneuver

The continuous ring structure of the cricoid cartilage is utilized when applying pressure on the cricoid to control regurgitation of stomach contents during the induction of anesthesia.

Relationship between Vocal Folds and Cricothyroid Ligament

Text Fig. 2-27 shows the relationship between the vocal folds and the cricothyroid ligament. It is clear that the folds may be damaged in puncture wounds in the front of the larynx.

Larynx in Children

In children the neck is shorter and the larynx is more cephalad than in adults (CD Fig. 2-6). At birth the cricoid cartilage lies at the level of the fourth cervical vertebra, and only at the age of 6 years does it lie opposite the sixth cervical vertebra. The glottis at birth lies opposite the second cervical vertebra.

The epiglottis is U-shaped and less flexible in children, which sometimes makes it difficult to line up the oral, pharyngeal, and tracheal axes when passing a laryngoscope.

The rima glottidis tends to be more anterior in children than in adults. The vocal folds in children have thicker submucosa, so that edema of the folds is more likely to occlude the glottis.

As mentioned previously, the cavity of the larynx is narrowest within the cricoid ring in children, whereas the glottis is the narrowest part of the cavity in adults.

Epiglottitis

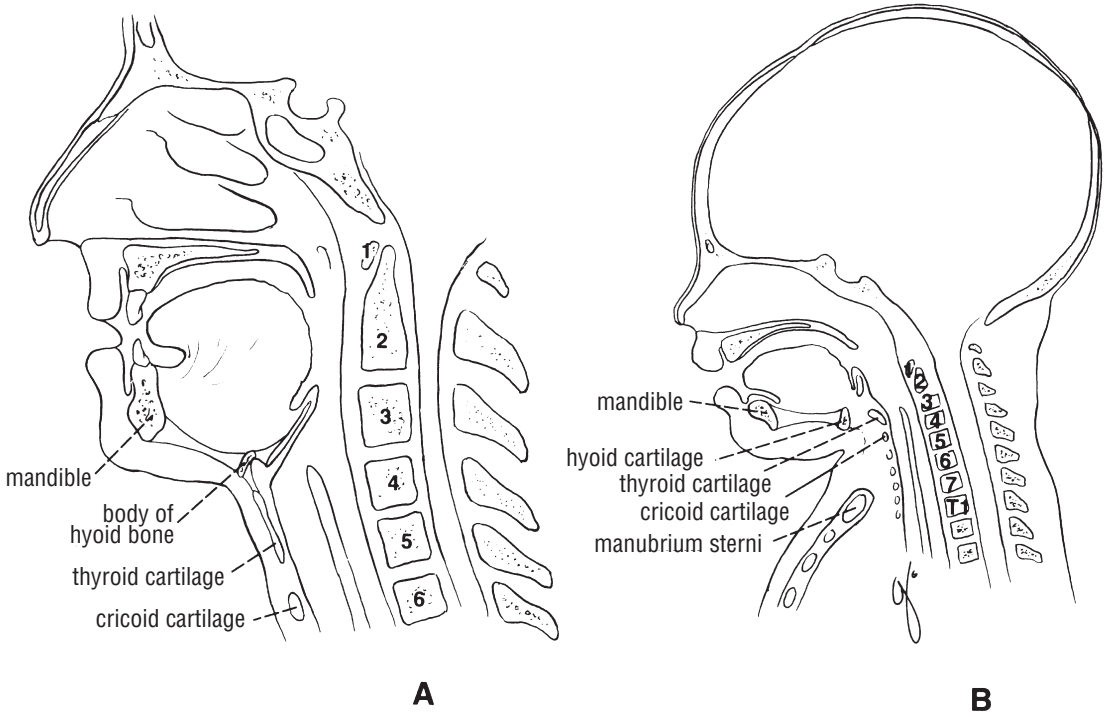
An acute inflammatory swelling of the mucous membrane of the epiglottis can compromise the upper airway. The inflammation may spread rapidly in the loosely arranged submucosa down to the vocal cords. Here the spreading stops because the mucosa is tightly adherent to the underlying vocal ligaments. The condition is most often seen in children where the narrow passageway quickly leads to upper airway obstruction.

Foreign Bodies in the Airway

The laryngeal and cough reflexes mediated through the vagus nerves are the natural defense mechanisms for expelling foreign bodies from the airway at all ages. If coughing is successfully freeing the obstruction, it should be encouraged to continue. If intervention is necessary, anatomic and physiologic age differences dictate treatment.

Anatomic Rationale for Differences in Procedures for Removing Foreign Bodies in Adults and Children

It is generally agreed that all maneuvers are directed toward the increase in intrathoracic pressure by compressing the



CD Figure 2-6 Sagittal sections of the neck of an adult (**A**) and an infant (**B**) shortly after birth. Different vertebral levels in these age groups are shown.

intrathoracic gas volume to expel the foreign body from the airway. For children older than 1 year and for adults, the abdominal thrust (Heimlich maneuver) should be used. The rapid compression of the abdominal viscera suddenly forces the diaphragm into the thoracic cavity. In infants, the relatively large size of the liver and the delicate structure of the abdominal viscera generally preclude its use. Children younger than 1 year should be placed face down over the rescuer's arm, with the head lower than the trunk, and measured back blows should be delivered between the scapulae. If this fails to open the airway, they should be rolled over, and four rapid sternal compressions should be administered.

It is now accepted that sudden blows to the back in the older age groups, especially in the standing or sitting position, extends the thoracic part of the vertebral column and may displace the foreign body further down the airway, leading to impaction or complete obstruction.

Lesions of the Laryngeal Nerves

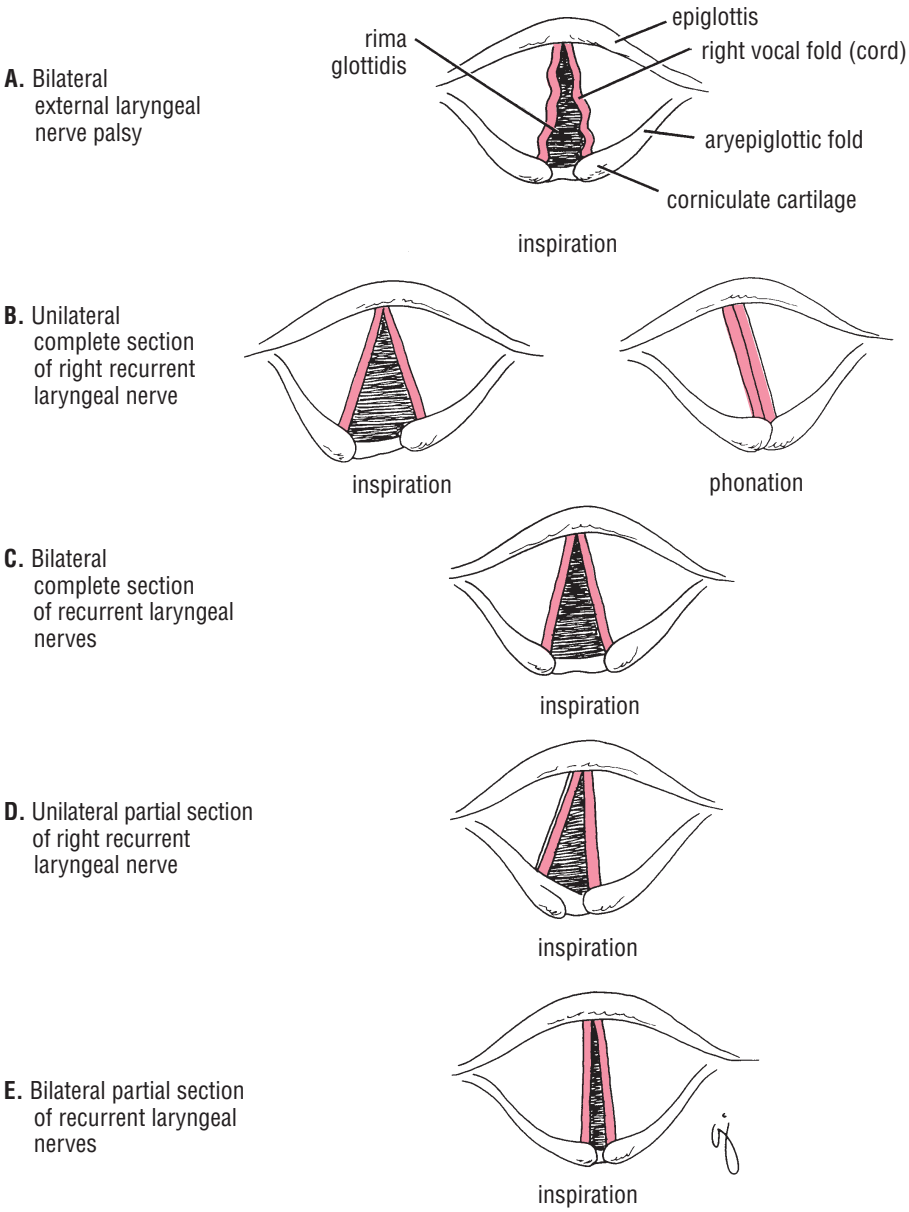
The muscles of the larynx are innervated by the recurrent laryngeal nerves, with the exception of the cricothyroid muscle, which is supplied by the external laryngeal nerve. Both these nerves are vulnerable during operations on the thyroid gland because of the close relationship between them and the arteries of the gland. The left recurrent laryngeal nerve may be involved in a bronchial or esophageal carcinoma or in secondary metastatic deposits in the mediastinal lymph nodes. The right and left recurrent laryngeal nerves may be damaged by malignant involvement of the deep cervical lymph nodes.

Section of the external laryngeal nerve produces weakness of the voice because the vocal fold cannot be tensed. The cricothyroid muscle is paralyzed (CD Fig. 2-7).

Unilateral complete section of the recurrent laryngeal nerve results in the vocal fold on the affected side assuming the position midway between abduction and adduction. It lies just lateral to the midline. Speech is not greatly affected because the other vocal fold compensates to some extent and moves toward the affected vocal fold (CD Fig. 2-7).

Bilateral complete section of the recurrent laryngeal nerve results in both vocal folds assuming the position midway between abduction and adduction. Breathing is impaired because the rima glottidis is partially closed, and speech is lost (CD Fig. 2-7).

Unilateral partial section of the recurrent laryngeal nerve results in a greater degree of paralysis of the abductor muscles than of the adductor muscles. The affected vocal fold assumes the adducted midline position (CD Fig. 2-7). This phenomenon has not been explained satisfactorily. It must be assumed that the abductor muscles receive a



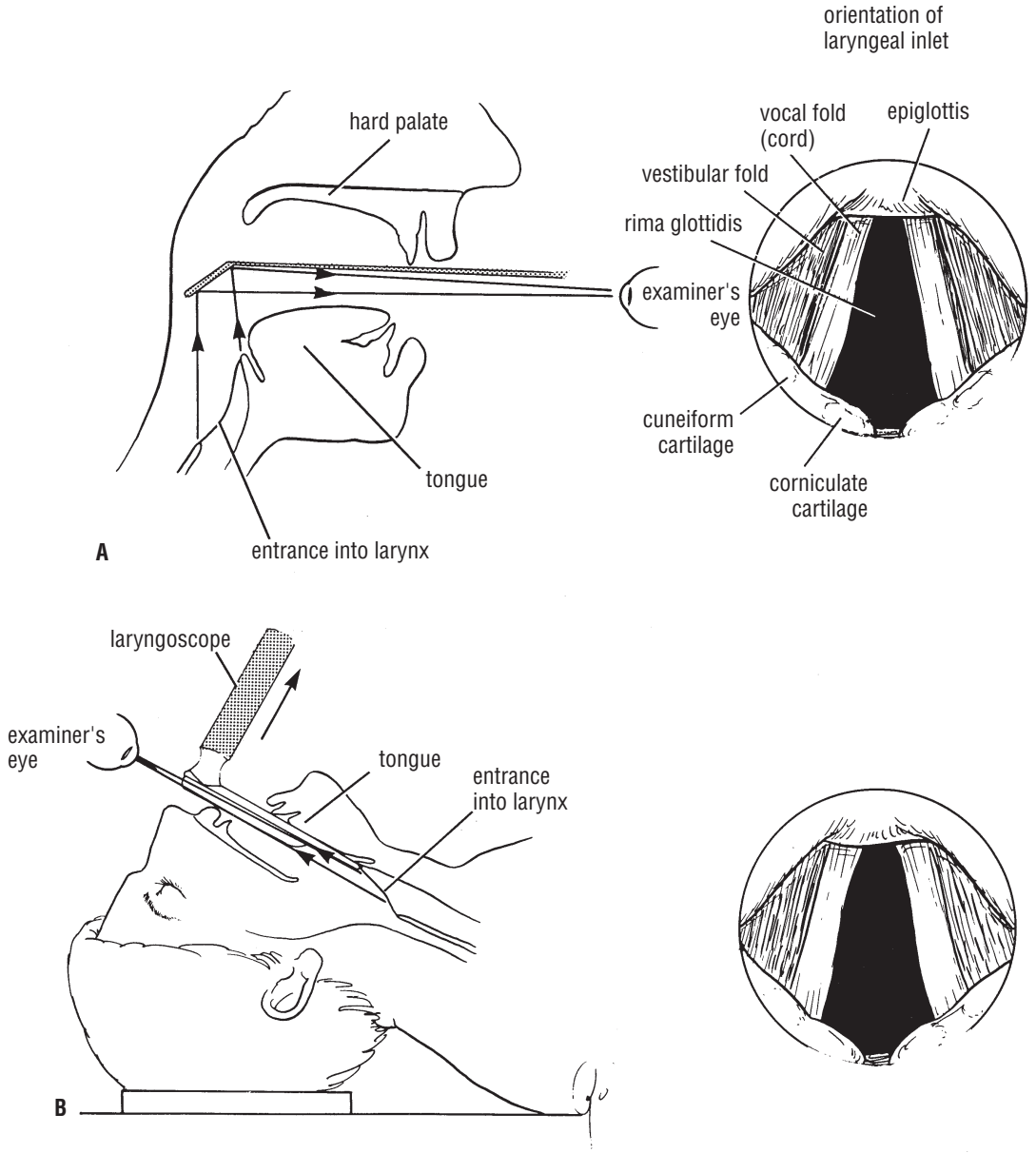
CD Figure 2-7 The position of the vocal folds (cords) after damage to the external and recurrent laryngeal nerves.

greater number of nerves than the adductor muscles, and thus partial damage of the recurrent laryngeal nerve results in damage to relatively more nerve fibers to the abductor muscles. Another possibility is that the nerve fibers to the abductor muscles are traveling in a more exposed position in the recurrent laryngeal nerve and are therefore more prone to be damaged.

Bilateral partial section of the recurrent laryngeal nerve results in bilateral paralysis of the abductor muscles and the drawing together of the vocal folds (CD Fig. 2-7). Acute breathlessness (dyspnea) and stridor follow, and cricothyroidotomy or tracheostomy is necessary.

Inspection of the Vocal Cords (Folds) with the Laryngeal Mirror and Laryngoscope

The interior of the larynx can be inspected indirectly through a laryngeal mirror passed through the open mouth into the oral pharynx (CD Fig. 2-8). A more satisfactory method is the direct method using the laryngoscope. The neck is brought forward on a pillow and the head is fully extended at the atlantooccipital joints. The illuminated



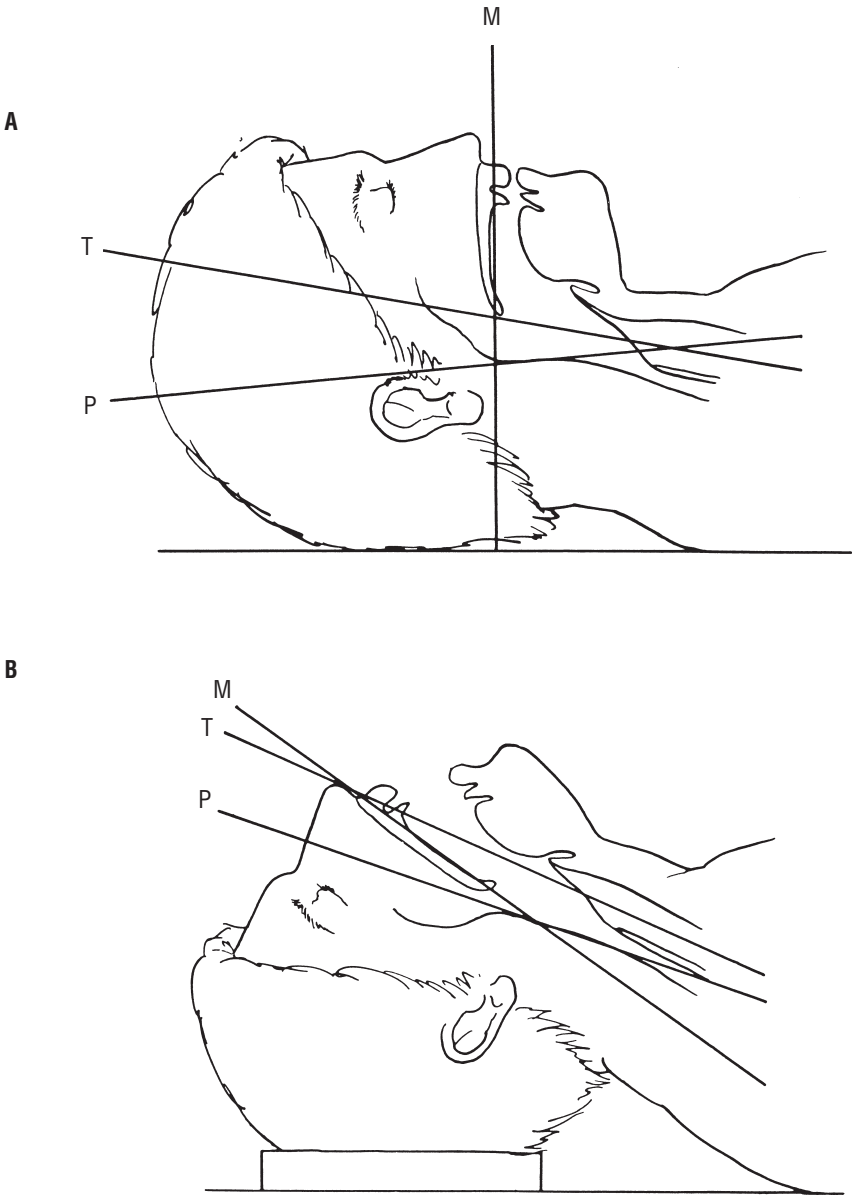
CD Figure 2-8 Inspection of the vocal folds (cords) indirectly through a laryngeal mirror (**A**) and through a laryngoscope (**B**). Note the orientation of the structures forming the laryngeal inlet.

instrument can then be introduced into the larynx over the back of the tongue (CD Fig. 2-8). The valleculae, the piriform fossae, the epiglottis, and the aryepiglottic folds are clearly seen. The two elevations produced by the corniculate and cuneiform cartilages can be recognized. Within the larynx, the vestibular folds and the vocal folds can be seen. The former are fixed, widely separated, and **reddish** in color; the latter move with respiration and are **white** in color. With quiet breathing, the rima glottidis is triangular, with the apex in front. With deep inspiration, the rima glottidis assumes a diamond shape because of the lateral rotation of the arytenoid cartilages.

If the patient is asked to breathe deeply, the vocal folds become widely abducted, and the inside of the trachea can be seen.

Important Anatomic Axes for Endotracheal Intubation

The upper airway has three axes that have to be brought into alignment if the glottis is to be viewed adequately through a laryngoscope—the axis of the mouth, the axis of the pharynx, and the axis of the trachea (CD Fig. 2-9).



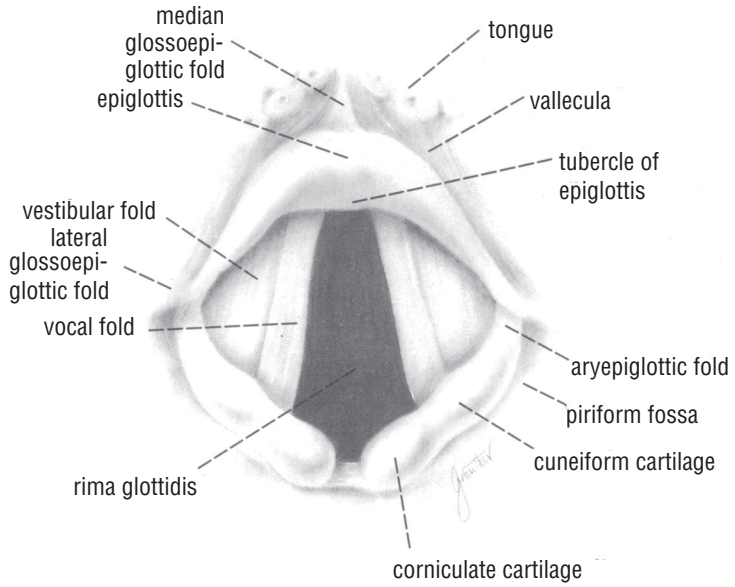
CD Figure 2-9 Anatomic axes for endotracheal intubation. **A.** With the head in the neutral position, the axis of the mouth (*M*), the axis of the trachea (*T*), and the axis of the pharynx (*P*) are not aligned with one another. **B.** If the head is extended at the atlantooccipital joints, the axis of the mouth is correctly placed. If the back of the head is raised off the table with a pillow, thus flexing the cervical vertebral column, the axes of the trachea and pharynx are brought in line with the axis of the mouth.

The following procedures are necessary: First the head is extended at the atlantooccipital joints. This brings the axis of the mouth into the correct position. Then the neck is flexed at cervical vertebrae C4 to C7 by elevating the back of the head off the table, often with the help of a pillow. This brings the axes of the pharynx and the trachea in line with the axis of the mouth.

Anatomy of the Visualization of the Vocal Cords with the Laryngoscope

1. The pear-shaped epiglottis is attached by its stalk at its lower end to the interior of the thyroid cartilage (see text Fig. 2-26).
2. The vocal cords (ligaments) are attached at their anterior ends to the thyroid cartilage just below the attachment of the epiglottis (see text Fig. 2-26).
3. Because of the above two facts, it follows that manipulation of the epiglottis and possibly the thyroid cartilage will greatly assist the operator in visualizing the cords and the glottis.

The patient's head and neck are correctly positioned so that the three axes of the airway (noted above) have been established and the patient has assumed the "sniffing" position. The laryngoscope is inserted into the patient's mouth, and the blade is correctly placed alongside the right mandibular molar teeth. The blade can then be passed over the tongue and down into the esophagus. The tip of the



CD Figure 2-10 The laryngeal inlet as seen from above.

blade must be fully inserted into the esophagus (so that you know where it is anatomically). The blade should by now have moved toward the midline and followed the anatomic curvature on the posterior surface of the tongue.

The laryngoscopic blade is then gently and slowly withdrawn. The tip of the blade is kept under direct vision at all times and is permitted to rise up out of the esophagus. Remember that the tip of the blade is at first in the esophagus and therefore distal to the level of the vocal cords. Once the blade tip has left the esophagus, it is in the laryngeal part of the pharynx, and a view of the glottis should immediately be apparent (CD Fig. 2-10). This is the critical stage. If the glottis is not visualized, then the operator is viewing the posterior surface of the epiglottis. **Now use your anatomic knowledge.**

With the tip of the blade of the laryngoscope applied to the posterior surface of the epiglottis, gently lift up and elevate the epiglottis to expose the glottis. If the glottis is still not in view, **do not panic!** Again use your knowledge of anatomy. With the right free hand grasp the thyroid cartilage (to which the cords and the epiglottis are attached) between your finger and thumb and apply firm backward, upward, rightward pressure (**BURP**). This maneuver realigns the box of the larynx relative to the laryngoscopic blade, and the visual axis of the operator and the glottis should immediately be seen.

Reflex Activity Secondary to Endotracheal Intubation

Stimulation of the mucous membrane of the upper airway during the process of intubation may produce cardiovascular changes such as bradycardia and hypertension. These changes are largely mediated through the branches of the vagus nerves.

THE TRACHEA

Palpation of the Trachea

The trachea can be readily felt below the larynx. As it descends, it becomes deeply placed and may lie as much as 1.5 in. (4 cm) from the surface at the suprasternal notch. Remember that in the adult it may measure as much as 1 in. (2.5 cm) in diameter, but in a 3-year-old child it may measure only 0.5 in. in diameter. The trachea is a mobile elastic tube and is easily displaced by the enlargement of adjacent organs or the presence of tumors. Remember also that lateral displacement of the cervical part of the trachea may be caused by a pathologic lesion in the thorax.

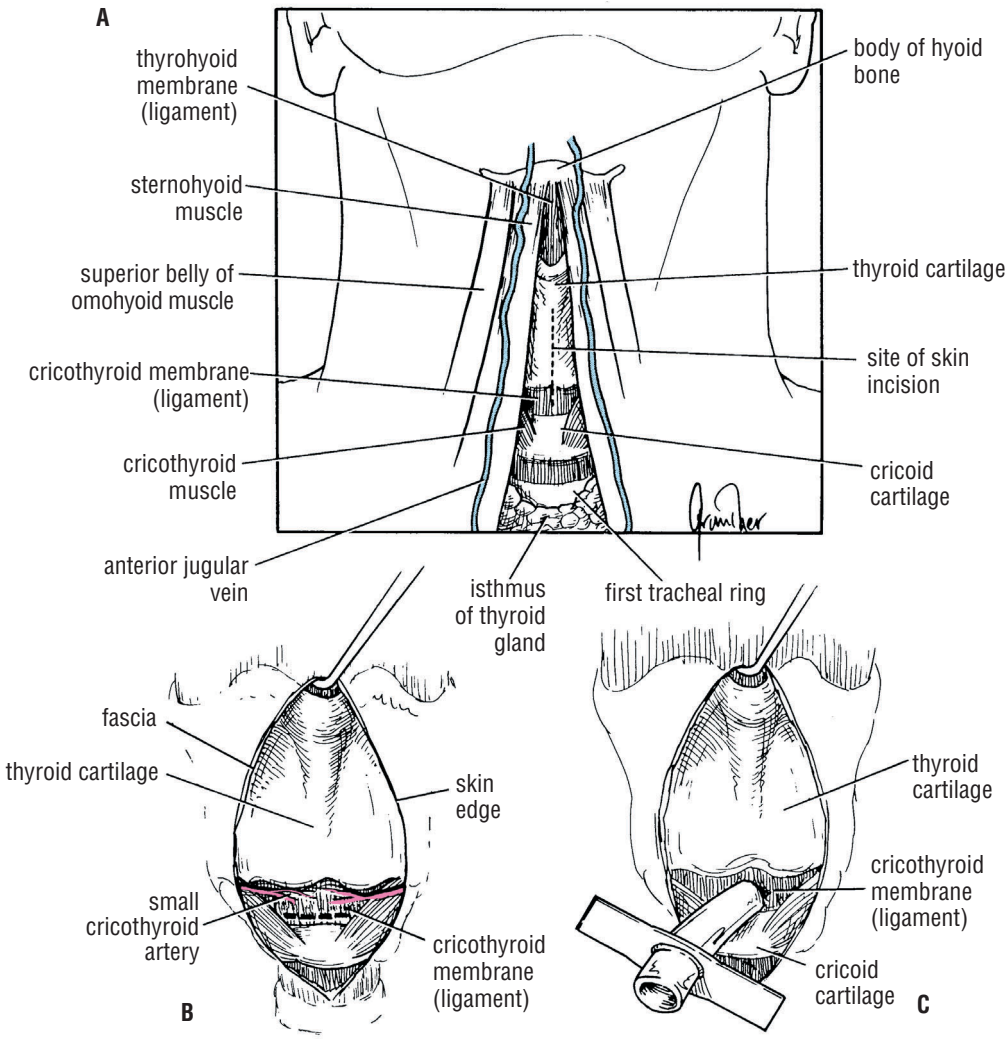
Compromised Airway

In a medical emergency immediate treatment is necessary.

Anatomy of Cricothyroidotomy

In cricothyroidotomy, a tube is inserted in the interval between the cricoid cartilage and the thyroid cartilage. The trachea and larynx are steadied by extending the neck over a sandbag.

A vertical or transverse incision is made in the skin in the interval between the cartilages (CD Fig. 2-11). The incision is made through the following structures: the skin, the superficial fascia (beware of the anterior jugular veins, which lie close together on either side of the midline), the



CD Figure 2-11 The anatomy of cricothyroidotomy. **A.** A vertical incision is made through the skin and superficial and deep cervical fasciae. **B.** The cricothyroid membrane (ligament) is incised through a horizontal incision close to the upper border of the cricoid cartilage. **C.** Insertion of the tube.

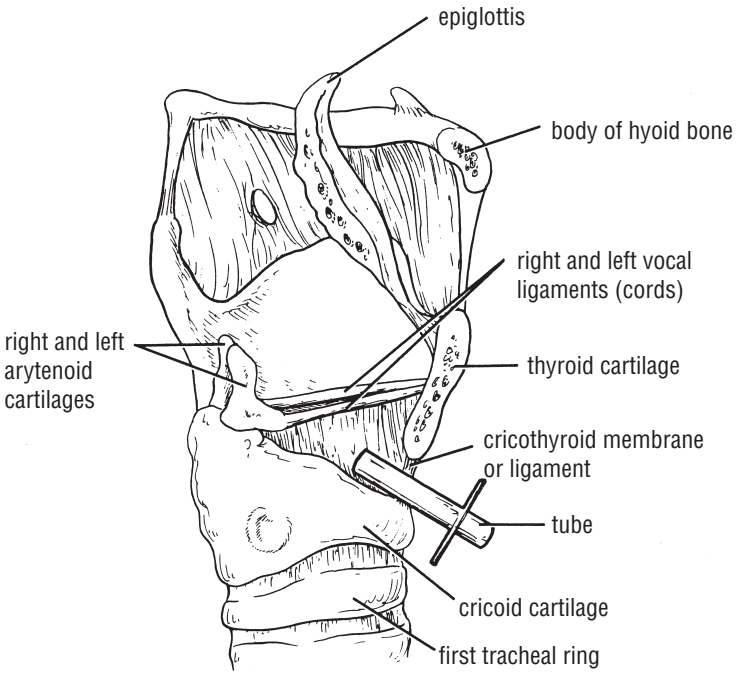
investing layer of deep cervical fascia, the pretracheal fascia (separate the sternohyoid muscles and incise the fascia), and the larynx. The larynx is incised through a horizontal incision through the cricothyroid ligament and the tube inserted (CD Fig. 2-12).

Complications

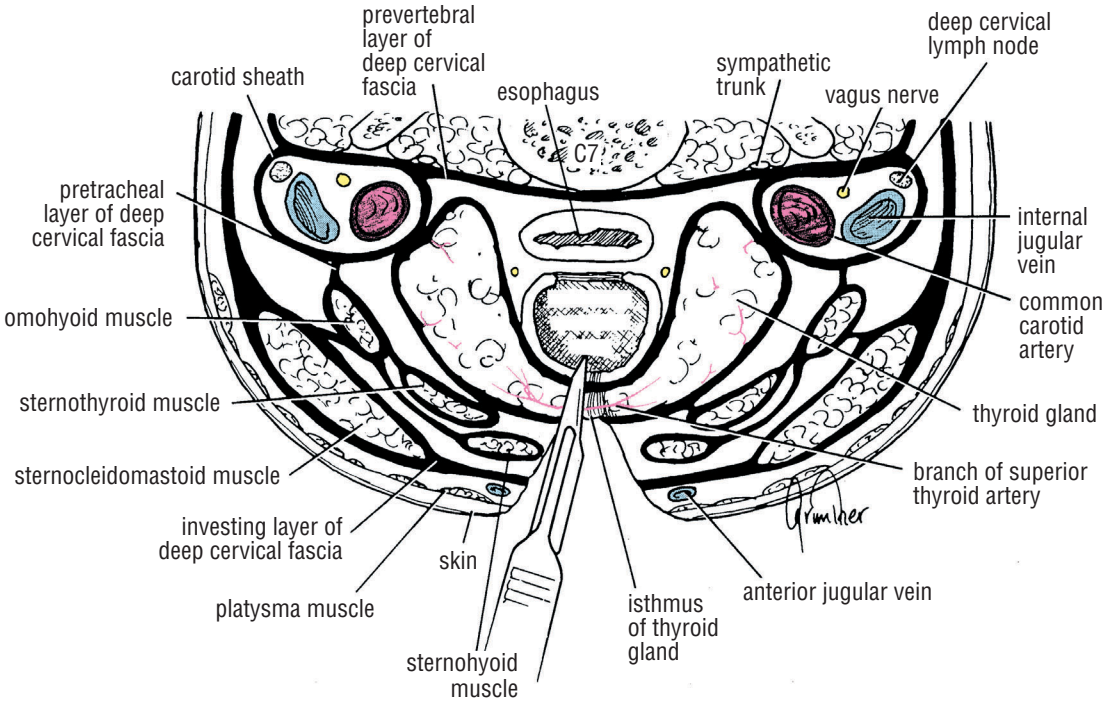
1. Esophageal perforation: Because the lower end of the pharynx and the beginning of the esophagus lie directly behind the cricoid cartilage, it is imperative that the scalpel incision through the cricothyroid membrane not be carried too far posteriorly. This is particularly important in young children, in whom the cross diameter of the larynx is so small.
2. Hemorrhage: The small branches of the superior thyroid artery that occasionally cross the front of the cricothyroid membrane to anastomose with one another should be avoided.

Anatomy of Tracheostomy

Tracheostomy is rarely performed and is limited to patients with extensive laryngeal damage and infants with severe airway obstruction. Because of the presence of major vascular structures (carotid arteries and internal jugular vein), the thyroid gland, nerves (recurrent laryngeal branch of vagus and vagus nerve), the pleural cavities, and esophagus, meticulous attention to anatomic detail has to be observed (CD Fig. 2-13).



CD Figure 2-12 View of the interior of the larynx as seen from the right side (the right lamina of the thyroid cartilage has been removed). Note the closeness of the deep end of the cricothyroidotomy tube to the vocal cords, especially if the tube is directed upward.



CD Figure 2-13 Cross section of the neck at the level of the second tracheal ring. A vertical incision is made through the ring, and the tracheostomy tube is inserted.

The procedure is as follows:

1. The thyroid and cricoid cartilages are identified and the neck is extended to bring the tracheal forward.
2. A vertical midline skin incision is made from the region of the cricothyroid membrane inferiorly toward the suprasternal notch.
3. The incision is carried through the superficial fascia and the fibers of the platysma muscle. The anterior jugular veins in the superficial fascia are avoided by maintaining a midline position.
4. The investing layer of deep cervical fascia is incised.
5. The pretracheal muscles embedded in the pretracheal fascia are split in the midline two fingerbreadths superior to the sternal notch.
6. The tracheal rings are then palpable in the midline, or the isthmus of the thyroid gland is visible. If a hook is placed under the lower border of the cricoid cartilage and traction is applied upward, the slack is taken out of the elastic trachea; this stops it from slipping from side to side.
7. A decision is then made as to whether to enter the trachea through the second ring above the isthmus of the thyroid gland; through the third, fourth, or fifth ring by first dividing the vascular isthmus of the thyroid gland; or through the lower tracheal rings below the thyroid isthmus. At the latter site, the trachea is receding from the surface of the neck, and the pretracheal fascia contains the inferior thyroid veins and possibly the thryoidea ima artery.
8. The preferred site is through the second ring of the trachea in the midline, with the thyroid isthmus retracted inferiorly. A vertical tracheal incision is made, and the tracheostomy tube is inserted.

Complications

Most complications result from not adequately palpating and recognizing the thyroid, cricoid, and tracheal cartilages and not confining the incision strictly to the midline.

1. Hemorrhage: The anterior jugular veins located in the superficial fascia close to the midline should be avoided. If the isthmus of the thyroid gland is transected, secure the anastomosing branches of the superior and inferior thyroid arteries that cross the midline on the isthmus.
2. Nerve paralysis: The recurrent laryngeal nerves may be damaged as they ascend the neck in the groove between the trachea and the esophagus.
3. Pneumothorax: The cervical dome of the pleura may be pierced. This is especially common in children because of the high level of the pleura in the neck.
4. Esophageal injury: Damage to the esophagus, which is located immediately posterior to the trachea, occurs most commonly in infants; it follows penetration of the small-diameter trachea by the point of the scalpel blade.

SOME IMPORTANT AIRWAY DISTANCES

CD Table 2-1 shows some important distances between the incisor teeth or nostrils to anatomic landmarks in the airway in the adult. These approximate figures are helpful in determining the correct placement of an endotracheal tube.

CHANGES IN THE TRACHEAL LENGTH WITH RESPIRATION AND POSITION OF THE HEAD AND NECK

On deep inspiration the carina may descend by as much as 3 cm. Extension of the head and neck, as when maintaining an airway in an anesthetized patient, may stretch the trachea and increase its length by 25%.

CD Table 2-1 Important Airway Distances (Adult)[a]

Airway	Distances (approximate)
Incisor teeth to the vocal cords	5.9 in. (15 cm)
Incisor teeth to the carina	7.9 in. (20 cm)
External nares to the carina	11.8 in. (30 cm)

[a]Average figures given ± 1–2 cm.

THE BRONCHI

Aspiration of Foreign Bodies and Stomach Contents

In adults, foreign bodies and stomach contents tend to be aspirated into the right principal bronchus, since this is more in line with the trachea than the left bronchus. In young babies, since both bronchi arise from the trachea at equal angles, no predilection for the right bronchus exists.

Suction Catheters, Endotracheal Tubes, and the Bronchi

Suction catheters and endotracheal tubes are more likely to enter the right more vertical principal bronchus than the obliquely positioned left principal bronchus in adults and older children.

BRONCHOPULMONARY SEGMENTS

See CD-ROM Chapter 3.

Clinical Problem Solving Questions

Read the following case histories/questions and give the best answer for each.

1. A 36-year-old man was taken to the emergency department after having been found lying unresponsive in a local park with an empty whisky bottle nearby. He was given oxygen by an open face mask during the 15-minute ride in the ambulance. The paramedic decided to improve the airway by passing a soft nasal tube. On attempting to pass the well-lubricated tube into the patient's nose, the paramedic found it impossible to push it much beyond the nasal vestibule on either side. What are the common anatomic causes of obstruction of the nasal airway?

2. A 12-year-old girl was brought to the hospital with a history of fever, malaise, anorexia, and a sore throat. She also had hoarseness, a cough, and rhinitis. On examination there was erythema of the posterior pharyngeal wall, with small ulcers on the palatoglossal folds and soft palate. The tonsils were seen to be red and enlarged, and an obvious white-yellow exudate was seen on the surface of the left tonsil. Examination of the deep cervical lymph nodes showed enlargement and tenderness of the node below and behind the angle of the mandible; the enlargement was greatest on the left side. A diagnosis of viral pharyngitis was made. List the various lymphoid organs found in the nasal and oral parts of the pharynx. Explain Waldeyer's ring.

3. A 3-year-old boy was playing with his toys on the floor when his sister decided to share some peanuts with him. A few minutes later he started to cough and gave a hoarse cry. The cough then became croupy, and aphonia occurred. The mother, hearing the commotion, rushed into the room and quickly realized what had happened. She turned the child upside down and hit his back several times, but with no effect. The child, now in obvious respiratory distress, was rushed to the local emergency department. On examination, he was tachypneic, with suprasternal retractions. He was not coughing, and although he attempted to cry, there was no sound. He would not tolerate being laid down. On the basis of your knowledge of the anatomy of the airway, where do you think the foreign body was lodged? Describe the normal protective reflexes that exist in the airway to *prevent* the inhalation of a foreign body. What is the anatomic and physiologic rationale behind the use of back blows, chest thrusts, and abdominal thrusts (Heimlich procedure) in the management of upper airway obstruction? Which of these procedures is most appropriate for a 3-year-old child?

4. A 17-year-old boy was driving his minibike at high speed along a country lane, when he suddenly saw what he thought was a shortcut through a gap in a hedge. He did not see that the gap was closed by a strand of barbed wire. He struck the wire with his neck and was thrown from the bicycle. On arrival at the emergency department, he had all the signs and symptoms of upper airway obstruction. Using your knowledge of the anatomy of the neck, explain the type of injury that could have occurred in this case. Does the position of the vocal cords at the time of impact influence the type of injury that occurs? What anatomic factors normally protect

the upper airway from serious blunt injuries? Does age play a role in the severity of the injury?

5. A 39-year-old man with extensive maxillofacial injuries following an automobile accident was brought to the hospital. Evaluation of the airway revealed partial obstruction. Despite an obvious fractured mandible, an attempt was made to move the tongue forward from the posterior pharyngeal wall by pushing the angles of the mandible forward. This maneuver failed to move the tongue, and it became necessary to hold the tongue forward directly in order to pull it away from the posterior pharyngeal wall. At times, why is it not possible to pull the tongue forward in the presence of a fractured mandible?
6. When a laryngoscope is passed it is important to align the mouth, the oropharynx, and the larynx into one plane. How do you bring the axes of the oropharynx and the larynx in line? How do you bring the axis of the mouth in line with the other axes? Describe the structures in the order that you can view them through a laryngoscope from the base of the tongue down to the trachea.

Answers and Explanations

1. The most common cause for difficulty in passing a nasal tube is a deflected nasal septum. This occurs more commonly in the male, and is thought to be due to previous trauma to the septum during the period of active growth. Nasal spurs and polyps may cause difficulty and swelling of the mucous membrane secondary to infection or chemical irritation, and can also cause blockage. The widest part of the nasal cavity is near the floor.
2. The lymphoid tissue around the openings of the mouth and nasal cavities into the pharynx include (1) the palatine tonsil, (2) the lingual tonsil, (3) the tubal tonsils, and (4) the pharyngeal tonsil. For details of Waldeyer's ring, see text Chapter 2.
3. The presence of severe respiratory distress with suprasternal retractions and aphonia indicates the presence of upper airway obstruction, probably located within the larynx. The airway is protected by a number of important reflexes, including the gag reflex, the laryngeal reflex, and the cough reflex. The gag reflex occurs in response to stimulation of the pharyngeal mucous membrane innervated by the glossopharyngeal nerve. The laryngeal and the cough reflexes are mediated via the vagus nerve. These protective reflexes are lost in descending order as a patient loses consciousness.

   All maneuvers that are directed toward freeing an obstruction of the airway by an inhaled foreign body are based on an attempt to increase the intrathoracic pressure by compressing the intrathoracic gas volume, so that the foreign body is expressed from the mouth. The underlying mechanisms involved in the use of back blows, chest thrusts, and abdominal thrusts are discussed in this CD chapter. It is now generally agreed that the best and safest method to use on a 3-year-old child is the abdominal thrust.
4. The impact of the wire to the front of the neck caused hyperextension of the cervical part of the vertebral column with stretching of the larynx and trachea. This effectively fixed the airway structures in the midline so that they were not deflected laterally at the moment of impact. Under these circumstances the cartilages of the larynx are fractured or crushed. Depending on the speed of the impact, the larynx could be completely avulsed from the trachea. In this situation the tone of the suprahyoid muscles would cause the larynx to be retracted superiorly and the elasticity of the trachea would cause it to retract inferiorly to the root of the neck or behind the sternum.

   If the glottis were closed at the time of impact, the raised intraluminal pressure within the upper airway may contribute to the severity of the injury. The upper airway receives a considerable amount of protection from blows to the front of the neck and chest because of the presence of the mandible and manubrium sterni. With the head and neck in the flexed position, the larynx and trachea are remarkably mobile and often deflected laterally by an anterior blow to the neck.

   In children, the very flexible nature of the laryngeal and tracheal cartilages and looseness of the supporting connective tissue reduce the likelihood of severe damage to these structures.
5. The root of the tongue is attached anteriorly to the mental spines on the posterior surface of the symphysis menti of the mandible by the right and left genioglossus muscles. If this bony origin were floating because of fractures on both sides of the body of the mandible, pulling the angles of the mandible forward would have no effect on the position of the tongue.

6. The axis of the oropharynx and the larynx are brought into direct line by flexing the cervical part of the vertebral column. The axis of the mouth is brought in line with the oropharynx by extending the atlantooccipital joints.

   The following structures may be viewed: (1) the base of the tongue; (2) the median glossoepiglottic fold, the two lateral glossoepiglottic folds, and the valleculae on each side of the median fold; (3) the upper edge of the epiglottis and the opening into the larynx, bounded in front by the epiglottis with its tubercle and laterally by the aryepiglottic folds—the rounded elevations of the cuneiform and corniculate cartilages in the folds can be recognized; (4) the reddish fixed vestibular folds; (5) the whitish mobile vocal cords; and (6) below the glottis the interior of the trachea with the upper two or three rings.