20 Management of Airway

HISTORY

The tracheal intubation in animals was first described by Vesalins of Padua, in 1543 and by R. Hooke of UK, in 1667. But after that there was prolonged silence and nobody had tried for intubation. Then, after a long interval, the end of the eighteenth century had again seen a flurry of researches and publications on tracheal intubation. It was triggered by the humanitarian factor for the resuscitation of drowned persons by mouth to mouth breathing. Because during that period mouth to mouth resuscitation of drowned person was condemned due to unhygienic ground. So, there was continuous search for alternative way to resuscitate a drowned person other than this unhygienic mouth to mouth artificial ventilation. Then, again after a century, in 1776, John Hunter described tracheal intubation by a metal tracheal tube. After that, in 1788, C. Kite had also described an oral and nasal intubation for resuscitation of a apparently drowned person. This is followed by James Curry who also described several different metal endotracheal tube in 1792. But, in 1827, Leroy had first showed that pneumothorax may result from high intrapulmonary pressures during artificial ventilation by tracheal tube. Then, John Snow used a tracheal catheter to resuscitate a newborn baby.

All these works described above was directed with an aim, either for resuscitation of a drowned person, or for the relief of an upper airway obstruction. Then, from 1848, passage of a metal tube or a catheter into the trachea was also routinely practised to resuscitate only the anaesthetic casualities, but not to administer sole anaesthesia. Gradually, there was a significant technical advancement to contemplate for deliberately administering anaesthetic vapours through this tracheal tube for sole anaesthetic purpose. So, John snow in 1852 had made a historical leap by intubating animals via a tracheostomy wound and providing anaesthesia through this tube. After that, in 1871, Friederich Trendslenburg of Rostock used this method in human while he was a surgical assistant to surgeon named Dr Langenbeck in Berlin. He used this method for operation in mouth. After performing a tracheostomy, he introduced a tube into the trachea and inflate the cuff for administering anaesthesia.

At that time, it had been assumed that if a tube was passed through the larynx it would not be tolerated, except tracheostomy. So, they were used to do tracheostomy for intubation. But in 1878, William MacEwen of Glasgow had first decided and try to avoid tracheostomy for intubation, if otherwise inevitable. So, after practising on the cadever, he passed a flexible metal tube through the mouth into the trachea, using his fingers as a guide in a conscious patient. Through this tube he gave choloroform and air mixture for the removal of carcinoma from the base of the tongue. A sponge was packed by him around the tube at laryngeal inlet to protect the lungs from contamination. He had also previously used rubber and gum elastic catheters into the trachea for the relief of obstruction in laryngeal diphtheria. Next in 1901, Franz Kuhn of Kassel had extended and developed this technique by using a flexible metal tube and introducing it through larynx with the help of curved wire guide after palpating the epiglottis with the fingers of his left hand. His preference was for inhalation anaesthesia and the patient was breathing to and fro through the tube. Then in 1907, Berthelemy and Dufour of Nancy, in France, blew the mixture of chloroform vapour and air into the lungs from a Vermon Harcourt inhaler through a rubber catheter which was guided into the trachea by hand, as laryngoscope was not invented at that time. It was the first kind of endotracheal insufflation technique of anaesthesia and was subsequently widely used in the forth coming World War I in 1914.

Largely after that due to their experience as anaesthetist during World War I, Mr Gillies, Mr Rowbotham and Mr Magill first used ether inhalation through one narrow gum elastic tube passed via larynx with the help of laryngoscope. During that period laryngoscope had already been invented which is described later. After that the first blind nasal intubation was performed by Rowbotham. Then, Magill also published his results of blind nasal intubation by using a wide bore rubber catheter during the years following 1928. This technique revolutionised the use of endotracheal tubes in anaesthesia, because not only it provides anaesthesia, but also gained early control of the airway and protect it. Inflatable cuffs had been used for many years but were again reintroduced by Guedel and Waters in 1928. A pilot ballon had been described first in 1893 by Eisenmenger. It was also described in 1906 by Green and was reintroduced by Langton in 1939.

While the methods of intubation by Magill and Rowbotham had earned the support and approval of the surgeons with whom they worked, but many other surgeons discouraged the use of intubation through larynx. This was partly because of the possibility of tissue damage and partly due to conservatism. Thus, it took many years before the intubation was accepted by the all anaesthetists. Those who learnt how to perform blind nasal intubation soon realised its great advantages, especially due to the fact that it would enable a patient to be taken to the necessary level of anaesthesia very quickly by the use of relaxant and IPPV than by the use of only volatile anaesthetics which at that time was the rule. In addition, they also realised that intubation provides a clear airway, prevents laryngeal spasm and enables the lungs to be proteced against aspiration of foreign materials.

During the previous period, intubation was performed only by deepening anaesthesia by volatile anaesthetics such as ether or chloroform which was only available at that time. After that, when the muscle relaxants became available, then it was possible to perform oral intubation easily and rapidly by direct laryngoscopy. Because intubation by only inhalational anaesthetic agent was difficult and need a long time to reach the necessary deep plane of anaesthesia for it. The use of muscle relaxants to facilitate intubation in UK was pioneered by Bourne. This turning point in anaesthesia was long over due. So, the credit was given to Bourne for convincing the postwar generation of anaesthetists of the value of relaxants for rapid and easy intubation.

The traditional tubes for either nasal or oral intubation were Magill endotracheal tubes, made of mineralised rubber. The red colour of the tube is due to the presence of preservative. The oral tubes had thicker walls than the nasal ones. The angled oxford tube was thicker in the pharyngeal part and thinner in the tracheal part. Then Polyvinyl chloride (PVC) tubes had started to replace the red rubber tube, progressively from 1950. The toxicity of the PVC tube was tested by implantation test in rabbit muscle (IT = Implantation Test) or by cell culture. The Z79 was the committee in USA that originally approved anaesthetic equipment to maintain a standard and was formed first in 1956. RAE preformed tubes were first developed in 1980.

During the evolution of direct laryngoscope, indirect laryngoscopy was also evolving. The indirect laryngoscopy with mirror was first introduced by M Garcia who was a teacher of singing in london. Then, it was widely used for diagonostic purposes. But, direct laryngoscopy was pioneered in 1895 by Alfred kirstein. After that Jackson himself designed a laryngoscope which was later modified by Magill in 1926 and by Miller and Macintosh in 1932. The light was originally powered from the electric mains. But later the light was supplied by a 3 volt battery which was incorporated into the handle of laryngoscope or by a fibreoptic cable. The Macintosh blade was shorter, curved and Z shaped on cross section. Its tip entered the valecula, lifted the base of the tongue and with it the epiglottis, so that the cords could be visualised. It does not generate so much laryngospasm as it does not pass over and stimulate the posterior surface of the epiglottis. Then, it was an immediate success and has continued to be so, as it can be used in lighter planes of anaesthesia. Macintosh also developed a laryngeal forcep which bear his name and is used for directing the nasal tubes under direct vision into the larynx.

Without using muscle relaxant, cocaine was first used to supress the laryngeal reflexes during general anaesthesia by Rosenberg in 1895 and by Magill in 1928 to aid intubation. Then many sprays also have been described such as applying local anaesthetic to the larynx to supress the reflexes for intubation. But lignocaine is now generally preferred because of its lower toxicity.

To remove the different disadvantages of endotracheal intubation, initially a small mask had been tried in the pharynx, but it was rejected. Then, the invention of laryngeal mask airway (LMA) had completed the cycle of history of airway management in anaesthesia. It was first developed by an anaesthetist, named Mr A Brain and was later manufactured by an equipment company, named Colgate Medical. After that improved materials and different designs of the laryngeal mask airway, coupled with the timely arrival of propofol which deeply supresses the pharyngeal and laryngeal reflexes allowed a successful outcome of it.

INTRODUCTION

An airway is defined as the passage through which air passes into and out of the lungs during respiration. Any artificial device with a lumen inside of it and which serves as a conduit, connecting between the atmosphere and lungs is also considered as an airway. These include oropharyngeal airway, nasopharyngeal airway, LMA, other supraglottic airways, endotracheal tube (ETT), ventilator's breathing circuit etc. It is estimated that about 600 patients die each year in a developed country from complications, related to the airway management. This picture in the under developed countries is further grimmer. On the contrary, about 98% of difficult airway in relation to mask ventilation or ET intubation can be predicted by proper preoperative evaluation or assessment of patient (Table 20.1).

Table 20.1: Preoperative evaluation of patient

1.	Facial anomalies Maxillary hypoplasia Apert syndrome, Crouzon disease. Mandibular hypoplasia Pierre-Robin syndrome, Treacher-Collins syndrome, Goldenhar syndrome. Mandibular hyperplasia Acromegaly, Cherubism.
2.	Affection of temporomandibular joint Ankylosis, rheumatism, trauma, infection, previous surgery, etc.
3.	Problems with teeth Loose teeth, false teeth, protruding incisior, edentulous.
4.	Problems with tongue Macroglossia due to Down syndrome, hypothyroidism, haemangioma, lymphangioma, tumour, scarring, etc.
5.	Problems with mouth Microstomia due to burns, trauma, scarring, etc.
6.	Problems with palate Cleft palate, narrow arched palate, palatal swelling, haematoma etc.
7.	Problems with pharynx Hypertrophic tonsils, large adenoids, pharyngeal tumours, abscess, retropharyngeal or para pharyngeal abscess, etc. Supraglottic-epiglotitis, tumour, injury etc.
8.	Problems with larynx a. Glottic—Laryngomalacia, granuloma, foreign body, papillomas. b. Infraglottic—Congenital stenosis, traumatic stenosis, oedema due to inflammation.
9.	Problems with nose Choanal atresia, hypertrophic turbinates, deviated nasal septum, polyp, foreign bodies, etc.
10.	Problems with trachea Tracheal stenosis, tracheal webbing mass of neck deviating trachea, mediastinal mass deviating trachea, trachea esophageal fistula, tracheomalacia, foreign bodies, etc.
11.	Problems of neck and spine a. Neck - large goiters, skin contractures. b. Spine - Klippel-Feil syndrome, surgical fusion, fracture of cervical vertebrae, traumatic subluxation, etc.

The difficult airway is defined by American Society of Anaesthetist (ASA) as the clinical situation in which a conventionally trained anaesthesiologist experiences difficulty during mask ventilation or difficulty during tracheal intubation or both. *Difficult mask ventilation* is defined by ASA as the clinical situation in which it is not possible by an unassisted trained anaesthesiologist to maintain O_2 saturation more than 90%, using 100% oxygen and mask for ventilation, provided preventilation O_2 saturation level was within the normal range. *Difficult laryngoscopy* is defined by ASA as clinical situation in which it is not possible to visualise any portion of the vocal cords with conventional laryngoscope. ASA also defines *difficult endotracheal intubation* as a situation when insertion of ET tube in the larynx requires more than 3 consecutive attempts or more than ten minutes with conventional laryngoscope and experience. The later definition of ten minutes provides a margin of safety for preoxygenated patients who are undergoing elective intubation in the operating room. Because such patients in stable circumstances can usually tolerate 10 minute of attempts without any bad consequences. *'Zero class airway view'* is defined as unability to see any portion of the epiglottis after opening the mouth and tongue protrusion. Approximately 1.8% patient of the total population belongs to this class of airway view. *Failed intubation* is defined as the condition when the placement of ET tube fails after multiple attempts of intubation.

The airway is divided into an upper and lower airway. The upper airway is comprised of oral cavity, nose, pharynx (nasopharynx, oropharynx and laryngopharynx) and larynx. The nose is again comprised of external nose and nasal cavity. The lower airway includes the trachea, bronchi, bronchiole, and its subsequent divisions and subdivisinos which terminate in the alveoli. The upper airway serves to warm, humidify and filter the air or gases before it enters the lower airway. Bypassing these structures by endotracheal intubation or tracheostomy makes an anaesthetist essential to provide warm, humidified and filtered air to the patient. Among the two airways, upper airway is more vulnerable to obstruction during anaesthesia. This is because in anaesthetised patient there is loss of muscle tone which allows the tongue to fall back on the pharynx, the pharyngeal wall to collapse and occlude the upper airway at the level of laryngo pharynx and then subsequently allows the epiglottis to occlude the airway at the level of larynx.

There are many different accquired and congenital conditions which affect the upper and lower airways and cause the difficult management of it. These are listed in the Table 20.1.

ANATOMY OF THE UPPER AIRWAY

Nose

Nose consists of external nose and nasal cavity.

External nose

It is a pyramid like projection on the face. It presents a free tip or apex and a root at its junction with the forehead. The rounded boarder between the tip and the root of the nose along with adjoining area is known as the dorsum of the nose. The inferior surface of the external nose presents a pair of pyriform apertures which is called the nostrils or nares. Each nostril is bounded medially by the mobile part of nasal septum and laterally by the ala of nose (Fig. 20.1).

The frame work of the external nose is formed by some bones and cartilages. Among them the upper part is supported by bones and the lower part is supported by cartilages. The upper part is supported by the following bones such as nasal bone, frontal process of the maxillary bone and nasal part of the frontal bone.

The lower part is contributed by the following cartilages:

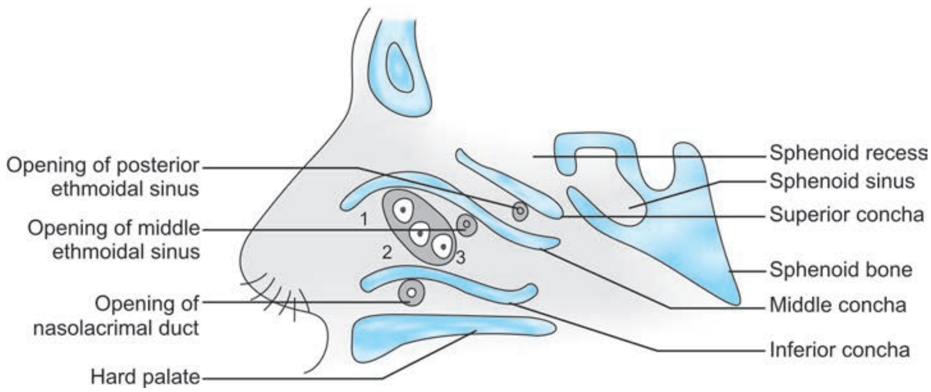


Fig. 20.1: The structures which open on the lateral wall of the nose. The cut margin of conchas are seen. 1. Opening of frontal sinus, 2. Opening of anterior ethmoidal sinus, 3. Opening of maxillary sinus

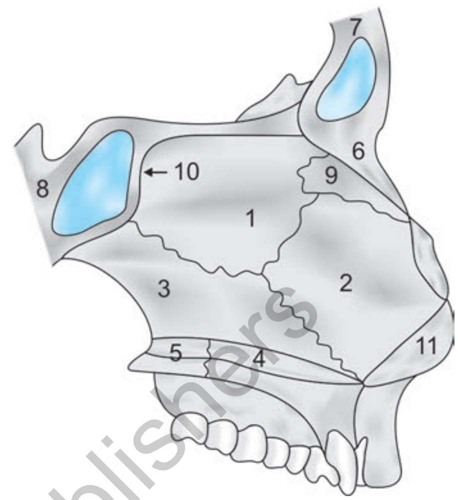


Fig. 20.2: The formation of nasal septum
1. Perpendicular plate of ethmoid
2. Septal cartilage
3. Vomer
4. Nasal crest of maxilla
5. Nasal crest of palatine bone
6. Nasal spine of frontal bone
7. Frontal bone
8. Sphenoid
9. Nasal crest of nasal bone
10. Rostrum of sphenoid
11. Septal process of inferior nasal cartilage.

i. anterior border of the septal cartilages,
ii. superior nasal cartilages, which is continuous with the septal cartilages,
iii. inferior nasal cartilage (or alar cartilage) which presents a septal process to form the mobile part of nasal septum,
iv. a few minor alar cartilages,
v. fibrofatty tissue in the lower part of the ala.

The skin overlying the bones at the root of the nose is thin and mobile. But it is thick and adherent to the underlying cartilages and fibrofatty tissue. The skin of nose is provided with multiple sebaceous glands.

The sensory nerves of external nose are derived from (i) the external nasal and the infratrochlear branches of opthalmic nerve and (ii) the infraorbital branch of maxillary nerve.

Nasal Cavity

The nasal cavity is triangular in shape and has an irregular surface. It is divided into right and left halves by the nasal septum. Each half of the nasal cavity extends anteriorly from the mucocutaneous junction of anterior nares to the nasopharynx posteriorly (posterior nares and choanac). Each nasal cavity has a roof, a floor, a lateral wall and a medial wall. The roof of the nasal cavity slopes downwards both in front and behind from the middle horizontal part. The middle horizontal part of the roof of the nasal cavity is formed by the cribriform plate of ethmoid bone. The anterior slope of the roof is formed by the nasal part of the frontal bone, nasal bone and the nasal cartilages. The posterior slope of the roof is formed by the inferior surface of the body of sphenoid bone. The floor of nasal cavity is formed by the palatine process of maxilla and the horizontal plate of palatine bone. The area of the nasal cavity close to the nostrils or anterior nares is known as the vestibule. It is lined by skin and provided with coarse hairs, sebaceous glands and sweat glands. Except vestibule, rest of the nasal cavity is lined by the mucous membrane (Fig. 20.2).

The lateral wall of the nasal cavity is irregular due to the presence of three shelf-like or scroll-like bony projections. These projections increase the surface area of the nose and ensure effective conditioning (warming and humidification) of the inspired air. Lateral wall separates the nasal cavity (i) from the orbital cavity above while the ethmoidal air sinuses interven between them, (ii) from the maxillary sinus below and (iii) from the lacrimal groove with lacrimal sac and the nasolacrimal canal with nasolacrimal duct in front (Fig. 20.3).

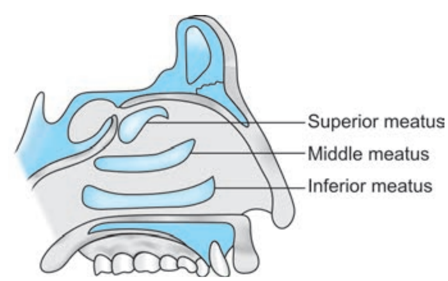


Fig. 20.3: The lateral wall of the nose

The lateral wall of the nasal cavity is formed by some bones. These are: nasal, frontal process of maxilla, lacrimal, labyrinth of ethmoid with superior and middle conchae, inferior nasal concha, perpendicular plate of palatine and medial pterygoid plate of sphenoids. There is a shallow depression which is situated just in front of the middle meatus and above the vestibule of the nose. This is called atrium (Fig. 20.4).

The bony lateral wall of the nasal cavity is convoluted by three turbinates. The superior and middle turbinates are formed by the medial aspect of the lateral mass (or labyrinth) of the ethmoid bone. The inferior turbinate is formed by

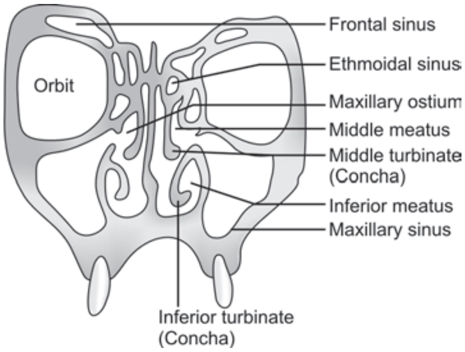


Fig. 20.4: The coronal section through nose and sinuses at the plane of maxillary ostium

separate bone called inferior nasal concha which is attached to the maxilla. In cross section, as the bones of turbinates look like whorl (turbinate) or scroll (concha), so they are named like that. Each turbinate hangs over a meatus or channel and the meatuses are named according to the name of the turbinate. The highest space in the nasal cavity above the superior turbinate is called the spheno-ethmoidal recess and sphenoidal sinus opens in this recess.

The olfactory cleft of nasal cavity is the area which lies between the superior turbinate, cribriform plate of ethmoid and the corresponding area of the septum. It is lined by specialised olfactory epithelium.

Several ducts drain on the lateral wall of the nose at the meatuses under the respective turbinate. The nasolacrimal duct open into the inferior meatus. The frontal, maxillary and anterior ethmoidal sinuses drain into the middle meatus. The posterior ethmoidal sinuses drain into the superior meatus. Sphenoethmoidal recess receives the sphenoidal sinus.

The nasal septum is situated in the midline and seperates the two nasal cavities. Posteriorly, it is bony in structure and anteriorly it is cartilagenous. Bony part of the nasal septum is formed almost entirely by vomer and the perpendicular plate of ethmoid bone. However, its margins are contributed by the nasal spine of frontal, the rostrum of sphenoid and the nasal crests of nasal, palatine and maxillary bone. The cartilagenous part of nasal septum is formed by the septal cartilage and septal process of inferior nasal cartilage. The attachement of the cartilagenous part of nasal septum are inferiorly to the maxillary crest, posteriorly to the vomer, posterosuperiorly to the perpendicular plate of the ethmoid. The nasal septum is rarely strictly in midline. It is usually deflected to one or the other side and the deflection is produced by the overgrowth of one or more of the constituent parts of it.

Mucous membrane

The mucus membrane of the nose is initially adherent to the periostium or the perichondrium with the exception at the olfactory area. At the olfactory area it is loosely attached. The nasal mucous membrane is subdivided into three parts: vestibular part, olfactory part and respiratory part.

Vestibular part

This part of the mucous membrane lies just inside the aperture of the nostril. It is lined by skin with coarse hairs, sweat glands and sebaceous glands. The hairs (vibrissae) which are curved forward here are moistened by the secretion of the sebaceous gland and arrest the foreign particles, carried by the inspired air.

Olfactory part

This part of the mucuous membrane contains the olfactory cells and its hairs. From the olfactory cells 15 to 20 olfactory nerves start which pass through the cribriform plate of the ethmoid bone and end in the olfactory bulb of cerebrum.

Respiratory part

The rest part of the mucous membrane of nose except the vestibular and olfactory area constitute the respiratory part. It is lined by thick, vascular, ciliated, columnar epithelium. The ciliated columnar epithelium is interspersed by goblet cells. It is thickest and most vascular over the lower aspect of the septum and the turbinates. Actually, over the inferior concha the mucous membrane contain masses of the erectile tissues with numerous arterio-venous shunts. It permits vascular engorgement to regulate the temperature and humidity of the inspired air. The secretion from the sub-epithelial thin walled vessels, serous glands and mucous glands contribute to the formation of mucous in the nose.

The mucous secreted in the nose has two phases – the gel phase and the sol phase. The sol phase is less viscous and is closely applied to the columnar cells of mucous membrane. The gel phase lies over the solphase and is more viscous. It moves backwards by the hooks of the beating cilia which are situated at the end of the ciliated columnar cells. The cilia beat the mucous of the nose back to the nasopahrynx. The mucus and nasal vibrissae (hair) helps to trap the contaminants or foreign particles from the inspired air. The vascularity of the nasal mucosa helps in warming and moistening of the inspired air.

Arterial supply of nose

The arterial supply of nose consists of the arterial supply of medial wall (or nasal septum) and the arterial supply of lateral wall.

A. Arterial supply of medial wall or nasal septum

The nasal septum is supplied by the following arteries.

i. Mobile part of the septum is supplied by the septal branches of superior labial artery which is the branch of facial artery (Fig. 20.5).
ii. Antero superior part of nasal septum is supplied by the anterior ethmoid artery, branch of ophthalmic artery.
iii. Postero inferior part of nasal septum is supplied by the sphenopalatine and greater palatine artery, branches of ophthalmic artery.

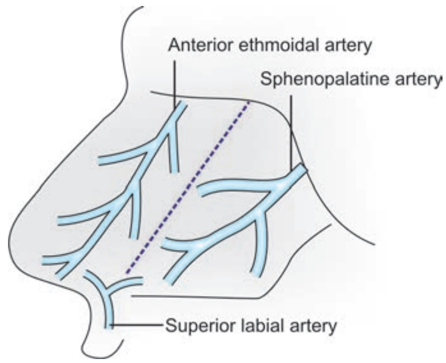


Fig. 20.5: The arterial supply of the nasal septum

An area on the antero inferior part of the septum is highly vascular and known as the Little's area of epistaxis. Because this is the common site for profuse arterial haemorrhage from nose. Here, the septal branch of facial artery, long spheno palatine and terminal branches of greater palatine arteries anastomose.

B. Arterial supply of lateral wall

Similar to the nasal septum, the lateral wall of nose is supplied by the branches of ophthalmic, maxillary and facial arteries. The branches are arranged into four quadrants.

i. Antero superior quadrant: It is supplied by the anterior ethmoid artery, branch of ophthalmic artery.
ii. Postero superior quadrants: It is supplied by the post ethmoidal artery branch of ophthalmic artery and sphenopalatine artery branch of maxillary artery.
iii. Anteroinferior quadrant: It is supplied by the alar branch of facial and terminal branches of greater palatine arteries.
iv. Postero inferior quadrant: It is supplied by greater palatine artery (Fig. 20.6).

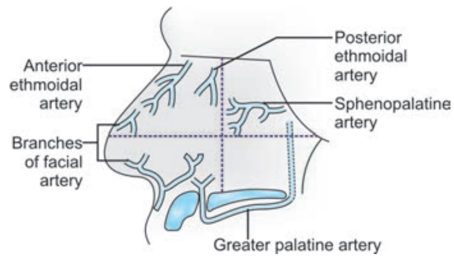


Fig. 20.6: The arterial supply of the lateral wall of the nose

Nerve supply of nose

Nasal septum

1. General sensory nerves – comes from the ophthalmic and maxillary divisions of trigeminal N and supply the whole septum.
   i. Anterosuperior part of septum – supplied by the intrernal nasal branch of anterior ethmoidal N – branch of opthalmic N – branch of trigeminal N.
   ii. Postero-inferior part of septum – supplied by the spheno-palatine branch of pterygopalatine ganglion – branch of maxillary N – branch of trigeminal N.
   Mobile part: supplied by the external nasal nerve, branch of the ophthalmic division of trigeminal nerve.
2. Special sensory olfactory nerves – supply the upper olfactory area (Fig. 20.7).

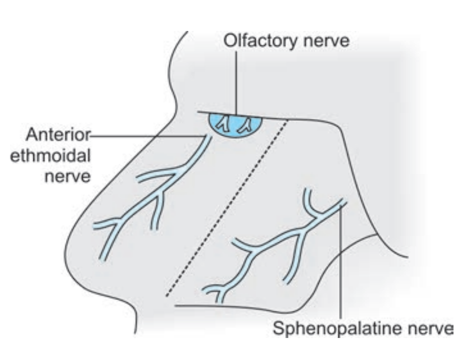


Fig. 20.7: The nerve supply of nasal septum

Lateral wall of nose

1. General sensory nerves: Like nasal septum the nerve of the lateral wall comes from the trigeminal nerve and distribute to the whole portion of it.
   a. Anterosuperior quadrant–supplied by the anterior ethmoidal nerve – branch of opthalmic nerve–branch of trigeminal nerve.
   b. Anteroinferior quadrant–supplied by the anterior–superior alveolar nerve – branch of maxillary nerve–branch of trigeminal nerve.
   c. Posterosuperior quadrant–supplied by the posterior–superior lateral nasal nerve–comes from pterygo–palatine ganglion–branch of maxillary nerve–branch of trigeminal nerve.
   d. Posteroinferior quadrant–supplied by the anterior palatine nerve–comes from pterygopalatine ganglion–branch of maxillary nerve–branch of trigeminal nerve.
2. Special sensory olfactory nerves – supply to the upper part just below the cribriform plate of ethmoidal bone up to the superior concha (Fig. 20.8).

Functions of the nose

The nose does the following important functions.

(i) Respiration

An adult patient usually takes inspiration through the nose, provided there are no obstructions. Then, the inspired air passes through a wide curve which begins at the nostril and continues through the upper part of the nose to end at the posterior choanae. The inspired air is laminar in flow by character. However, the expired air does not follow this laminar flow like the inspired air. But, it is broken up by the turbinates into turbulent and eddies flow and then passes out through the nostrils. It has been

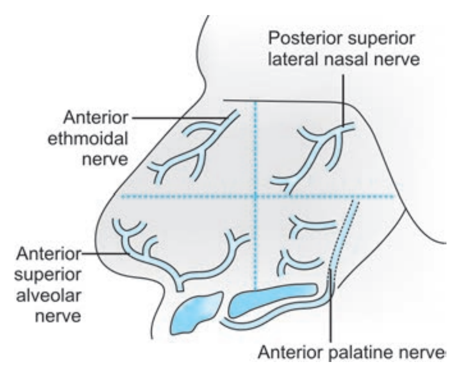


Fig. 20.8: The nerve supply of the lateral wall of nose

postulated that this is because the outlet is smaller than the inlet as the posterior choana is much larger than the nostril. Inevitably, always there is also certain degree of recirculation of air.

In a normal adult subject, the resistance for air to flow through the nose is one and half times greater than the mouth and accounts for nearly 2/3 of the total airway resistance. This explains why a patient takes mouth breathing when high air flow rates are necessary. So, it is always advisable to taste the patency of nasal passage before the nasal intubation is performed. Deflection of nasal septum sometimes become severe and diminishes the lumen of the respiratory airway. Thus, it prevents the passage of all, but the smallest of endotracheal tube.

(ii) Defence

The presence of stiff hairs in the anterior part of nasal fossa (vestibule), the thick and highly vascular (spongy) mucous membrane, the ciliated colmnar epithelium, the extensive lymphatic supply and the bacteriocidal property of the secreted mucous provide a powerful defensive action of nose against the invasion of any organism directly from air. Intermittent flushing action of the watery secretion of nose by sneesing also lies in the reserve of defence action of it.

(iii) Warming and humidification

The most important work that the nose has to perform is the warming and humidification of the inspired air, which is about 10,000 litres in 24 hours in a normal healthy adult. This is only possible due to the high vascularity of nasal mucous membrane. For example, if the temperature of the inspired air is 17°C which is equivalent to the normal room temperature is raised to 37°C which is equivalent to the normal body temperature during its passage through the nose and upper airway. The inspired air temperature also may vary from 25°C to 0°C according to the temperature of the enviornment. But, its passage through the nose produces more or less 1°C difference than that of the body temperature, when it reaches the laryngeal inlet or alveoli (Fig. 20.9).

When the air passes through the air passages, then with rising of temperature also the qauantity of water, needed to saturate the air by water vapour increases. As for example, at room temperature of 17°C the air normally contains 2 volume percent of water to become fully saturated. But, at body temperature of 37°C the air should contain 6 volume percent of water vapour to become fully saturated. The nose and the respiratory tract, therefore, have to perform this heavy task of warming and humidification of the inspired air by adding large quantities of heat and water vapour in the inspired air to make it warm and saturated with water vapour. Warming and humidification of inspired air is achieved by the dilatation of vessels of large vascular mucosal beds of the turbinates of nose. They normally change their volume after every 4 hours of interval (nasal cycle) and each side alternates.

The humidification of inspired air in the air passage is done by the supply of moisture (or water vapour) which comes as transudation of fluid from the mucosal epithelium of nose, pharynx and larynx, and to a lesser extent from the secretion of mucous glands and goblet cells, present in the nasal and pharyngeal mucous membrane. The daily volume of nasal secretions is about 1 litre. Of which about 3/4 is used to humidify the inspired air. Nose also collects the moisture from the expired air to prevent the excessive loss of water from the body.

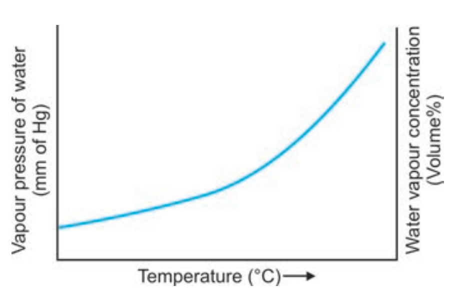


Fig. 20.9: The relationship between the tension of water vapour and the temperature

During intubation and tracheostomy, relatively dry and cool anaesthetic gases or air reach the trachea directly. Because nose and pharynx is bypassed and so proper warming and humidification of inspired air is not done. This compell the mucosa of the trachea and bronchus to perform the heavy duties of nasal and pharyngeal mucous membrane. Therefore, the mucosa of lower airways becomes dry and ciliary activity ceases in such circumstances. Later the tracheal and bronchial mucosa adapts itself to this changed condition. So, endotracheal anaesthesia is frequently followed by tracheitis and bronchitis.

In the most anaesthetic machine, compressed-dry-cooled gases are used. But, these gases are warmed itself to the room temperature before entering into the body during their passage through the long flexible breathing tube. On the other hand, by the 'to and fro' breathing system which occurs in the canister and which is situated near the patient's mouth, the temperature of the inspired gases can be raised upto 37°C (body temperature). So, this system provides (canister which is not used now) very efficient method for warming and humidification of the inspired air. But it has other disadvantages which is discussed in appropriate chapter. But during the passage of expired air through CO_2 absorber in circle system the expired air gains some heat and water vapour produced during absorption of CO_2. In non-rebreathing valve system such as if Ruben and Frumin valve is attached with the circuit, the inspired air is always at room temperature (17°C) and contains only 2 volume percent of water vapour at full saturation which is the normal content of air. But as there is no rebreathing, so the expired air at 37°C containing 6 volume percent of water vapour at full saturation passes out through the valve. In the absence of rebreathing heat with water vapour is also lost from the body to the atmosphere. Thus it does not help to warm and humidify the inspired air.

In the circle absorption system, the inspired gas mixture contains fresh dry gases coming from cylinder and pipelines and also some expired gases containing water vapour at room temperature. The expired gas leave the patient at body temperature containing water vapour. But by the time they have traversed the breathing tube of the apparatus, they become cool to the room temperature and so have lost the major part of their water content in the apparatus. Dry, cool, fresh gas is again added to the system for inspiration and is mixed with the expired gas coming from the absorber. So, the circle absorption system does much help in warming and humidifying the inspired gases.

(iv) Resonance

Nose as surrounded by multiple air cavities, so gives some resonance to the voice and helps in talk. It also protects the transmission of sound of one's own speech to his own ears. It also equalises the pressure during respiration between internal and external pressure.

(v) Filter

Nose also helps in filtering and clearing the suspended particles from the inspired air. It also transports the mucus posteriorly to lubricate the pharynx.

(vi) Olfaction

Nose also acts as an integral part of the olfactory system.

Some methods of humidification of Inspired air

The inspired air can be humidified by various ways. These are:

(i) Direct instillation of water

Inspired air can be humidified by direct fine drop by drop instillation of normal saline into an endotracheal or tracheostomy tube.

(ii) Water bath

Here, inspired air is passed over the surface of water, kept in a thermostatically controlled and heated water bath. This type of humidifier should be placed on the inspired limb and the gases will flow from the water bath to the patient by the shortest possible route. The tube in shortest route should be insulated to prevent the heat loss with consequent water condensation during the passage of heated and humidified inspired air through the tube. Another method to deliver the inspired gas at body temperature with full saturation by water vapour but without condensation in the breathing circuit is to raise the temperature of the water bath few degrees above the body temperature for compensation to loss which occurs during passage through inspiratory limb. The exact temperature setting of the water bath depends on the surface area of the water, flow rate of gases and the amount of cooling and condensation which take place in the inspiratory limb after the water bath. This type of humidifier should always be kept below the level of the patient to prevent the water being blown accidentally into the patient (Table 20.2).

(iii) Moisture exchanger

It is also called the 'artificial nose'. It is mainly consists of replaceble condenser that can be taken out and cleaned. It is very light and a moderately efficient method of humidification of inspired air. As this system works at room temperature which is much below the body temperature, so part of the water vapour of expiratory gases is condensed on its inner surface and this condensed water again humidifies the dry inspired gases. It can not, of course, achieve full saturation owing to the lower temperature. There are two demerits of this system. One is the colonisation of bacteria and another is the increasing of airway resistance due to the condensation of moisture. These disadvantages can be overcome by using disposable and sterilised unit.

Table 20.2: The percentage of humidity of inspired gases in different anaesthetic system

Anaesthetic system	*% of humidity*
Nose	100
Close circuit	40 - 60
'To and fro' system	60 - 100
Non-rebreathing valve	0
T-piece	0

(iv) Mechanical nebuliser

This is operated by pneumatic power and breaks up the drops of water into small particles. In this system the water passes up through a capillary tube to its summit where it is crushed by the jet of air into microparticles. In this type of nebuliser 80% of the water particles are in the range of 2 to 4 microns and the remainder are smaller. So most of these particles are deposited around the bronchial level and for many patients this is sufficient. Contrary, the water particles which are less than 2 micron reach the small bronchi and alveoli. Those water particles which are above 4 microns do not float. They coalesce and fall back in the reservoir. This type of nebuliser for humidification of inspired air can be used pre and post-operatively with the face mask to improve the lung function.

(v) Ultrasonic nebuliser

This is the most efficient instrument for humidification of inspired air. Here the drops of water is passed through a capillary tube, and completely nebulized to aerosal by a vibrating transducer head which is activated by a high frequency ultrasonic energy. Here, 70% of the water particles get the size of 0.8 to 1 micron. So usually, most of the particles of less than 1 micron are deposited in the lower airways and alveoli of the lungs. At the maximum rate of 12 drops of water/ min falling on the transducer head and with a ventilator delivering of 10 litres of gas/min, 72 ml of water as vapour can be provided with each litre of gas . This corresponds to the relative humidity of 160% at 37°C.

Among all the methods of humidification of inspired air, ultrasonic nebuliser produces the most satisfactory humidification. It can also be used for the administration of water soluble aerosal drugs. The two demerits of this instrument are: (i) over hydration, due to extreme effeciency and (ii) difficulty to sterilise by conventional method.

Ciliary Activity of Airway

Throughout the upper and lower respiratory tract the continuous ciliary activity of mucous membrane plays a very important function. This is the prevention of accumulation of mucous secretion which is needed for the efficient functions of nose, pharynx and larynx. By ciliary action in the nose, the mucous secretion are swept posteriorly towards the pharynx and in the bronchial tree the mucous secretions are carried upwards towards the larynx (Fig. 20.10).

The Cilia are fine hair like structures. They are 7 µm in long and 0.3 µm in width. The tips of cilia are always bend towards the direction of the flow of mucous. In the shaft of the cilia which are occupied by cytoplasm there are microtubules containing dyenin arms. The longitudinal fibrils or microtubles in the shaft of the cilia are arranged in a fashion like that a pair of microtubles is situated in the centre and it is surrounded by nine pairs of microtubles at the periphery. The activity of the cilia depends mainly on the mucous blanket, covering it. The covering mucous blanket consists of two layers. The outer gel layer is thick and viscous. It is designed to entrap the floating particles from inspired gas such as dust, soot, microorganisms etc. The inner sol layer is thin serous like fluid. It is designed to lubricate the action of the ciliary movement. The tips of cilia come just in contact with the outer gel layer with each beat. Acting in union, the cilia set the outer gel layer in motion. Thus gathering momentum, the mucous flows towards the pharynx from nose and towards the larynx from the bronchus and trachea. They beat forward in an effective stroke pulling the gel phase by the action of hooks at the end of the cilia and then beat backward in a recovery stroke. Their action is reminiscent of a corn field being blown by the wind. This movement is called metachrony, as opposed to the synchrony where all the cilia beat together. At 37°C, the cilia of the nasal mucosa beat about 10 to 16 times per second. The average estimated speed of movement of mucous blanket over the mucous membrane is 0.25 to 1 cm/min. Thus, the entire mucous content of the nose take 20 to 30 minute to be emptied into the pharynx (Fig. 20.11).

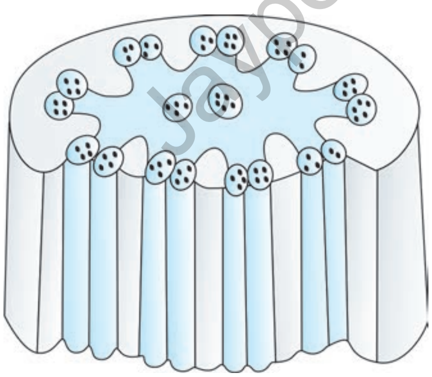


Fig. 20.10: The transverse and longitudinal section of a nasal cilium at the middle of the shaft of it

In some conditions, ciliary action may be defective, for example, Kartagener's syndrome. This is a genetic disorder in which there is defect in the ultrastructure of the cilia. This is due to the failure of synthesis of protein which form the dyenin arm of cilia. The congenital absence of this dyenin arms which normally contain ATP and power the cilia makes the cilia immobile. So, these patients have a constantly running nose, secretory otitis media, chronic sinusities, bronchiectasis and often situs inversus. The tail of sperms have the similar structure like cilia. So that in this syndrome there is also male infertility due to reduced sperm motility.

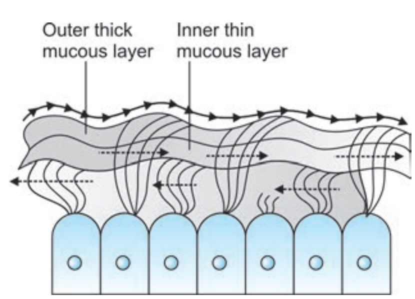


Fig. 20.11: The ciliary movement

Factors influencing ciliary activity

The factors which influence the ciliary activity are: temperature, mucous, changes in pH and drugs.

Temperature

There is a definite range of temperature when the cilia acts optimally. This is 28°C to 35°C. Ciliary activity ceases when the temperature of the mucosa falls from 7°C to 10°C. It is also depressed when the temperature of cilia rises above 35°C, while the average nasal temperature is about 32°C. Actually the direct effect of temperature on ciliary action is minimal and the effect is largely caused indirectly by alterations in the amount of mucus secreted.

Mucous

Cilia cannot work without the optimum temperature and the blanket of mucus. Drying out of the mucus blanket over them can stop ciliary activity, though the temperature is maintained at optimum level. So, excessive dry and cool air, volatile anaesthetics, atropine, etc; decrease mucus secretion and subsequently stop the ciliary activity.

Changes in pH

Cilia acts better in alkaline media. They become paralysed in acid solutions at pH 6.4 or less. A rise of pH to 8 or more also causes depression of the ciliary activity.

Drugs

All volatile anaesthetics, opiates, atropine, etc, also depress ciliary activity. But, N_2O has no effect on it.

Pharynx

The pharynx or the pharyngeal airway is a fibromuscular structure. It extends proximally from the base of the skull at the posterior aspect of the nose to distally upto the level of the 6th cervical vertebra or cricoid cartilage where it becomes continuous with the oesophagus and the larynx. Anteriorly the pharynx communicates with the nasal cavities, the oral cavity and the larynx from above downwards. Thus, pharynx is divided anatomically into nasopharynx, oropharynx and laryngopharynx (hypopharynx). Soft palate separates the nasopharynx from the oropharynx and the plane drawn at the upper border of epiglottis separates the oropharynx from laryngopharynx. Except the nasopharynx which is covered by ciliated columnas epithelium, the oropharynx and laryngopharynx is covered by the stratified squamous epithelium. The middle fibrous layer of pharynx consists of the pharyngobasilar fascia. The outer muscular layer of pharynx is comprised chiefly of the three constrictor muscles such as superior, middle and inferior constrictor muscle of pharynx and overlap one on another from below upwards.

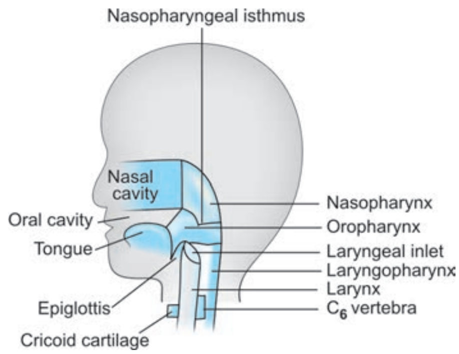


Fig. 20.12: The sagittal section of head showing the different parts of pharynx

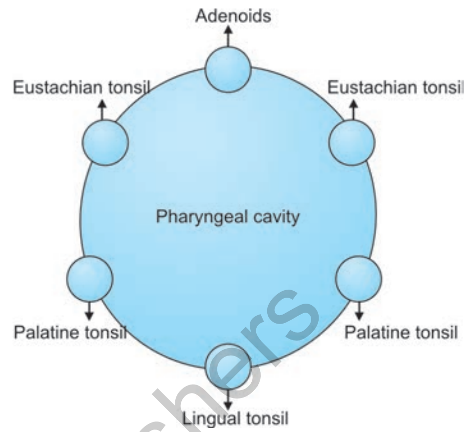


Fig. 20.13A: The ring of Waldeyer

Nasopharynx (Fig. 20.12)

It extends above from the base of the skull to below upto the level of hard palate and soft palate. Anteriorly nasopharynx communicates with the nasal cavities through the posterior nares and posteriorly it is bounded by the body of C_1 and C_2 vertebrae. Nasopharyngeal isthmus is the aperture situated between the nasopharynx and oropharynx and is surrounded by the free margin of the soft palate anteriorly and the posterior wall of the pharynx posteriorly. This opening is closed during the 2nd stage of deglutition by the soft palate. At the junction of the roof and the posterior wall of the nasopharynx and at the base of the skull, there lies a small mass of lymphoid tissue, embedding in the mucous membranes called the pharyngeal tonsil or adenoids. By the side of adenoid, there is an opening of Eustachian tube, which connect the middle ear cavities with the nasopharynx. It is also lined by ciliated columnar epithelium and is continuous with the nasopharynx. There is also a collection of lymphoid tissue around the Eustachian tube opening and is called the Eustachian tonsil. Lying close to the base of the adenoids there is a small recess, called the pharyngeal bursa which often impedes the passage of a nasal endotcheal tube. If force is applied, the tube may then penetrate the bursa and can create a false passage. This may lead to the collection of blood and postoperative sepsis. As the pharynx is riched with the lymphatic supply, so the enlargement of these lymph glands and the swelling of the overlying mucosa may lead to the partial obstruction of the airway. All the lymph glands of nasopharynx are arranged in a circular fashion, called the Waldeyer ring. It consists of adenoids (A), Eustachian tonsil (E), palentine tonsil (P) lying between the pillars of the fauces, and the small lingual tonsil (L) at the base of the tongue. The motor nerve supplying to the constrictors muscle of pharynx comes from vagus. The sensory nerve supply of pharynx comes from the trigeminal nerve (Fig. 20.13A).

Oropharynx

This part of the pharynx extends from the level of hard palate and soft palate above to the level of the hyoid bone below. It is bounded above and infront by the soft and hard palate; below and infront by the dorsal surface of base of the tongue up to the upper border of epiglottis. It is bounded posteriorly by the bodies of C_2 and C_3 vertebrae. The free edge of the soft palate forms the palatine arch. From the centre of the palatine arch uvula hangs downwards. From the side of the arch, on either side, two folds of mucous membrane run downwards. These two folds of mucous membrane are raised up by the bands of muscle fibres, named the palatoglossus and palatopharyngeus muscle. They form the pillar of the fauces and between which lies the palatine tonsil. The glossopharyngeal and trigeminal nerve supplies the sensory of the oropharynx.

Hypopharynx

It is a part of the pharynx lying below the oropharynx. It extends from the plane drawn at the upper border of the epiglottis above to the lower border of the cricoid cartilage or C_6 vertebrae below, where it is continuous with the larynx in front and the oesophagus at behind. The inlet of larynx, posterior surface of cricoid and arytenoid cartilage lie in front and 4th, 5th and 6th cervical vertebrae lie behind the hypopharynx. Laterally, the hypopharynx present the pyriform fossa on each side of the inlet of larynx. Pyriform fossa is bounded medially by the eryepiglottic fold and laterally by the thyroid cartilage and the thyrohyoid membrane. Beneath the mucosa of the pyriform fossa lies the internal laryngeal nerve which is a branch of superior laryngeal nerve (Fig. 20.13B).

The motor supply of hypopharynx comes from the cranial accessory nerve through the pharyngeal branches of glossopharyngeal nerve. Vasomotor of pharynx is supplied by the superior cervical sympathetic ganglion. The vagus nerve supply the sensory to the airway below the level of epiglottis. The superior laryngeal nerve, a branch of vagus, divides into an external (motor) nerve and an internal (sensory) laryngeal nerve that supply sensory to the hypopharynx and larynx between the epiglottis and vocal cord. Another branch of vagus, the recurrent laryngeal nerve, supply the larynx below the vocal cord and trachea.

Larynx

Larynx acts as an organ of voice, air passage and inlet valve for the lower respiratory tract.

It extends from the base of the tongue above to the trachea below. It lies opposite to the body of C_3 to C_6 vertebrae. In children it lies more anteriorly and at more higher level than adult. Larynx is consist of cartilages, ligaments, muscles and membranes. The cartilages are total 9 in number. Among them 3 are paired (arytenoid, corniculate and cuneiform) and 3 are unpaired (epiglottis, thyroid and cricoid). The epiglottis is a leaf-shaped cartilage with broad and free upper margin. The lower end of it is pointed and attached to the angle between the two laminae of the thyroid caritlage. Anteriorly the epiglottis is connected to the base of tongue by 3 mucosal folds – a median glossoepiglottic fold and a pair of lateral glossoepiglottic folds. The depression between the median and lateral glossoepiglottic fold is called the vallecula and this is the site where the tip of the blade of Macintosh laryngoscope rests. The epiglottis projects into the hypopharynx and overhangs on the laryngeal inlet. Sealing of the laryngeal inlet by epiglottis during swallowing and deglutition is not absolutely necessary. The lateral margins of the epiglottis is attached to the quadrate membrane which extends from the arytenoid cartilage (situated posteriorly) to the margins of the epiglottis (situated anteriorly). The lower free border of this quadrate membrane forms the vestibular fold and the upper free border forms the aryepiglottic fold. Arytenoid is a small pyramidal shaped cartilage and situated at the upper border of the lamina of cricoid caritlage. The Apex of arytenoid cartilage again articulates with corniculate and cuneiform cartilage. Vocal cord is attached to the vocal process of this arytenoid cartilage. Corniculate and cuneiform cartilage lie in the posterior part of aryepiglottic fold (Fig. 20.14).

The thyroid cartilage is a V-shaped cartilage and is made up of two quadrilateral laminae. They are fused > 90° angle in male and > 120° angle in female anteriorly. The line of junction of these two laminae forms in male the Adam's apple. The Posterior border of the thyroid cartilage is free and projects both upwards and downwards as superior and inferior cornu. The Inferior cornu articulates with the cricoid cartilage. On the outer surface of the laminae of thyroid cartilage there is an oblique line which gives attachment to sternothyroid, thyrohyoid and inferior constrictor muscle of the pharynx. The Upper border of the thyroid cartilage gives attachment to the thyrohyoid membrane

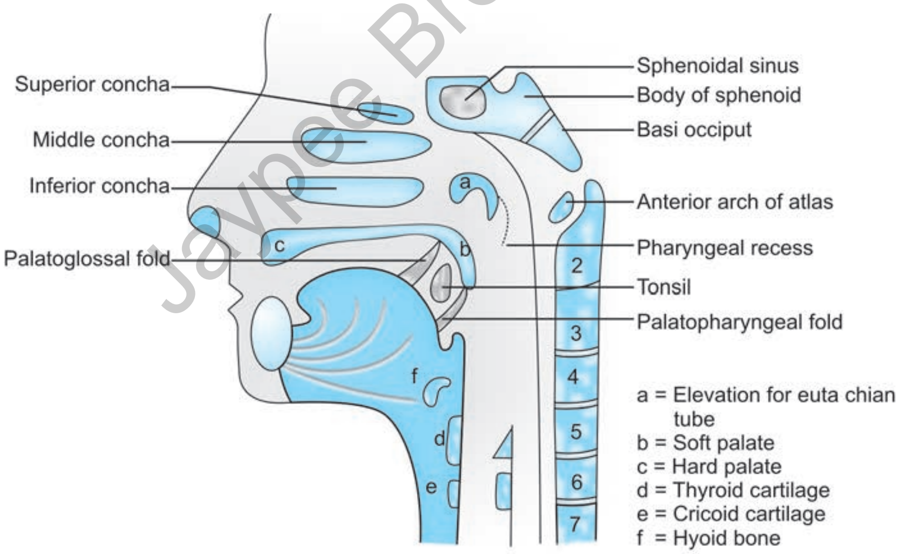


Fig. 20.13B: The sagittal section through the pharynx, nose, mouth and larynx

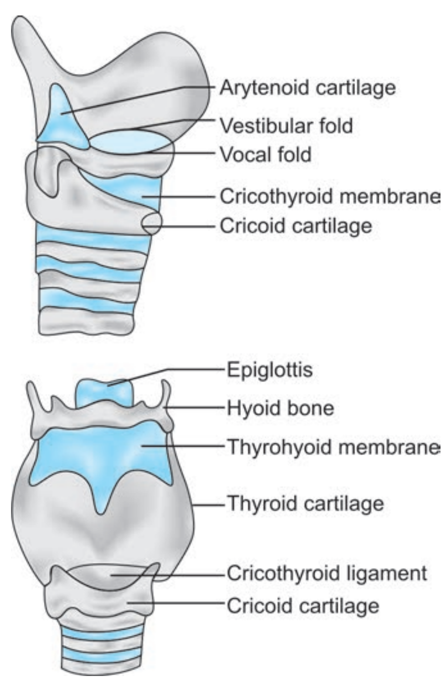


Fig. 20.14: Cartilages and ligaments of larynx

which is pierced by the internal laryngeal nerve and superior laryngeal vessels (Fig. 20.15).

The cricoid cartilage is looked like a signet shaped ring and encircles the larynx. The narrow anterior part of this ring shaped cricoid cartilage is called the arch and the broad posterior part is called the lamina. Superiorly the lamina is attached with arytenoid cartilage and at the side with the inferior cornu of the thyroid cartilage. A membrane named the conus elasticus or cricovocal membrane extends upwards and medially from the upper border of the arch of cricoid cartilage to the thyroid cartilage in front and the vocal process of the arytenoid cartilage behind. The anterior part of this membrane is thick and is known as the cricothyroid ligament. The upper free border of this conus elasticus membrane forms the vocal cord (Fig. 20.16).

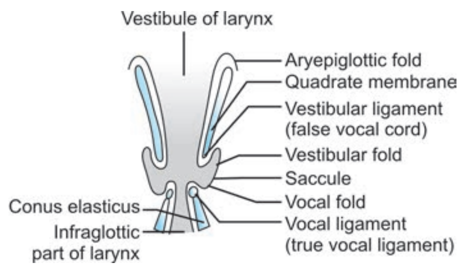


Fig. 20.16: Coronal section showing the parts of the cavity of larynx

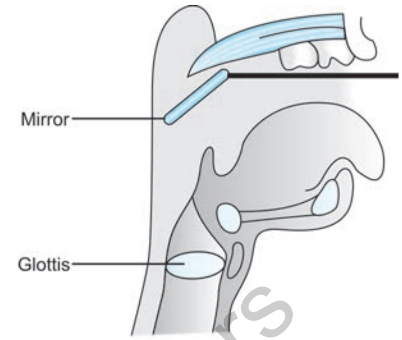


Fig. 20.17: Indirect laryngoscopy by mirror

Cavity of larynx

The cavity of the larynx extends above from the inlet of the larynx to the lower border of the cricoid cartilage below where it is continuous with the trachea. The inlet of larynx opens above in the laryngopharynx or hypopharynx and bounded anteriorly by the epiglottis; posteriorly by the interarytenoid fold of mucous membrane and on each side by the aryepiglottic fold which is the upper border of the quadrate membrane (Fig. 20.17).

Within the cavity of the larynx, on each side there are two folds of mucous membrane. The upper folds are called the vestibular folds and the space between these two vestibular folds is called the rima vestibuli. The lower folds are called the vocal cords and the space between these two vocal cords is called the rima glottis.

The vestibular fold and the vocal fold divide the cavity of the larynx into three parts. The part of the larynx above the vestibular fold is called the vestibule of larynx. The space between the vestibular folds and the vocal folds is called the sinus of the larynx and the part below the vocal folds is called the infraglottic part of the larynx. The anterior part of the sinus of larynx is prolonged upwards as a diverticulum between the vestibular fold and the lamina of thyroid cartilage. This extension of the sinus is called the saccule of larynx and contains mucous glands which helps in lubrication of the vocal folds (Fig. 20.18).

In the vestibular folds, under the mucous membrane, a narrow bands of fibrous tissue passes from the anterolateral surface of the arytenoid cartilage to the angle of the thryoid cartilage at the point of attachment of the epiglottis. This is called the vestibular ligament. On the otherhand, in the true vocal folds under the mucous membrane a tough fibrous vocal ligament extends from the vocal process of arytenoid cartilage to the angle of thyroid cartilage. Since, as there is no true submucous layer with the usual network of blood vessels within it, so the true vocal cords or folds have the characteristic pale appearance.

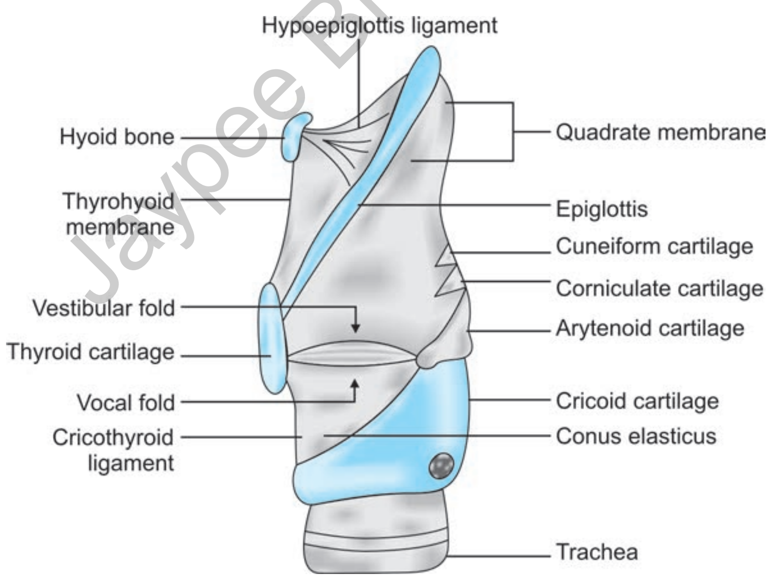


Fig. 20.15: Ligaments and membranes (mainly quadrate membrane and conus elasticus) of larynx

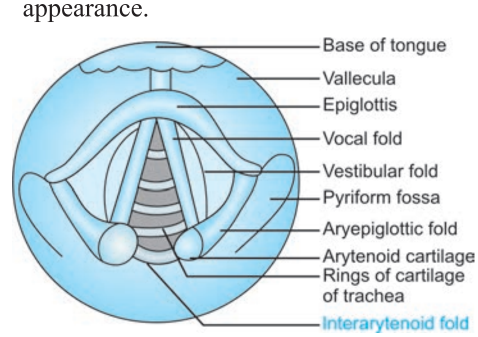


Fig. 20.18: The laryngeal image on mirror during indirect and direct laryngoscopy

In an adult the narrowest part of the laryngeal cavity is the area which is situated between the vocal cords. But in children, under ten years of age, the narrowest part of the larynx is just below the vocal cords at the level of the cricoid cartilage. The clinical significance of this anatomical difference in larynx between an adult and child is found, when small children are intubated. The significance is that in children an endotracheal tube which can be passed between the vocal cords may yet be too large to pass beyond the cricoid cartilage.

Mucous membrane of larynx

The total anterior surface of the epiglottis, upper ½ of the posterior surface of epiglottis, the upper parts of aryepiglottis folds and the vocal folds are all lined by the stratified squamous epithelium. Otherwise, the rest of the laryngeal mucous membrane is covered with the columnar ciliated epithelium. All parts of the mucous membrane of laryngeal cavity are loosely attached to the cartilages, except over the vocal ligaments and posterior surface of the epiglottis where it is thin and firmly adherent to the underlying structure. So, this prevents further spread of laryngeal oedema and accumulation of tissue fluids downwards in the larynx causing suffocation. Mucous glands are absent over the vocal cords. But they are plenty over the anterior surface of the epiglottis, around the cuneiform cartilages and in the vestibular folds. In other parts of the larynx this mucous glands are scanty.

Nerve supply of larynx

Both the superior and the recurrent laryngeal nerves which are branches of vagus supply the sensory and the motor of the larynx. The superior laryngeal nerve descends on the lateral wall of the pharynx, passes posteriorly to the internal carotid artery and at the level of the greater cornu of hyoid bone it divides into an internal and external laryngeal branch (Fig. 20.19).

The internal laryngeal branch is entirely sensory, apart from a few motor filaments

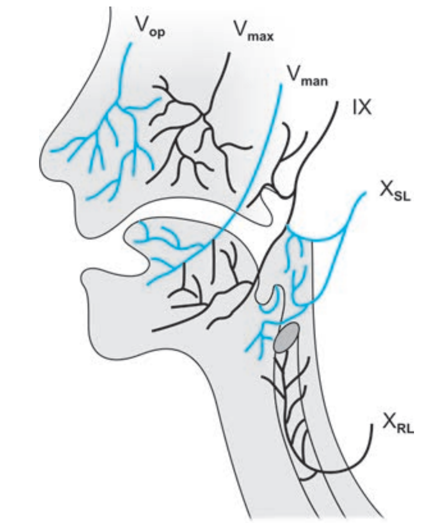


Fig. 20.19: Sensory supply of airway.

V_{op} = Ophthalmic division of trigeminal nerve (anterior ethmoidal nerve)
V_{max} = Maxillary division of trigeminal nerve (sphenopalatine nerve)
V_{man} = Mandibular division of trigeminal nerve (lingual nerve)
IX = Glossopharyngeal nerve
X_{SL} = Vagus superior laryngeal nerve
X_{RL} = Vagus recurrent laryngeal nerve

to the arytenoid muscles and descends on the thyrohyoid membrane. It pierces this membrane above the superior laryngeal artery and then again divides into two branches. The upper branch supplies the mucous membrane of the lower part of the pharynx, epiglottis, vallecula and the vestibule of larynx. The lower branch passes medial to the pyriform fossa beneath the mucous membrane and supplies the aryepiglottic fold and mucous membrane of the posterior part of the rima glottis. The external laryngeal branch, carrying only the motor fibres, innervates the cricothyroid muscle (Table 20.3).

The recurrent laryngeal nerve travels upwards deep to the lower border of the inferior constrictor muscle of the pharynx, accompanying with the laryngeal branch of the inferior thyroid artery. Apart from the sensory fibres which supply the mucous membrane of the larynx below the level of the vocal cords, this nerve innervates all the muscles of the larynx except the cricothyroid and a small part of the arytenoid muscles.

Summary

The upper airway derives its sensory supply from cranial nerves. This can be summarised as follows. Anteriorly the nose gets its sensory supply from the anterior and posterior ethmoidal branch of the opthalmic division of the trigeminal nerve (Vth cranial nerve). Posteriorly the nose is supplied by the sphenopalatine branch of the maxillary division of trigeminal nerve. The soft and hard palate get its sensory supply from the palatine nerve which is branch of the trigeminal nerve. The lingual nerve, a branch of mandibular division of the trigeminal nerve supply the sensory of anterior 2/3 of tongue. The glossopharyngeal nerve or the 9th cranial nerve, supply the sensory of posterior 1/3 of the tongue. Facial and glossopharyngeal nerve provide the sensation of taste of anterior 2/3 and posterior 1/3 of the tongue respectively. The glossopharyngeal nerve also provides the sensory supply to the roof of pharynx, the tonsils and the under surface of the soft palate. The vagus nerve or the 10th cranial nerve, supplies the sensory of the airway below the epiglottis through its superior

Table 20.3: Laryngeal innervation

Nerve	*Sensory*	*Motor*
Superior laryngeal (anterior or internal branch)	Base of tongue, epiglottis and supraglottic mucosa	None
Superior laryngeal (posterior or external branch)	Only anterior subglottic mucosa	Cricothyroid (tensor of vocal cord)
Recurrent laryngeal	Whole subglottic mucosa	Posterior cricoarytenoid (abductor), lateral cricoarytenoid (abductor), interarytenoid (abductor), thyroarytenoid (abductor)

laryngeal (divides into internal and external branch) and recurrent laryngeal branch which is described above (Fig. 20.20).

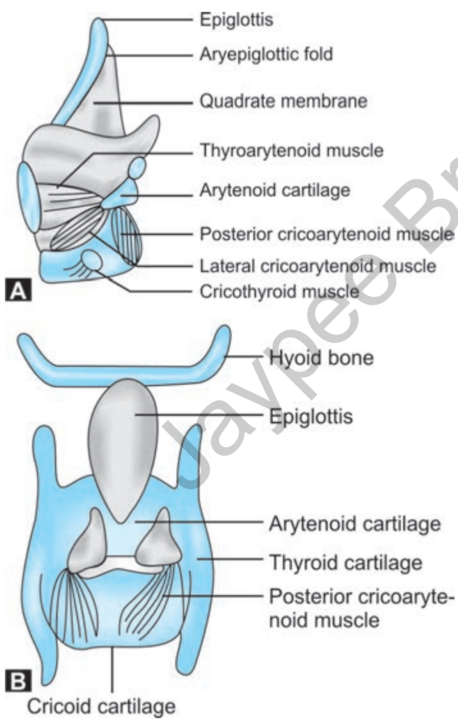
Actions of the intrinsic muscles of the larynx

i. Muscles for closing and opening of the laryngeal inlet.
   a. Closing – aryepiglottic
   b. Opening – thyroepiglottic
ii. Muscles for closing and opening of the rima glottis.
   a. Closing – lateral cricoarytenoids, transverse arytenoid, cricothyroid, thyroarytenoids.
   b. Opening – Posterior cricoarytenoids.
iii. Muscles which tense and relax the vocal cords.
   a. Tense – cricothyroid.
   b. Relax – thyroarytenoids and vocalis.

Movements of the vocal cords

Movements of the vocal cords affect the shape and size of the rima glottis as follows:

i. During quiet breathing (in resting condition), the inter membranous part of the rima glottis is triangular and the inter cartilagenous part is quadrangular in shape.
ii. During forced inspiration the both parts of the rima glottis (intermembranous and intercartilagenous) are triangular, so that the entire rima is lozenge-shaped and the vocal cords are fully abducted.
iii. During phonation (speech), the rima glottis is reduced to a chink by adduction of the vocal cords.
iv. During whispering, the intermembranous part of the rima glottis is closed, but the intercartilagenous part is widely open (Fig. 20.21).



Figs 20.20A and B: The intrinsic muscles of larynx

Applied Anatomy

i. Damage or block of the internal laryngeal nerve which is a branch of superior laryngeal nerve produces anaesthesia of mucous membrane of the supraglottic part of larynx. So, any foreign body can readily enter into the laryngeal inlet as reflexes do not work. But the function of vocal cord is not jeoparadised.
ii. Damage to the external laryngeal nerve which is an another branch of superior laryngeal nerve causes some weakness of phonation. It is due to the loss of tightening effect of the cord by paralysis of the cricothyroid muscle which is supplied by it. On the contrary bilateral damage of the superior laryngeal nerve result in hoarseness and easy tiring of voice. But airway control by vocal cord is not jeoparadised through reflexes of laryngeal inlet is impaired like the injury of internal laryngeal nerve.

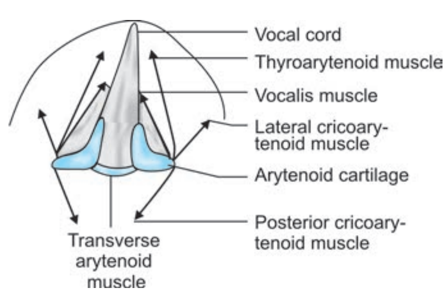


Fig. 20.21: The different directions of movement of muscles of vocal cord

iii. When both the recurrent laryngeal nerves are interrupted or blocked, then the vocal cords lie in position of complete adduction due to the unopposed action of cricothyroid muscle. So, patient suffers from stridor and respiratory distress. But airway problem is less frequent in chronic bilateral recurrent nerve interruption. This is because of various compensatory mechanisms which always develop. When only one recurrent laryngeal nerve is paralysed, the vocal cord of opposite side compensates for that. Then there is no difficulty in respiration but only deterioration of voice quality occurs. Bilateral interruption of vagus nerve affects both the superior and recurrent larngeal nerve. Thus it produces flaccid, midpositioned vocal cord as seen after administration of muscle relaxants.
iv. Larynx can be seen directly by a laryngoscope (direct laryngoscopy) or by a laryngeal mirror (indirect laryngoscopy). By these procedures one can see the base of the tongue, valleculae, epiglottis, aryepiglottic folds, pyriform fossae, vestibular folds and the vocal cords.
v. Since glottis of larynx is the narrowest part of the respiratory passage in adult, so if foreign body enters the respiratory passage, it usually lodged at glottis. Once it crosses glottis, it would easily pass through the trachea to lodge in some peripheral narrow bronchus or bronchiole.
vi. Laryngeal oedema may occur due to variety of causes which may be traumatic, allergic or infective, etc. This produces inspiratory stridor, dyspnoea and symptoms of hypoxia.
vii. Laryngismus stridulus is a condition which is characterized by attacks of laryngeal spasms in children, usually during night. In between the attacks, the child is normal.

Physiology of Airway Protection

The pharynx, epiglottis and the larynx protect the lower airway from aspiration of foreign bodies. An important mechanism for expelling or preventing the entry of foreign bodies into the lower respiratory passage below the vocal cord is cough. Although epiglottis covers the laryngeal inlet, but it is not always absolutely essential for the airway protection. Closure of the vocal cords by reflex mechanism is the most vital mechanism for lower airway protection, which also produces the protective laryngeal closure during deglutition. The physiological exaggeration of this reflex closure of vocal cord is called the laryngospasm. Therefore, laryngospasm consists of prolonged intense glottic closure in response to the stimulation by inhaled agents, foreign bodies or stimulation from visceras. Laryngospasm is associated with sound ranging from high peached squeaky to total absence, depending on the degree of spasm. Complete laryngospasm is usually silent and should be diagnosed and treated immediately.

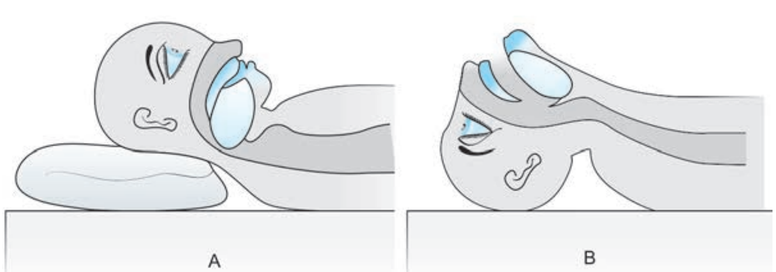
The ideal treatment for complete laryngospasm is the use of muscle relaxant and mask ventilation or intubation. But before muscle relaxants, forward displacement of the mandible, and IPPV by mask and bag with 100% O_2 should be tried. In most of the cases it is effective, because strong pressure applied manually with the help of a bag which is full of O_2 can force the gas effectively through the adducted cords. Thus, tracheal intubation can be avoided. In such situation the traditional view regarding limiting the pressure to avoid barotrauma of lungs are not important and stomach should be watched closely for if air is entering the oesophagus forcefully or not. Another way of management of laryngospasm is IV administration of propofol or thiopentone, making the patient deeply sedated, provided airway is clear of any foreign body. A patient who is scheduled for elective surgery, but experiences repeated intermittent laryngospasm and arrhythmia is a poor candidate for continued attempt of intubation.

Upper Airway Obstruction

One of the foremost duties of an anaesthetist is to maintain an unobstructed airway in an unconcious patient. This obstruction of airway may be total or partial. Partial obstruction is associated with diminished tidal volume (but not completely absent), retractive movement of the rib cages and neck muscles, tugging movement of diaphragm and snoring sound. If the obstruction is near the laryngeal inlet, then there will be inspiratory stridor. The total obstruction of airway is characterised by complete lack of movement of air in and out of the lungs or zero tidal volume which is recognised by no movement of breathing bag and paradoxical movement of the chest and abdomen. The air entry and exit from the lungs should be perceived by the feeling with hand placed over the nose and mouth, looking the non-paradoxical movement of chest and abdomen, and seeing the movement of the bag. An inexperienced person, usually wrongly interprete this retractive movement of chest, abdomen (see-saw paradoxical movement) and neck as a breathing affort. So, recognition of airway obstruction depends on the close observation of the movement pattern of the chest and abdomen and high index of suspicion (Fig. 20.22).

Upper airway obstruction is commonly due to the soft tissue obstruction byfalling back of the tongue on the posterior pharyngeal wall. It may also be due to the tumour, foreign bodies or laryngospasm, etc. But here we will only discuss the obstruction of upper airway by the base of the falling tongue (obstruction of airway by laryngospasm is discussed before). Because it is the commonest cause of upper airway obstruction during anaesthesia and is due to the relaxation of the tongue and jaw muscles. This occurs as soon as the consciousness is lost and the muscles supporting the tongue relax. So, the tongue falls back on the posterior wall of the oropharynx or hypopharynx or on the inlet of the larynx. If the tongue is brought forward by manipulation, then the laryngeal opening once again is cleared and opened. This can be achieved by the following methods.

i. Simple extension of the neck will clear the airway in 75% of cases. It causes the forward movement of mandible and the stretching of anterior tissues of the neck which, in turn, produces the forward traction of the tongue. Thus simple extension of neck release the airway obstruction.
ii. Extension of the neck also causes the mouth to fall open due to down ward pull of the neck tissues. In such condition, simple closing of the mouth in extended position of neck will often improve the airway by straightening the anterior tissues of the neck still further. Thus the resultant changes in head position have been shown to modify the upper airway resistance significantly.
iii. If there is still obstruction, airway can be restored by preventing the mandible from falling back with the tongue. This



Figs 20.22A and B: A. The fall of tongue on the posterior pharyngeal wall and the collapse of pharyngeal wall due to the relaxation of muscles of the airway (mainly genioglossus). B. Extension of neck and elevation of the angle of mandible removes the falling base of the tongue from posterior pharyngeal wall and maintains a clear airway

can be done by drawing the mandible forward and upward by placing the fingers behind the angles of the jaw and exerting an upward pressure towards roof.

iv. If the above mentioned procedures also fail, then the removal of obstruction of the airway can be accomplished with some mechanical contrivnaces, termed the oropharyngeal or nasopharyngeal airway, though other types of airways are discussed later. The idea behind both the oropharyngeal or nasopharyngeal airway is to lift the base of the tongue from the posterior wall of the pharynx and thus to remove the obstruction. The nasopharyngeal airway is better tolerated in light plane of anaesthesia than the oropharyngeal airway. But, the mere placement of any of the above mentioned airway does not gurantee unobstructed air flow. This is because these airways do not get any support from the relaxed mandible due to the relaxation of jaw muscles and is displaced. So, it is often necessary with the oropharyngeal or nasopharyngeal airway to support the mandible further by forward traction or by pressing upward at the angles of it. In the anaesthetised patient, pharyngeal and laryngeal reflexes are obtunded. If these reflexes are still active, then insertion of any airway to prevent the obstruction may precipitate further gagging, emesis or laryngeal spasm, causing more obstruction (Fig. 20.23).

Oral airways are generally made up of plastic and its size ranges from 0, 1, 2 (50 to 60 to 70 mm) for children to 3, 4, 5 (80 to 90 to 100 mm) for adults. It is inserted first with the upside down direction while passing through the oral cavity and then is rotated 180 degrees into the position of function. During insertion of oral airway teeth can be injured and the airway itself can pushes the base of the tongue into the pharynx. Thus it can actually increase the airway obstruction instead of removing it. Hence, an anaesthetist must be careful during insertion of airway.

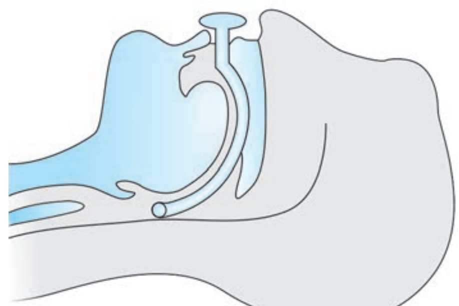


Fig. 20.23: Oropharyngeal airway elevating the tongue

To remove obstruction of upper airway by falling tongue soft nasal airways are useful for patients who are not deeply anaesthetised. However, contraindications to the use of nasal airways include coagulopathy, basilar skull fracture, large adenoids, nasal infections, nasal deformities, etc. Introduction of nasopharyngeal airway can be facilitated by phenylephrine nasal drops (causing vasoconstriction of nasal mucosa) or by lubricating the airway with lignocaine or K-Y gel. During introduction, tip of the nasal airways should be perpendicular to the face and is advanced slowly along the floor of the nasal passage. At any circumstances the tip of the airway should not be directed upward towards the cribriform plate. The length of the nasopharyngeal airways is roughly estimated by the distance from the tip of the nose to the meatus of the ear. When such manoeuvres and the use of artificial airways provide inadequate relief of upper airway obstruction by soft tissues, then the insertion of an endotracheal tube or other methods to by pass the upper airway obstruction should be comtem-plated.

EVALUATION OF THE AIRWAY

Introduction

One of the most important thing that an anaesthetist has to learn is the efficient management of airway. On the otherhand, proper evaluation of an airway is an essential part of the efficient management of airway. So, before every induction for anaesthesia, the airway of a patient should be evaluated or assessed properly by an anaesthetist. Thus, the discussion regarding the assessment and evaluation of airway has been widely accepted in anaesthesia for long time. Although, multiple predictive methods and scoring system for evaluation of airway has been suggested, but nothing can give 100% correct prediction. So, we will take only true scientific predictive protocol that all anaesthesiologists can depend upon it. This is because still now sometimes the unanticipated difficult airway in apparently normal patients sends us the signals for our inability to solve this problem.

The questions in these predictors tell us about the different terms which are frequently used such as difficult airway, difficult ventilation or difficult intubation. Because the answers to these questions are different. These three different technical skills are: unable to expose the glottis by conventional laryngoscope (difficult airway), unable to ventilate the patient maintaining $SPO_2 > 90\%$ (difficult ventilation) and unable to insert a ET tube into the larynx (difficult intubation). The former is generally termed difficult if one gets a poor view of the target organ i.e glottis (Cormack Lchane grade 3 or 4). The second is termed difficult if one without any assistance can not maintain $SPO_2 > 90\%$ by ventilating with 100% O_2. The third is termed difficult if after an arbitrary number of attempts (usually 3), the ET tube cannot be placed into the trachea (difficult intubation). All these three should be evaluated together or separately based on the history, clinical examination and radiological diagnostic tests. For easy and quick intubation good view of larynx is mandatory. So difficult laryngoscopy and bad view of larynx (difficult airway) is associated with difficult intubation. Hence, the assessment of difficult airway and difficult intubation should be discussed together. The assessment for difficult ventilation is discussed under separate heading.

Airway can be classified on the basis of predictions and ultimate difficulties or outcome into three categories.

i. A predicted normal airway.
ii. A predicted abnormal airway.
iii. An unpredicted difficult airway.

Among them, the patients of group three are the most dangerous. Even, among the patients of group three, those which have failed intubation and mask ventilation is also not adequate, actually presents the life threatening condition.

Evaluation of airway can be performed under three headings.

Table 20.4: Common congenital syndrome causing difficult airway and intubation

(i)	Pierre-Robin syndrome:
	Micrognathia, macroglossia, cleft palate.
(ii)	Treacher-Collin's syndrome:
	Auricular and ocular defects, mandibular hypoplasia.
(iii)	Down's syndrome:
	Poorly developed nasal bridge, large tongue, small mouth.
(iv)	Klippel-Feil syndrome:
	Fusion of vertebra, restricted neck movement.
(v)	Goldenhar syndrome:
	Mandibular hypoplasia, cervical spine abnormality, occipitalization of atlas, auricular and ocular defects.
(vi)	Goitre:
	Compression and deviation of trachea.

There are many other diseases such as rheumatoid arthritis which may progress gradually and may cause airway problem during present anaesthesia which might have no airway complication during previous anaesthesia.

History

One of the most important point during history taking for evaluation of the airway is if there is any difficulty during previous general anaesthesia, more specifically during mask ventilation or ET intubation. This history should be properly documented and passed on to the next anaesthesia caregiver.

History of other previous and present diseases such as infection, trauma, neoplasia and inflammation which may affect the airway and subsequently the mode of anaesthesia should be taken properly. Some other present conditions that could predispose to difficult airway are: oedema of the face and neck, burn, active bleeding in the oral cavity, tracheal and oesophageal stenosis or aspiration of gastric content etc. There are many other congenital syndromes which are associated with airway problem and intubation difficulty during anaesthesia should also be kept in mind.

These common congential syndrome causing difficult airway and intubation are given in table (Table 20.4).

Physical Examination

After history taking, every patient should be properly examined physically to predict any difficulty of airway management during anaesthesia. Many additional clinical tests to predict difficult laryngoscopy and difficult intubation have also been described, but none of these tests is totally reliable. Their use may complement each other and also the routine physical examination of the airway. The routine physical examination of air way should start from the simple inspection of head and neck of patient to identify any obvious problem such as massive obesity, cervical collars, external injury, burns, contracture, restricted jaw movement, reciding mandible, bucked teeth, etc. to whole body inspection to some comprehensive scoring system. For example, congenital presence of some ear and hand abnormalities suggest associated presence of some congenital cardiovascular disorders and abnormal airway. Adequate nasal airway should also be evaluated before any nasal intubations (Table 20.5).

Regarding teeth; loose teeth, protuberant upper incisors, false teeth and other dental works such as crown, bridges, braces, etc. should be noted. Edentulous patients presents seldom difficulty to intubate unless other associated problems are severe. Protuberant upper incisors may make laryngoscopy difficult and can cause damage to the teeth. Severe loose teeth should be removed or fixed by ligature before laryngoscopy to avoid aspiration of it. Artificial dentures should be removed (Table 20.6).

Table 20.5: Wilson has identified five risk factors on the basis of which 0, 1, 2 points are awarded and a scoring system has been developed. A score of 5 to 10 would predict severe laryngoscopy and intubations difficulty

	Risk factors	*Scoring*
Weight	< 90 Kg	0
	90 - 110	1
	> 110	2
Head and neck	> 90°	0
	± 90°	1
	< 90°	2
Jaw movement (Inter incisor gap = IG)	IG > 5 cm	0
	IG = 5 "	1
	IG < 5 "	2
Receding mandible	Normal	0
	Moderate	1
	Severe	2
Bucked teeth	Normal	0
	Moderate	1
	Severe	2

Table 20.6: Conditions associated with difficult airway and intubations

Tumours	
	Large goitre, cystic hygroma, lipoma, haemangioma, haematoma, adenoma, papillomatosis, any tumours of pharynx or larynx etc.
Arthritis	
	Rheumatoid arthritis
	TM joints ankylosis, restricted spine.
	Ankylosing spondylitis
	Cervical spine ankylosis, restricted cervical spine mobility.
Infections	
	Abscess (peritonsilar, retropharyngeal submandibular etc), Ludwig's angina, epiglottitis, trismus, laryngeal oedema, laryngitis etc.
Trauma	
	Maxillary fracture, mandibular fracture, basilar skull fracture, cervical spine fracture, inhalation, burn, laryngeal fracture, oedema of airway, etc.
Foreign body: Anywhere in pharynx and larynx	
Obesity	
	Short neck, sleep apnoea, extra tissue in oropharynx.
Acromegaly	
	Macroglossia, prognathism.
Other anatomical variations	
	Micrognathia, high arched palate, prominent upper incisor, scleroderma, sarcoidosis.
Congenital syndrome	
	Discussed before

Next, opening of the mouth should be assessed and it depends on the function of the temporomandibular joint. Any previous and present disease of the temporomandibular joint make the mouth opening difficult and visualization of any pharyngeal and laryngeal structure is impossible. Normally, an adult should be able to open their mouth, so that there is 50 mm distance between the upper and lower incisior teeth (Figs 20.24 and 20.25).

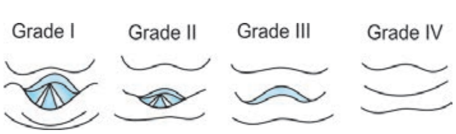


Fig. 20.24: Grading of the laryngeal view (Cormack-Lehane)

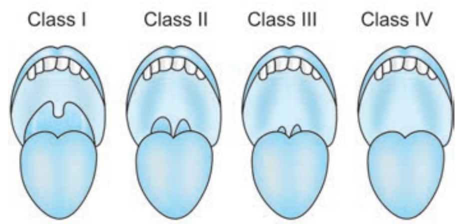


Fig. 20.25: Mallampati classification or test of oral opening

After assessment of mouth opening, oral cavity should be examined for large tongue, high arched palate, long narrow mouth, etc., which may cause difficult laryngoscopy and intubation. In 1983, Mallampati has evaluated a scoring system by observing the structure of the oral cavity through opened mouth by which difficulty of laryngoscopy and subsequent difficult intubation can be assessed or predicted. This is based on the visualisation of soft palate, uvula and faucial pillar. This test is performed with the patient sitting upright, head in neutral position, mouth opened as wide as possible and tongue protruded as far out as possible. Originally, there was three grades in Mallampati scoring system. The scoring system of Mallampati predicts approximately 50% difficult intubation. Then in 1987 Sampson and Young in their modification of Mallampati scoring system further added grade IV (Table 20.7).

Another way of assessing the difficulty in laryngoscopy or visualization of glottis and subsequent difficult intubation is to measure the distance from the symphysis of mandible to the hyoid bone. This distance should be at least 2 large finger breaths in adults. The space between the mandible and the hyoid bone is important, because during laryngoscopy the tongue is displaced into this place for visualization of glottis. If this space is narrow, glottis cannot be seen properly.

Then, the neck should be examined for its mobility, particularly for extension. A thick short muscular neck may result in difficult mask ventilation and as well as laryngoscopy and intubation. The normal amount of neck extension is 35 degrees. The measurement can be made by simple visual estimation or more accurately with goniometer. Any reduction in extension of neck is expressed in grades (Table 20.8).

Cervical spondylosis, ankylosis, rheumatoid arthritis of cervical vertebral joint etc; may restrict the flexion and extension of the inter cervical vertebrae or atlanto-occipital joint and cause difficulty in visualization of glottis by laryngoscope. Thus difficult intubation may precipitate. Extension of the neck also can be quantified by measuring the distance from the symphysis of mandible to the thyroid notch (thyromental distance) with the head fully extended. If the distance is more than 65 mm (3 large finger breaths), then visualization of the larynx and intubation will not be difficult. If this thyromental distance varies between 60 and 65 mm (or 6 and 6.5 cm) then visualization of larynx would be slightly difficult. The thyromental distance below 60 mm definitely suggests that laryngoscopy would be more difficult. The explanation of this observation is that if the thyromental distance is short then the laryngeal axis will make a more acute angle with the pharyngeal axis and it will be difficult to achieve alignment between the laryngeal and pharyngeal axis. This scoring system is developed by Patil, Sterling and Zanden. These three specific tests such as Mallampati, thyromental distance and extension at the atlanto-occipital joint together have

Table 20.7: Mallampati grading

Grade I	Anterior and posterior faucial pillar, soft palate and uvula is visible.
Grade II	Only soft palate and uvula is visible.
Grade III	Only soft palate is visible.
Grade IV	Soft palate is not visible.

Table 20.8: Mallampati grading for neck extension

Grade I : > 35 degree
Grade II : 22 to 34 degree
Grade III : 12 to 22 degree
Garde IV : < 12 degree

almost 100% reliability in predicting airway difficulty. Another way of assessment of neck mobility is the measurement of sternomental distance. If the sternomental distance is less than 12.5 cm, then intubation will be difficult. Lesser the distance greater will be the difficulty. This distance should be measured with head in full extension and mouth closed (Fig. 20.26).

It should be noted that the combination of several minor physical anomalies may result in a difficult laryngoscopy and difficult intubation even when no single factor or test is severely abnormal. Difficult intubation may occur occasionally for reasons that are currently unexplained and none of the available indices predicts it. Even though the airway may look normal on external assessment, one may come across difficulty during laryngoscopy and intubation due to the variations in internal anatomy of upper airway. Cormack and Lehan have defined four grades of laryngoscopic view and predict subsequent difficult intubation which is given below.

Grade I : Visualization of entire laryngeal aperture including full length of vocal cord and arytenoid cartilage.

Grade II : Visualization of epiglottis, aryte-noid cartilage and posterior part of vocal cord only.

Grade III : Visualization of epiglottis only.

Grrad IV : Epiglottis not visible.

Comparison of Mallampati and Cormack-Lehan grading.

Grade I Grade I

Grade IV, Grade III and IV

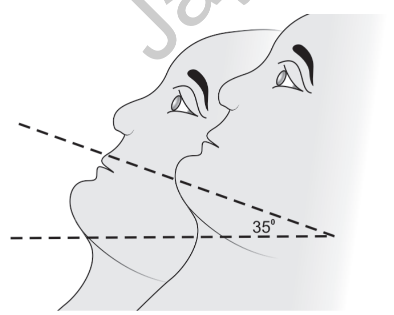


Fig. 20.26: Assessment of neck mobility by measuring sternomental distance

Grade II and III Relatively uniform distribution in all grades

The application of external pressure can reduce the incidence of grade III view from 9% to between 5 and 1%.

Investigations

The other ways of assessing the airway are laboratory investigations such as X-ray, CT scan and MRI of head and neck. Lateral X-ray of the head and neck along with distance marking between the bony land marks have been used to predict the difficult laryngoscopy and difficult intubations. In radiology plate the measurement of atlanto- occipital distance and interspinous gap between C_1 and C_2 vertebrae may also have a predictive value. Other radiological examinations for airway assessment include: decreased posterior depth of the mandible (PDM) and increased anterior depth of mandible (ADM). A ratio of more than 3.6 between the mandibular length and posterior mandibular depth has also been shown to indicate the difficult intubation by White and Kander (Fig. 20.27).

Some Rules and Laws

What is lemon law?

LEMON law stands on:

L = Look externally,

E = Evaluate the 3-3-2-1 rules,

M = Mallampati scale,

O = Obstruction,

N = Neck mobility.

Look externally

It is the external indicators of either difficult laryngoscopy or difficult ventilation or difficult intubation. It includes: presence of huge beard or large moustache, abnormal facial shape, extreme nourishmentmal or over, a person without teeth, facial trauma, obesity, large front teeth, high arched palate, receding mandible, short bull neck, severe contracture, etc.

Evaluate 3-3-2-1 rule

i. 3 finger mouth opening. The normal interincisor distance is 4.6 cm or more. While < 3.8 cm of interincisor distance predicts difficult airway and < 3 cm indicates TM joint dysfunction. If the distance is < 2.5 cm, it indicates the difficult laryngoscopic view and < 2 cm indicates laryngoscopy and intubation is impossible.

ii. 3 fingers is the normal distance between the tip of the jaw and the begining of the neck (hypomental distance), while it is fully extended. Alignment of the laryngeal and pharyngeal axis is difficult if this distance is less than 3 fingers breath (or < 6 cm) in adult. If the length varies between 6 and 6.5 cm then alignment is less difficult and while the distance is > 6.5 cm it is normal.

iii. 2 fingers breath is the normal distance between the thyroid notch and the floor of the mandible. When this distance is < 2 fingers breath, then difficult airway and intubation is predicted. (Fig. 20.28)

iv. 1 finger is the normal subluxation of lower jaw anteriorly.

Mallampati scale

Grade I: 80 to 100% easy intubation.

Grade II: Intubation is possible with proper positioning and optimal laryngeal maneuver technique.

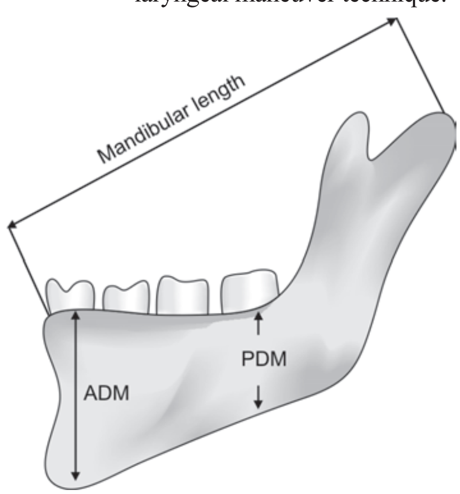


Fig. 20.27: ADM = Anterior distance of mandible
PDM = Posterior distance of mandible

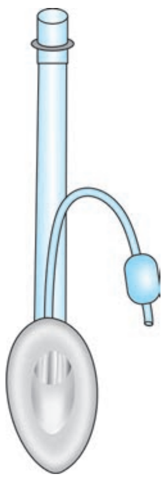


Fig. 20.28: Laryngeal mask (classic)

Grade III: Intubation is still possible with special laryngeal blade or with the use of gun elastic bougie.

Grade IV: Intubation is almost impossible.

This test should be repeated twice to avoid the false positive and false negative results.

Obstruction

For obvious difficulty during laryngoscopy and intubation anaesthetist must consider the obstruction of airway with foreign body, tumour, abscess, epiglottitis or expanding haematoma, etc.

Neck mobility

(Movement of atlanto-occipital joint and flexion-extension of the neck)

Normally the atlanto-occipital (A-O) joint movement ranges arround 35°. Limited A-O joint movement is present in cervical spondylosis, rheumatoid arthritis, halo-jacket fixation, etc. The grading of A-O joint movement is done as follows.

Grade I : > 35 degrees
Grade II : 22-34 degrees
Grade III : 12-21 degrees
Grade IV : < 12 degrees

Airway assessment based on LEMON law or method is able to stratify, successfully, the risk of difficult laryngoscopy and subsequent intubation or ventilation by mask.

What is LMMAP rule of airway assessment?

It stands for :

L = Look for external deformity of face and neck,
M = Mallampati,
M = Measurement 3-3-2-1 or 1-2-3-3 fingers,
 3– fingers mouth opening
 3– fingers hypomental distance
 2– fingers distance between the thyroid notch and the floor of the mandible
 1 – finger subluxation of lower jaw
A = Atlanto-occipital (A-O) extension
P = Pathological airway obstruction

What are the 4Ds?

The following 4Ds also suggest the difficult airways:

- Dentition filtered = Prominent upper incisors, receding chin, etc.
- Distortion filtered = Oedema, blood, vomits, tumour, infection, etc.
- Disproportion filtered = short chin to laryngeal distance, bull neck, large tongue, small mouth, etc.
- Dismobility= TM joint and cervical spine

What are the Magboul 4 Ms?

There is another easier way to memorize the prediction of difficult laryngoscopy and intubation. This is described as Magboul 4 Ms with STOP sign. The 4 Ms are:

a. Mallampati
b. Measurement
c. Movement of neck
d. Malformation

The STOP signs are

S = Skull (hydro and microcephalus)
T = Teeth (buck, protrud, loose)
O = Obstruction
P = Pathology

(cranio-facial abnormality and syndrome: Treacher-Collins, Pierre-Robin, Goldenhar's Waardenburg syndrome, etc).

Cass and James risk stratification

In 1965, they summarised 6 common anatomical causes of difficult intubation and stratification of risk. These are:

i. Short muscular neck.
ii. Receding jaw with an obtuse mandibular angle.
iii. Protruding upper incisor teeth.
iv. Long and high arched palate.
v. Poor mobility of mandible.
vi. Decreased distance between alveolar and mental ridge which is required for wide opening of mandible for introduction of laryngoscope.

Rapid assessment of airway by "1-2-3 rule"

Rule 1: Ability to insunate at least one finger in front of the tragus when the patient opens his mouth. This establishes the integrity of movement of TM joint.

Rule 2: Determing the adequacy of the opening of mouth by measuring the interincisor gap. This should be at least 2 finger breadths.

Rule 3: Measurement of thyromental distance. It should be at least 3 finger breadths.

Type variable score

i. Receding chin or temporomandibular distance less than 7 cm. 3 points
ii. Mallampati Grade IV. 2 points
iii. Restricted head extension. 2 points
iv. Protruding teeth. 2 points
v. Mouth opening < 4 cm. 2 points
vi. Vertical neck length < 7.5 cm.1 point
vii. Neck circumference > 33 cm. 1 point

The study reveals that a score of 6 or more correctly identify 22 out of 23 difficult intubation.

AIRWAY MANAGEMENT BY MASK VENTILATION

In emergency situation where the patient is apnoeic after giving muscle relevant and patient is unintubated or we fail to intubate then ventilation by mask and bag is life saving. Usually anaesthetic face mask is employed for ventilation by administering air or O_2 and/or anaesthetic gases.

The rim of the face mask is contoured or conformed to a variety of facial features to create a airtight seal with the patient's face. The 22 mm orifice of these face mask is attached to the breathing circuit of the anaesthetic machine through a right angle connector. These face masks are made of different materials which vary from rubber or plastic to silicon. It is also available in different shapes and sizes for newborn to large adult face. The transparent masks are more advantageous because they are less frightening and facilitate observation of the patient for cyanosis and vomiting.

Mask can be held with one hand or both the hands (if necessary, to fit the mask tightly over the face). If both the hands of anaesthetist are used to fit the mask on the patient's face, then an assistant is needed to ventilate the bag or anaesthetic ventilator can be used to supply the positive pressure breaths. By the thumb and the first finger of anaesthetist's left hand the mask should be held tightly on the patient's face, while the other three fingers of the hand will displace the mandible upward by giving upward thrust on the angle of it. Care should be taken that fingers should be kept on the ramus of the mandible, but not on the soft tissues of the neck and the floor of the mouth. Because pressure on the soft tissues of neck by fingers produces discomfort and push the base of the tongue towards the posterior pharyngeal wall, causing more airway obstruction. Mandibular upward displacement along with the upper cervical extension and lifting of the chin upward by fingers tend to pull the tongue and soft tissues away from the posterior pharyngeal wall. Thus, it relieves the upper airway obstruction that occurs in the paralysed and anaesthetised or unconcious patient.

But this mask ventilation is difficult for obese patient, thick neck, short neck, big face, endentulous patients, etc. In edentulous patients, the mask ventilation can be helped by leaving the dentures in place or by using packs or employing the mask strap to pull up the sagging cheeks. Mask ventilation in paediatric patients are more easier than adult patients, provided there is no laryngospasm. Though mask ventilation is very helpful in emergency condition and more easier than ET intubation, but the most serious problems with mask ventilation include failure, distension of stomach by air, pulmonary aspiration and pressure damage to the eyes.

How Do we Predict Difficult Mask and Bag Ventilation ?

Langeron et al suggested five recognised criteria as independent predictors of difficult bag and mask ventilation and that can be summarised as the word OBESE. It is a simple visual way to remember what to look for when evaluating and assessing the airway for difficult mask and bag ventilation.

O = Obese (Body mass index > 40 Kg/m^2)
B = Bearded
E = Elderly (older than 55 years)
S = Snorers
E = Edentulous

The presence of any two of these criterias is best indicated as difficult mask and bag ventilation with a sensitivity of 0.72 and specificity of 0.73.

Obesity is asociated with decreased posterior airway space behind the base of the tongue. This is due to the accumulation of fat in the pharyngeal soft tissue. Thus, it causes more impairment of airway patency during sleep due to fall of tongue on posterior pharyngeal wall and is a risk factor for obstructive sleep apnoea syndrome. Upper airway obstruction can occur early after induction of anaesthesia with the posterior displacement of soft palate, base of the tongue and epiglottis in morbidity obese patients (BMI > 40 Kg/m^2). Age is also closely related to the increased pharyngeal and laryngeal resistance to airflow and is more common in men than women. Lack of teeth and the presence of beard are also associated with difficult mask ventilation. It is due to the decrease in airtight seal of facemask and increased air leak around the mask with more difficult positive pressure ventilation.

AIRWAY MANAGEMENT BY LARYNGEAL MASK AIRWAY (LMA)

Laryngeal mask airway is a new device whose status regarding the management of airway is lying somewhere between the face mask with oropharyngeal airway and the endotracheal tube (ET). This is because it provides more definite airway than the former, but not the more reliable air way protection and maintenance than the later. It sometimes acts as an essential airway device to provide emergency airway and ventilation when conventional mask ventilation and attempts to intubation fails. Therefore, although LMA was originally developed for airway management in routine cases with spontaneous ventilation, but it is now listed in the ASA difficult airway algorithm at 5 different places as a ventilatory device or as a conduit for endotracheal intubation. It is a new device designed to maintain a seal around the laryngeal inlet for spontaneous ventilation and also permits positive pressure controlled ventilation at modest level of pressure (up to 15 cm H_2O). But because of the limited ability of LMA to seal off the laryngeal inlet tightly, the elective use of this device is contraindicated in any of the condition where there is an increased risk of aspiration and where ventilation under high pressure is needed. In patients without these predisposing factors, the risk for pharyngeal regurgitation appears to be low and the use of LMA is safe (Fig. 20.29).

Now, LMA is available in seven different sizes for neonates to large adults. LMA classic is a reusable device. It is made of medical grade silicone and is free from latex. It is to be discarded after 40 autoclaving. There are three main components of a LMA classic: an airway tube, a laryngeal mask with inflating cuff and a cuff inflating pilot catheter with balloon. The

Fig. 20.29: Proseal LMA (PLMA)

airway tube is of large bore with 15 mm standard male adaptor which can be connected with breathing circuit. Its other end is fitted to the mask which has an inflatable cuff. The cuff can be inflated or deflated via a valve located on the pilot catheter. Two aperture bars guard the distal end of the large bore airway tube. The mask of the LMA is specially designed to conform to the contours of the hypopharynx. Now, several new variants of the LMA except classic are available. These are : LMA Flexible, LMA Unique (disposable LMA, Sizes 3, 4, 5), intubating LMA or LMA Fastrach and most recently LMA Proseal. All variants of LMA, except unique variety, are made of silicone or latex free rubber. Unique variety of LMA is made of medical grade PVC. Just enough air to seal the laryngeal inlet can raise the intracuff pressure around 60 cm of H_2O. During cuff inflation, after the introduction of LMA the tube should not be hold by hand as this prevents the mask from setting into its own correct location from itself in hypopharynx. A small outward movements of the tube is often noted during inflation of the cuff as the device seats and adjusts itself in the hypopharynx.

The Proseal Laryngeal Mask Airway (PLMA) is the latest addition to the various modification of the original LMA. Like LMA, the PLMA is also made of latex free silicone and is reusable. The mask and the inflation assembly of this variety of LMA is identical to the classic variety of it. Here, the original larger ventral cuff is fixed to a second cuff which is attached to the dorsal surface of the first cuff. The dorsal cuff, when inflated, improves the seal by pushing the ventral cuff more firmly on the periglottic tissues. So a properly placed PLMA can withstand a leak pressure of approximately 35 cm of H_2O, as against 25 cm of H_2O offered by the LMA classic. The PLMA airway tube is flexible, wire reinforced and double lumened. One lumen is used as airway tube for ventilation and another lumen is used as gastric drainage tube for aspiration of gastric contents during regurgitation. The rationale to place the two tubes side by side, except at the level of the mask is to give greater stability to the device, while once placed in the oral cavity. The PLMA bowl is deeper through which traverses the drainage tube and open most distally. This drainage tube in the bowl helps to eliminate the aperture bars. However, the main purpose of the drainage tube is : to facilitate the gastric tube insertion, to divert the regurgitated fluid away from the respiratory tract and to prevent gastric insufflation. The PLMA comes with a reuseable introducer which is an easily clip-on / clip-off device. A built in bite block has also been added at the proximal end of the two tubes which prevents the patient from biting and collapsing the airway tube. It also helps to bond the two tubes firmly. Introduction of LMA needs adequate depth of anaesthesia, but not so deep as required for tracheal intubation. So, it is not suitable for conscious emergency room patients (Fig. 20.29).

LMA insertion requires an anaesthetic depth which is slightly greater than that required for the insertion of an oral airway, but lighter than ET tube intubation.Under an adequate depth of anaesthesia, an appropriate size of LMA is gradually introduced into the mouth and then into the cavity of laryngopharynx with the aperture facing towards the base of the tongue. It is performed by pressing the cuffed tip of LMA against the posterior pharyngeal wall and guided by the index finger of the dominant hand. The LMA is pushed in hypopharynx till a resistance is felt which indicates that the tip of it has reached the upper esophageal sphincter. Some anaesthetists prefer to introduce LMA with deflated cuff and some with fully inflated. But, it is better to introduce LMA with partially deflated cuff and when the tip felt the resistance, then the cuff is fully inflated again with the addition of appropriate volume of air and is secured with tape.

The correct position of the cuff should be checked by auscultation of lungs and capnography. The other signs of correct placement of LMA cuff include one or more of the following : (i) the slight outward movement of the tube after the inflation of LMA cuff, (ii) the presence of a smooth oval swelling on the neck around the thyroid and cricoid area, (iii) no portion of cuff should be visible in the oral cavity. Before taping the LMA in place, a bite block should be inserted. It not only stabilizes the LMA, but also prevents the occlusion of tube from bitting. Reinforced flexi LMA are more prone to biting and bite block should be placed, until LMA is removed.

One of the principal cause of obstruction during the use of LMA is the downward displacement of epiglottis by LMA or curling up of tongue on the laryngeal inlet. An ideally positioned cuff of LMA is bounded by the base of the tongue superiorly, the pyriform fossa laterally and the upper oesophageal sphincter inferiorly. If the inlet of oesophagus lies within the rim of the cuff, then gastric distension and reguritation become a distinct possibility. The anatomic variations of hypopharynx prevent adequate functioning of LMA in some patients. So, if an LMA is not functioning properly after attempts to improve the condition, most anaesthetists will try another LMA which is one size larger or smaller. However, introduction of LMA under direct vision with the help of laryngoscope or fibreoptic scope may prove beneficial in difficult cases (Fig. 20.30).

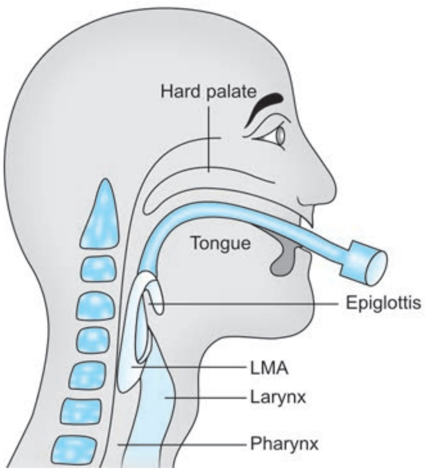


Fig. 20.30: LMA in position

The main advantages of LMA are:

i. It provides an emergency airway in patients, where either mask ventilation or tracheal intubation is difficult or has been failed.
ii. In case when intubation is not mandatory and operation can simply be done by spontaneous face mask ventilation, but airway cannot adequately be maintained by simple Guedel's oropharyngeal airway and face mask.
iii. Introduction of LMA eliminates the presence of a relatively large face mask and anaesthetist's hand on the patient's face that may interfere with surgical access, especially when the surgical site is situated over the head and neck. On the otherhand, availability of new flexible LMA provides an easy connection with the anaesthetic machine at any angle from the mouth, while resisting kinking and displacement.
iv. LMA also provides an emergency airway in awkward position, such as in the lateral and prone position of the patient and in emergency settings when laryngoscope and other equipment for intubation are not available. Instead of mouth to mouth breathing, mouth to larynx breathing through LMA in emergency condition is a better alternative.
v. LMA sometimes provides a conduit to facilitate fibre optic guided or gum-bougie guided or blind oral tracheal intubation during difficult situations of intubation. LMA, specially designed to facilitate such tracheal intubation, is now available and is called intubating LMA.

Disadvantages of LMA are: pulmonary aspiration, laryngospasm, failure to function in the presence of pharyngeal and laryngeal disease, failure to provide high inflation pressure during decreased compliance of lungs and thorax and also due to resultant leak around the cuff by high pressure ventilation. Therefore, the contraindication of use of LMA are: full stomach (e.g. pregnancy, hiatal hernia, intestinal obstruction, etc.) pharyngeal pathology (e.g. tumour, absces, etc.), pharyngeal obstruction, low pulmonary compliance (e.g. asthma, COPD, etc.) requiring peak inspiratory pressure greater than 30 cm of H_2O, etc.

AIRWAY MANAGEMENT BY COMBITUBE

Like LMA, combitube is another supraglottic airway device that provides an emergency airway when tracheal intubation is failed and mask ventilation is not effective or fails. It is a double lumen tube that combines the features of both a conventional tracheal tube and that of an esophageal obturator airway. Both the lumens of tube are connected at its proximal (outer) end with a 15 mm connector that helps it to be attached with the main anaesthetic machine. It is especially useful for patients in whom direct visualization of the vocal cords is not possible as in patients with massive airway bleeding or regurgitation, limited access to the airway and in patients in whom neck movement is contraindicated. As combitube is made of natural rubber or latex, so it may cause allergic reactions. It has two latex cuffs or balloons – one is oesophageal and another is oropharyngeal. The pharyngeal cuff or balloon is blue in colour and larger in volume (100 ml) than the oesophageal cuff or balloon (15 ml). The longer lumen is blue in colour and ends at the patient's side with multiple apertures between the two cuffs while the shorter lumen ends at the most distal end of this device (Fig. 20.31).

Combitube can function effectively whether is placed in the trachea or much more commonly in the oesophagus when it is introduced blindly. Ventilation is usually started first through the blue longer tube. This is because, placement of the distal end which proximally begin with shorter tube is usually in the oesophagus when combitube

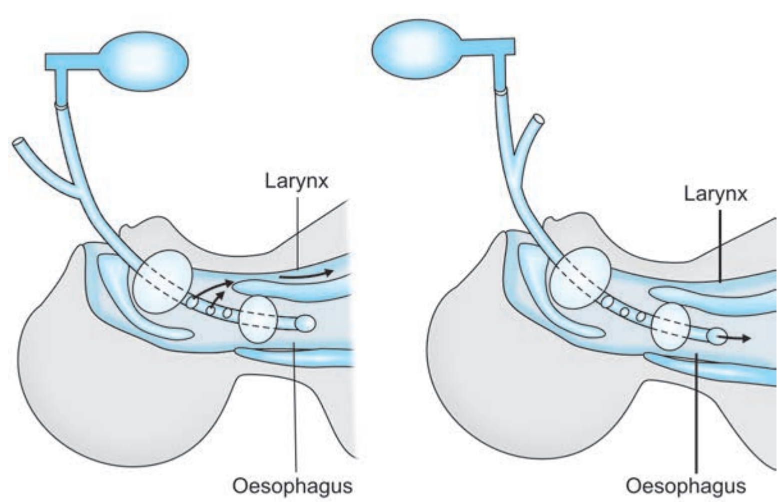


Fig. 20.31: The mechanism of action of combitube

is introduced blindly through oral cavity. Then, if auscultation of the breath sound is positive and auscultation of gastric insufflation is negative, ventilation is continued. In this situation, multiple apertures which are continuous with the longer blue lumen is situated at the laryngopharynx between the two cuffs and air passes from the laryngopharynx through the laryngeal inlet into the lungs. Under this condition, the shorter tube which ends at distal aperture and now is in the oesophagus may be used to remove the gastric fluid with a suction catheter. In such circumstances if inflation of lung is absent and the stomach is being insufflated, then ventilation should be started through the transparent shorter tube which communicate with the distal single aperture beyond the oesophageal balloon. Under this situation, the multiple apperture which are continuous with the longer blue tube and through which ventilation was done before are situated above the laryngopharynx and distal end which is connected with the transparent shorter tube is situated in the trachea. So, the air is passing from blue tube through oropharynx and oesophagus to the stomach. Then, ventilation should be continued through the transparent shorter tube which can be confirmed by auscultation of breath sound and absence of gastric insufflation.

The combitube has also been successfully used during emergency cardiopulmonary resuscitation and in such circumstances esophageal balloon provides protection from aspiration which may represent an distinct advantage of it over the LMA. But, care must be taken to avoid excessive deep placement of combitube in the oesophagus, which can further obstructs the glottic opening by the pressure of distal cuff from oesophagus. Though, it is listed in the management of difficult airway in advanced life support algorithm, still combitube is rarely used by anaesthetists now. Because they prefer LMA or other device in such difficult situations.

AIRWAY MANAGEMENT BY ENDOTRACHEAL (ET) TUBE – INTUBATION

The introduction of an ET tube into the tracheal lumen through glottic opening is called intubation. This is the best way of airway management, but not without any disadvantages or complications.

There are many indications for endotracheal intubation, but the principle head lines are:

i. maintenance of unobstructive airway,
ii. protection of airway from aspiration,
iii. application of positive pressure ventilation,
iv. adequate oxygenation and delivery of anesthetic gases.

Equipment for Intubation

The main equipment needed for intubaton are: endotracheal tube, laryngoscope and some accessories in difficult situations such as stylate, bougie, light weight, etc.

Endotracheal (ET) tube

In present practice, the commonly used ET tubes are now made of clear polyvinylchloride (PVC) with high volume low pressure cuff, though red rubber tubes with low volume and high pressure cuffs are still manufactured. The distinct advantage of a clear PVC made ET tube is that it helps to obseve the condensation of water vapour in expired air which occurs during expiration and confirm the ET-tube in the trachea. They are numbered according to their internal diameter (ID) measured in mm, as for example the internal diameter of 7 no. ET tube is 7 mm. The external diameter of ET tube varies with the thickness of the tube's wall which again varies according to the different manufacturers. Less commonly, some ET-tubes are numbered in the French scale which indicates external diameter in mm multiplied by 3. The choice of diameter of a ET tube for a particular patient always runs through a compromise between maximizing the flow of gases through a large size and minimizing trauma with a small size. Tubes are manufactured in 0.5 mm ID increments from 2.5 to 9 mm. A radioopaque line is impregnated into the wall of the tube which aid its later visualisation by X-ray in case of displacement or aid in determination of tube position after intubation. The radiopaque barium sulphate stripe also significantly lowers the temperature at which ignition of the tube occurs and thus decreases the risk of fire during laser surgery (Fig. 20.32).

An ASTM (American Society for Testing and Materials) standard for manufacturing of tracheal tube recommends the following things which include: the material from which the tube should be constructed, inside diameter, length, inflation system, cuff, radius of the curvature of the tube, markings, Murphy eye, packaging and labeling, etc. A separate standard also covers the testing of the shaft of tracheal tube for laser resistance.

The standard specifies that the radius of curvature of a conventional ET tube should be 140 ± 20 mm. The internal and external walls should be circular. A tube whose lumen is oval or elliptic in shape is more prone to kinking than one that is circular. The machine end of the ET tube receives the connector and projects from the patient mouth or nose. By cutting with scissors it should be possible to shorten this end if necessary. The patient end of the ET tube is inserted into the trachea. It usually has a slanted opening which is

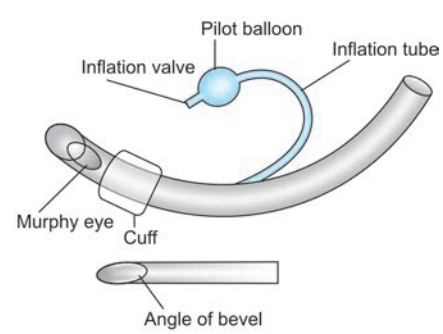


Fig. 20.32: The cuffed Murphy eyed endotracheal tube

called the bevel. The angle of this bevel is acute which is formed between the axis of the bevel and the longitudinal axis of the tracheal tube. A standard tracheal tube has a bevel angle of 38 ± 10°. The opening of the bevel looks left when viewing the tube from its concave aspect. This is because most often the ET tube is introduced in the larynx from the right side of the patient. So as the bevel faces left, it facilitates better visualization of the larynx when the tube is being inserted.

Sometimes, there is a hole on the side opposite to the bevel. This is known as the Murphy eye and an ET tube with this feature is called the Murphy-type tube. The purpose of this eye is to provide an alternate pathway for gas flow, if the bevel is occluded sometimes due to any reason. Some anaesthetists think that having such an eye is a disadvantage, because secretions may accumulate there and forceps, tube changers, fibrescope, etc, which are sometimes used for different purposes through the ET-tube may inadvertently advance through this Murphy eye instead of passing through the bevel. Some tubes have a second eye on the bevel side. This Murphy eye may also provide a measure of safety, if the tube accidently advances into the right mainstem bronchus. The endotracheal tubes lacking Murphy eye are known as Magill type tubes. Lack of Murphy eye allows the cuff to be placed closer to the tip. This may decrease the chance of inadvertent bronchial intubation.

The result of IT (implantation test) and Z-79 seal is usually stamped upon the tube. This means that the tube is compatible with human tissues, free of toxins and have no irritant properties. There are other various markings on the tube which include: (a) whether or not it is designed for nasal or oral use and (b) the distance in cm between the tip of the tube and the place where that tube is emerged either at the nose or at the mouth.

The pressure in the cuff of the tube is important. This is because high pressure in the cuff is transmitted to the tracheal mucosa and can cause ischaemic injury. So the cuff should be inflated to such a minimum volume and pressure that there is just no leak of air on positive pressure ventilation through the gap between the cuff and the tracheal mucosa. This will allow for reasonable airway protection from aspiration without excessive lateral wall pressure on the tracheal mucosa that may cause ischaemic injury and subsequent complication later. The cuff pressure that afford good protection from aspiration is 20 to 25 mm of Hg and it is just below the perfusion pressures of the tracheal mucosa which is about 25 to 35 mm of Hg. Therefore, this 20 to 25 mm of Hg cuff pressure does not cause ischaemic injury to the tracheal mucosa. The N_2O used during the maintenance of anaesthesia can also diffuse into the cuff and can increases the cuff pressure which in turn can increase the risk of ischaemic tracheal mucosal injury. But, if high volume and low pressure cuff is used for less than 24 hours, it is of no clinical significance or importance. On the otherhand, tubes with high volume and low pressure cuff produces more difficulty during insertion, because the cuff often obscures the (Fig. 20.33) view of the tip of the tube and larynx. So, the trauma to the airway by this tube is more common. The otherways to avoid this problem is to remove the air from the balloon intermittently, guided by the tension of the pilot balloon. Alternatively, cuff should be inflated by N_2O of clinical concentration or N_2O should be totally avoided from the maintenance of anaesthesia. Inflation of the cuff by 5 to 10 ml of air would be sufficient to achieve an effective seal if the selection of ET-tube is correct. If the amount of air required is more than 10 ml, then the ET tube should be changed to a size of 0.5 to 1 mm ID larger than that had already passed. High volume – low pressure cuff also increase the incidence of sore throat (due to larger mucosal contact area), aspiration, spontaneous extubation and difficult insertion due to floppy cuff. But still because of low incidence of mucosal injury, high volume-low pressure cuff are more commonly recommended now.

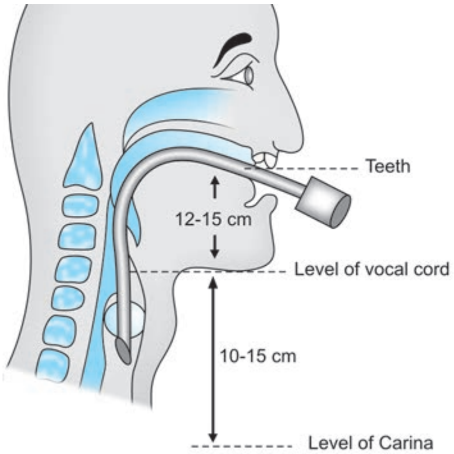


Fig. 20.33: The distances relating to the ET tube position

In younger children below the 8 years of age uncuffed tubes have generally been used. This is because the narrowest subglottic area is believed to limit the use of a cuffed tubes due to difficulty in introduction and in paediatric patients tacheal mucosa is more sensitive to ischaemic injury. In such circumstances endotracheal tube leak pressure is a clinically useful guide to confirm the proper selection of the uncuffed tube size in childrean. Leak should occur in a properly selected tubes at 15 to 20 cm of H_2O pressure and above. Below this pressure there should be no leak if the tube's size is properly selected. In this pressure there is no ischaemic injury of tracheal mucosa and aspiration.

Now, the use of a cuffed ET tube in paediatric group of patients has brought new discussion, keeping in mind the following advantages of it: require low fresh gas flow, reduce waste gas exposure to OT personal and avoide repeat laryngoscopy without any increased incidence of croup.

Generally, larynx is smaller in female than male. So, in an adult male an ET tube of 8 mm ID is appropriate, whereas for female a 7 mm ID tube is appropriate. In adult, the glottic aperture limits the size of an ET tube, but in children the subglottic area (cricoid cartilage) is the narrowest part of larynx and limits the size of ET tube. The tube size or the internal diameter (ID) of on ET tube for children up to the age of 14 years is calculated from the formula: {(16 + age) ÷ 4}. But practically, a tube of 0.5 to 1 mm ID size, smaller or larger than the estimated must be immediately available. There are other two popular formulae for calculating the probable size or ID of ET-tube to be used for paediatric patients are:

A. For children up to 3 years or less: Age/3 + 3.5 = ID of tube in mm.
B. For children 4 years and above : Age/4 + 4.5 = ID of tube in mm.

However, a crude clinical guide to calculate the outer diameter of the ET-tube, appropriate for a paediatric patient, is that of his little finger.

A special type of ET tube is used in head-neck surgery, neurosurgery or other surgeries where there is every possibilities of kinking of it. This type of ET tube is called the armoured tube. Here, the wall of the tube is reinforced with a spiral wire to reduce the chance of kinking and collapse. This armoured ET tube is also useful when it is placed through a tracheostomy or laryngectomy stoma to provide an clear airway.

Another type of special ET-tube, called RAE (Ring-Adair-Elwin) tube, is sometimes used which is available as both oral and nasal versions. It is best used when it is necessary to keep the tube out of the respective surgical fields. The curvature of these tubes are predefined to facilitate surgery over the head and neck. There is a preformed bend in the tube that helps the outer portion of it to pass directly over the chin (oral version) or forehead (nasal versions). It may be temporarily straightened during intubation and again takes its preformed shape automatically after the introduction in trachea. Like nasal and oral versions, they are also available in cuffed and uncuffed versions. As the diameter of this type of tube increases, simultaneously the length or distance from the distal tip to the curve also increases. Usually, there is a mark at the bend. In the majority of cases when this mark is at the teeth or naris, it is assumed that the tube is correctly positioned in the trachea, provided the proper size of tube for that patient is selected. However this mark is taken only as a guide but should not be used as the sole criteria for confirming the correct positioning of the tube in trachea.

The nasal preformed RAE tube has a curvature opposite to the curvature of the oral RAE tubes. It is because when this nasal version is in place the outer portion of the tube is directed over the patient's forehead. This helps to reduce the pressure on the nares. Thus, RAE tube may be useful for oral intubation of patients who are to be placed in the prone position or is scheduled for otolaryngologic procedures. The oral preformed RAE tubes are shorter than nasal ones. The external portion of the oral RAE tube is bent at an acute angle. So, when in place it rests on the patient's chin.

These RAE tubes are easy to secure. Their use may reduce the risk of unintended extubation. The curvature of the tube allows the breathing system to remain away from the surgical field during operation, especially around the head and neck without the use of any special connectors. It also helps to protect against kinks. The long length of RAE tube may also make them useful for insertion through an LMA.

The main disadvantage of preformed RAE tubes is difficulty in passing a suction catheter through them. When necessary, suctioning can be accomplished by cutting the tube at the preformed curvature and reinserting the connector of anaesthetic machine into the cut end. They offer more resistance to airflow than conventional ET tubes of comparable size. As the length of these tubes are designed to fit the average group of patient, so a tube may be either too short or too long for a given patient. When selecting the tube size, the reference to the height and weight of a patient may be more useful than the age in years, and the user should always be alert to the possibility of bronchial intubation or accidental extubation.

Other varieties of ET tubes are : microlaryngeal tube, double lumen tube, Parker Flex Tip tube, Cole tube, spiral embedded tube, Carden bronchoscopy tube, Carden laryngoscopy tube, injectoflex tube, different laser resistant tubes, etc. Detailed discussion of these tubes is not possible here.

Laryngoscope

A laryngoscope is an instrument which helps to see and examine the larynx and also helps to facilitate the intubation of trachea. It is of two types: rigid and flexible fibreoptic. Standard rigid laryngoscope consists of two parts: detachable blade with bulb and handle containing batteries. Each standard laryngoscope blade has: (i) a spatula which compresses the tongue in the submandibular space, (ii) a flange for displacing the tongue to one side, and (iii) an open side for visualization of the larynx by elevating the epiglottis indirectly by pressing on the glossoepiglotic fold or directly by pressing on the posterior surface of epiglottis. The batteries in the handle light the bulb at the tip of the blade. Alternatively, it powers a fibreoptic bundle that terminates at the tip of the blade and acts like a bulb. This light, emitting from the end of this fibreoptic bundle, is less diffused, more intense and more direct. This rigid laryngoscope with fibreoptic bundle in the blade also can be made MRI compatible.

According to the different shapes of blade, laryngoscope may be of different types which is not possible to discuss in detail here. However, among these few are discussed below.

Macintosh Laryngoscope

It is the most popular laryngoscope for use in adult. Its blade is curved and Z-shaped on cross section. Its tip lies beneath the pharyngeal (or anterior) surface of the epiglottis. Sizes of blade ranges from 1(smallest blade) to 4 (largest blade). Among these no 3 blade is most frequently employed for the adult use. But the no 4 blade is reserved for the unusual large or different patients. The smaller size blades are used for the paediatric patients. Tip of the Macintosh blade enters the valeculla and lifts the base of the tongue and the pharyngeal subtissues from the front of epiglottis. Thus, it elevates the epiglottis indirectly, so that cords can be visualized (Fig. 20.34).

Miller Laryngoscope

Unlike Macintosh laryngoscope its blade is straight with slight curved tip. The size of the blade ranges from 0 (smallest blade) to 4 (largest blade). Here, the tip of the blade elevates the epiglottis directly from behind and thus the cords are visualized. Another commonly used straight blade laryngoscope is Wisconsin blade which has a straight tip. Although, the straight blades may be advantageous in younger children, but the choice of blade in older children and adults is really a matter of familiarity and taste of an anaesthetist. Sometimes, in adults this straight blade Miller laryngoscope is also recommended for use in patients with a more anteriorly placed larynx. But, an anaesthetist should have a habit of using both the curved and straight blade, because when laryngoscopy

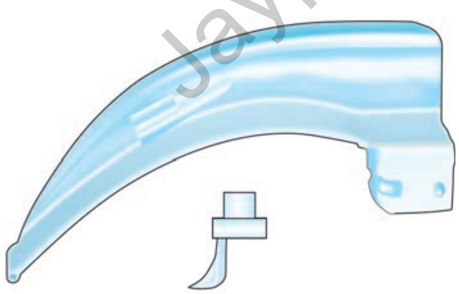


Fig. 20.34: Macintosh laryngoscope

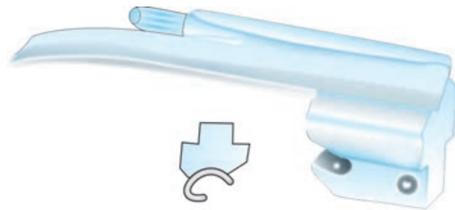


Fig. 20.35: Miller laryngoscope

becomes difficult with one type of blade, use of other type may permit adequate visualisation of glottis. For neonates and babies another type of straight blade such as oxford infant blade – is also very useful (Fig. 20.35).

McCoy Laryngoscope (Flexi – tip laryngoscope)

The peculiarity of this laryngoscope is that it has a hinged tip, assembled by lever which is positioned alongside the length of the handle on the opposite side of the blade. After insertion, once the tip of the blade is in the valeculla, pressure on the lever elevates the hinged tip with the epiglottis. This becomes specially useful for grade 3 intubation (of course in combination with cricoid pressure).

Bullard Laryngoscope

Bullard intubating laryngoscope is useful when the neck is immobile and mouth opening is very restricted. It has a long curved blades with fibreoptic illuminating system, suction port and intubation channels. It is made as both adult and paediatric versions (Fig. 20.36).

Wu-laryngoscope

Like Bullard laryngoscope, it has also a curved blade with elongated tip, fibreoptic light source, suction port, oxygen port and intubating channels through which tracheal tube is passed. It is designed to help to see the glottis in patient with very large tongue or whose glottis is very anteriorly placed. Anaesthetists should gain experience in using this Bullard and Wu-laryngoscope

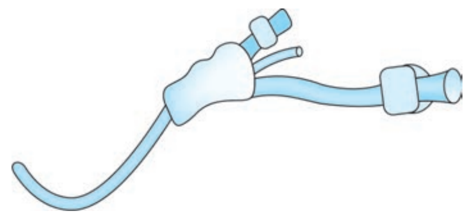


Fig. 20.36: Bullard laryngoscope

in normal patients, before using it urgently on patient with difficult airway. Many anaesthetists thought that these devices are preferred in patients where difficult airway is anticipated. But, others are not as they have no experience (Fig. 20.37).

Stylet and Bougie

Stylet

It is made up of a flexible metal and is inserted into an ET tube in order to maintain a chosen shape of it. This will facilitate the intubation when visualisation of glottis is minimal or absent. It should be remembered that the tip of the stylet should not cross the tip of ET tube. Otherwise, it will injure the trachea. The other uses of stylet are: rapid sequence intubation and when the haemodynamically stressfull time for laryngoscopy should be minimised, e.g cardiac patients. During use, stylet should be lubricated to facilitate its movement

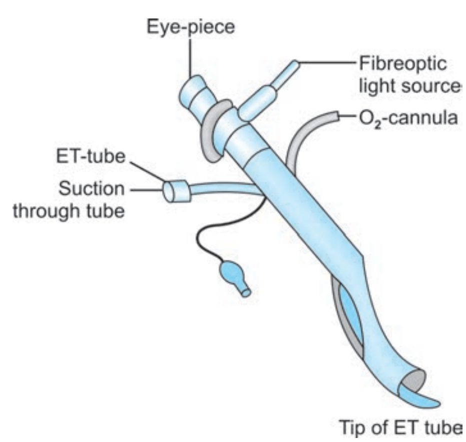


Fig. 20.37: Wu-laryngoscope

within the ET tube. The stylet should be removed as the tip of the ET tube enters the larynx to avoid undue trauma.

A special type of Stylet with a light source at the tip is called light-wand. The advantage of this light wand is that it can be guided with the ET tube into trachea by observing the movement of light under the skin of the neck from outside. Generally the room should be dark as the light can be seen adequately from the surface. The ET tube is placed over the light wand and is then introduced in the midline through the hypopharynx with the patient in standard sniffing position. The wand is then manipulated until a flare of light down the trachea is seen illuminating the neck. When the ET tube with the light wand is correctly positioned above the vocal cord in the midline, a distinct glow is seen in the anterior neck. Then, the tube is gently pushed into the trachea and the light wand is withdrawn. A special type of light wand is called 'Trachlight'.

Bougie

It is most commonly known as the gum-elastic-bougie. But, it is neither gum, nor elastic, and nor a bougie. It is actually called the Eschmann introducer and is such designed that it provides both stiffness and flexibility. The length of this introducer is 60 cm and the external diameter is 5 mm. It has a 35° bend, 2.5 cm from the patient's end which is inserted into the trachea.

Like stylet, it is also a very useful instrument to facilitate intubation when the laryngoscopic view of glottic is very poor. It is also very useful in limiting the degree of necessary neck movement during intubution with potential cervical spine injuries. It can also be used as tube exchanger. When the bougie is used, the tip of it is introduced first into the larynx through the glottic inlet blindly under reduced vision by laryngoscope. Then, keeping the laryngoscope in place, the ET tube is glided over the bougie upto the laryngeal inlet. After that 90° anticlockwise turn facilitates the glottic passage of ET tube, by presenting the bevel posteriorly. Then, bougie is withdrawn.

Technique of Intubation

In the technique of intubation the usual sequences are: pre-oxygenation, induction by administering rapid acting intravenous or volatile inducing agent, administration of rapid acting neuromuscular blocking agent, cricoid pressure, mask ventilation, laryngoscopy and followed by intubation. Both laryngoscopy and intubation are noxious stimuli and are sometimes more powerful than the surgical stimuli. So, deeper level of anaesthesia is required to blunt the stress response of laryngoscopy and intubation. This stress responses have deleterious effects on respiratory, CV and neurological systems. Thus, during laryngoscopy and intubation, these stress effects should be blunted to whatever degree if possible, especially when the patient falls into a high-risk category (e.g hypertension, CAD, ↑ICP, cerebral aneurysm, asthma, etc).

Before giving neuromuscular blocking agent, every anaesthesiologist must assesses his or her own patient, if mask ventilation will be possible or not when the patient will be fully paralysed. Therefore, if there is any doubt regarding the maintenance of patient's airway and ventilation by mask after induction and paralysis, then a conscious intubation with sedation and/or local anaesthetic agent should be considered before paralysis.

The general view regarding the pre-oxygenation is that breathing of 100% O_2 for 3 minutes or 4 vital capacity breaths with 100% O_2 before induction of anaesthesia provides added margin of safety. So, routine pre-oxygenation is optional, but strongly recommended before induction of anaesthesia and intubation for high risk group of patients. In patients with full stomach, where 'rapid sequence' intubation is chosen, there pre-oxygenation and cricoid pressure (Sellick maneuver) is mandatory and mask ventilation is not provided before intubation after administration of muscle relaxant unless unsuccessful intubation necessitiates it. Pre-oxygenation also can be omitted in patients : (i) who object to accept face mask, (ii) who are free of pulmonary diseases and (iii) who do not have any difficult airway.

Once the decision for induction of anaesthesia and intubation is taken, varieties of drugs can be used for induction and muscular paralysis and a variety of methods can be chosen to achieve the acceptable intubating conditions. For induction of anaesthesia intravenous, inhalation or oral route can also be used. But, usually intravenous route for adult and inhalation route for paediatric group of patients for induction of anaesthesia are chosen. For intravenous induction thiopental and propofol are most widely used now. But, other rapidly acting barbiturates (methohexital, thiamylal), benzodiazepines, narcotics, ketamine, etomidate, etc, also can be used. However the choice of inducing agents depends on the status of CVS, the status of CNS, effects on bronchomotor tone, presence of allergy, pharmacokinetics and pharmacodynamics of the agent etc. But among these the most important is the experience of the clinicians.

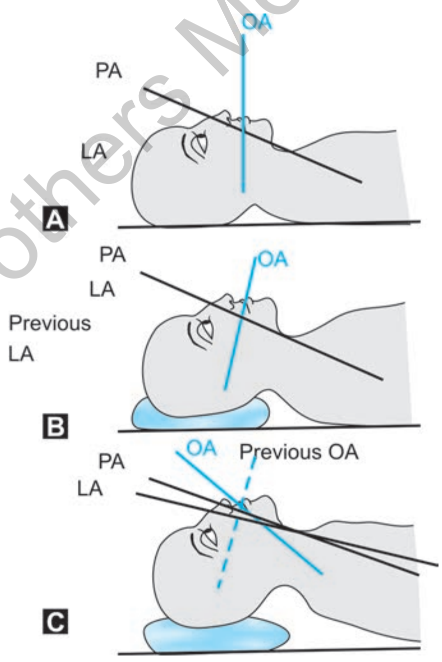
Both the depolarising and non-depolarising muscle relaxants are used for muscular paralysis, needed for intubation. But, due to some disadvantages such as masseter spasm, malignant hyperthermia, hyperkalaemia, burns, ↑IOP,↑ intracranial pressure, etc, the choice of succinylcholine for intubation has recently been questioned. However, still it is routinely used in many centres due to some of its advantages such as excellent intubating condition within a minute, rapid offset of action by ester hydrolysis if airway cannot be secured, and the patient's own ventilation will return much more quickly than any of the currently available nondepolarising muscle relaxants. So, still it is the relaxant of choice in many potentially difficult intubation cases, unless there are contraindications. However, recently rapid onset and excellent intubating condition produced by a nondepolarising drug such as rocuronium is achieved instead of succinylcholine. Other alternative non-depolarising drugs such as atracuronium, vecuronium, cisatracuronium etc. are not quite as rapid in onset of action as rocuronium.

Intubation may also be accomplished with only intravenous or inhalation anaesthetic agent without muscle relaxants when there is any doubt of difficult airway and failed intubation. But, this approach posses difficulties such as the potential for laryngospasm. So, a very deep level of anaesthesia should be achieved to avoid untowards laryngospasm if one wants to intubate only by intravenous or inhalational anaesthetic agents. In practice, the majority of clinicians employ lesser degree of muscle relaxation by reducing the dose of muscle relaxants (1/4th of the usual dose for quick recovery) to facilitate intubation in such circumstances.

Oral intubation

For successful oral intubation, position of the head is also very important. Unless there is contraindication for oral intubation, the head and neck is maintained in the classical 'sniffing position' to align the oral, pharyngeal and the laryngeal axes in a straight single line. Elevation of head by a small pillow with the shoulders remaining on the table first causes alignment of the pharyngeal and laryngeal axes. It causes flexion of the neck by about 25 to 35°. Then subsequent extension of the head at the atlanto-occipital joint (85°) causes alignment of oral axis with the pharyngeal and subsequently with the laryngeal axis. Thus, it serves to create the shortest possible distance and most nearly straight line from the incisior teeth to the glottic opening. But no such head elevation is required in paediatric age group (< 8 years) as their large head circumference produces the neck in flexion (Fig. 20.38).

Usually, the laryngoscope is held by the left hand of an anaesthesiologist and by the right hand mouth of the patient is opened. Then the blade of the laryngoscope is gently inserted into the patient's mouth from the right side of it and the tongue is kept left by the flange of the laryngoscope. During this procedure pressure on the teeth, gums or lips by the blade of laryngoscope should be avoided. After visualization of the epiglottis, the tip of the curved blade (Macintosh) is inserted into the vallecula and the laryngoscope is pulled forward and upward to elevate the epiglottis indirectly which expose the glottis. During that period gentle downward pressure on the cricothyroid cartilage from outside by an assistant may bring a non-visualised larynx into view. Then, the ET tube is inserted through the right side of the mouth and is pushed into the trachea between the paralysed, opened and abducted vocal cords under the direct vision. Instead of curved blade, if the straight blade is used then the tip of the blade is usually advanced behind the epiglottis, so that the epiglottis is included within the structures which are lifted up by the laryngoscope blade. Choice of the blade of laryngoscope depends on the clinicians preference and peculiar anatomy of the individual patient. When one blade does not become successful, then other types of blade become. So, skill should be developed in the use of different types of blades by an anaesthetist.



Figs 20.38A to C: A. The oral axis (OA), pharyngeal axis (PA) and laryngeal axis (LA) in usual position. B. Elevation of head about 10 cm by a pillow with the shoulders remaining on the table aligns the LA with the PA. C. Extension of head at the atlanto occipital joint aligns the OA with the PA. So, these three axis more or less come on a single straight line

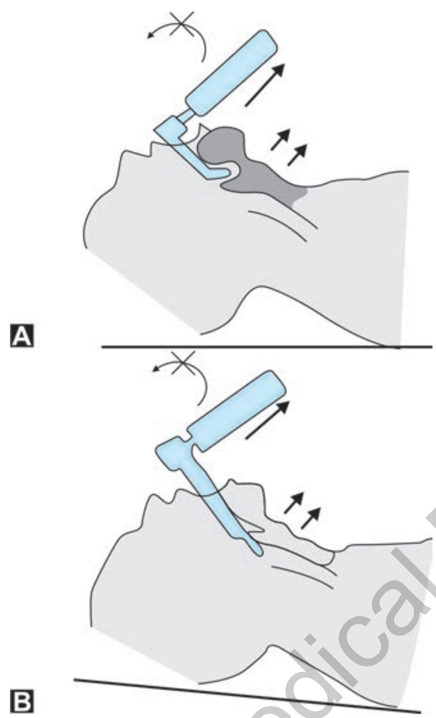
The cuff of the ET tube should lie in the upper part of trachea above the carina, but beyond the larynx or vocal cord. The cuff should be inflated with the least amount of air which is just necessary to create a tight seal in the trachea during positive pressure venitlation and minimize the injury of tracheal mucosa caused by the pressure transmitted to it from the cuff. Feeling of the pilot balloon is not a reliable sign of determining the adequacy of cuff pressure. After intubation, the chest and epigastrium are immediately ausculted. Capnographic tracing is also monitored to ensure the intratracheal location of the ET-tube. Because the persistent detection of CO_2 by capnograph is the best way of confirmation of tracheal placement of a ET-tube. But, it cannot exclude the bronchial intubation. The bronchial intubation is best diagnosed early by an increase in peak inspiratory pressure. The proper placement of an ET tube in the trachea also can be confirmed by palpating the cuff on the suprasternal notch, while compressing the pilot balloon with the other hand. The cuff of an ET-tube also should not be kept above the cricoid cartilage. Because prolonged intralaryngeal location of the cuff between the vocal cord may result in postoperative hoarseness of voice and increase the incidence of accidental intraoperative extubation. The true position of an ET tube can also be documented by X-ray. But, this is rarely needed except in ICU. If there is still any doubt, whether the tube is in the oesophagus or trachea, then it is prudent to remove the tube and ventilate the patient with a face mask (Fig. 20.39).

Under normal conditions the common causes of non-visualisation of vocal cords are mainly due to the wrong head position, or wrong blade position that is too far advanced, or not enough advanced, or reluctance to apply the adequate upward force.

The ET tube is usually inserted into the trachea by keeping the lip 23 cm away from the tip of the tube in adult male for correct position of cuff in trachea. In that position the tip of an ET tube lies 4 cm above the carina. In adult female this distance from the lip to the tip of the tube is 21 cm. Too far advancement of tube in trachea causes endobronchial intubation (usually right), whereas inadequate advancement of tube causes protrusion of the cuff through the vocal cords of larynx leading to risk of accidental extubation. In children, the distance (in centimeter) between the lips and the tip of the tube can be estimated from the formula: 12 + age/2 (Table 20.9).

There is also another simple formula to calculate the probable distance of ET tube from the mouth opening or from the external nares to the carina, which is as follows:

A. Mouth opening to carina = 0.16 × Height of child (cm) + 2.5 cm.
B. External nares to carina = 0.16 × Height of child (cm) + 4.5 cm.



Figs 20.39A and B: The proper position of the curved and straight blade of the laryngoscope during exposure of glottic opening. In figure A, the tip of the curbed laryngoscope blade (Macintosh) is placed in the space between the base of the tongue and the pharyngeal surface of the epiglottis (vallecula). In figure B, the tip of the straight laryngoscope blade (Miller or Jackson Wisconsin) is placed on the laryngeal (posterior) surface of the epiglottis. Irrespective of the type of blade, forward and upward force shown by the arrow should be applied along the handle of the laryngoscope to elevate the epiglottis and to expose the vocal cord

When a patient is at particular risk for aspiration due to full stomach, intestinal obstruction, gastric paresis, etc; then rapid sequence intubation is employed. Like the general principles of intubation during rapid sequence, if there is sufficient doubt about the ability to intubate such patient, then a concious intubation with judicious use of topical (Table 20.10) anaesthesia with or without sedation, should also strongly be contempleted. For rapid sequence intubation, pre-oxygenation is mandatory. Normally 4 vital capacity breaths with 100% O_2 is suffiient for nearly complete denitrogenation of healthy lung. But diseased or aged lungs require longer period of preoxygenation (3 minutes) to ensure adequate washout of N_2 from body. During very urgent surgery, where every second is counted, then four vital capacity breaths with 100% O_2 are adequate. After pre-oxygenation, intravenous rapid acting inducing agent and rapid acting muscle relaxant (usually succinylcholine) are administered. When the patient becomes unconscious, proper cricoid pressure is

Table 20.9: Magboul et al scoring system

Score	*1*	*2*	*3*	*4*
Mallampati	*Grade 1*	*Grade 2*	*Grade 3*	*Grade 4*
Measurement	3 fingers mouth open	3 fingers hypomental	2 fingers thyromental	1 fingers subluxation
Movement of neck	Left	Right	Flexion	Extension
Malformation	Skull hydrocephalus	Buck teeth, Loose teeth Macro and micro jaw	Obstruction, obesity, neck swelling	Syndrome and pathology

If the patient scores 8 or higher, he is likely to be a subject of difficult intubation. Mogbul et al reported 100% correct prediction from this score, but obviously more multicentre study and data will be needed to support this opinion.

Table 20.10: ET tube size and length calculated based on patient's age

Age	*ID (mm)*	*French unit*	*Distance from teeth to tip of tube in trachea (cm)*
Premature	2.5	10	10
Newborn	3	12	11
1-6 months	3.5	14	11
6-12 years	4	16	12
1-2 years	4.5	18	13
2-4 years	5	20	14
4-6 years	5.5	22	16
6-8 years	6	24	17
8-10 years	6.5	26	18
10-12 years	7	30	20
12-14 years	7 (Female)	30	22
	7.5 (male)	32	
> 14 years	7.5 (female)	32	24
	8 (male)	34	

applied to prevent aspiration whether muscle relaxant is administered or not. Proper cricoid pressure (or sellick manouvre) is applied by giving gentle downward pressure with thumb and first finger on the cricoid cartilage. This downward pressure on the cricoid cartilage occlude the esophageal lumen behind the cartilage. Because only the cricoid cartilage form a complete ring or have a posterior cartilagenous bar that can press and occlude the oesophagus and thus prevents regurgitation. But this pressure cannot prevent the regurgitation resulting from forceful vomiting. Only the force of vomiting is blunted by the muscle relaxant. Laryngoscopy and intubation in this setting are then performed without any preceding manual mask bag ventilation, if possible. If intubation is not possible in first attempt then only, mask ventilation should be started and continued while cricoid pressure is maintained. It is important to say that the cricoid pressure should be correctly applied such that it actually does not impede the visualisation of the glottis or passage of tube through it by any means. Cricoid pressure also decreases the flow of gas in the stomach and inturn limits the regurgitation.

Nasal intubation

In the operating room, oral intubation is the usual method. But, in some conditions when the surgery is performed in the oral cavity or on the mandible, or in any where on the face when both the surgeon and anaesthetist struggle for the space, then the nasal intubation is the choice. Nasal intubation is usually performed under direct vision. But, it also can be accomplished in difficult airway condition blindly or with the help of fibre optic scope under sedation and topical anaesthesia. Blind or fibre-optic nasal intubation is also chosen, where direct laryngoscopy is impossible.

However, there are certain contraindications for nasal intubation. These are: Coagulopathy, severe intranasal pathology, basilar skull fracture, the presence of CSF leak from the base of the skull, etc.

In any case when both the oral and nasal intubation has one or more contraindication, then anaesthetist must take any one decision, after discussing the relative risks and benefits of tracheostomy, oral intubation and nasal intubation with the surgeon to arrive at an acceptable compromise. Nasal intubation is sometimes chosen, because it may be quicker and more comfortable than oral intubation in the topicalised and less sedated patient (Table 20.11).

Technique of nasal intubation

Nasal intubation may be blind or under direct vision. It will be helpful if phenylephrine as a vasoconstrictor is applied on the nasal mucosa before nasal intubation. After the induction of anaesthesia and administration of muscle relaxant and mask ventilation, ET tube is introduced into the nose in a plane, perpendicular to the face up to a certain length when the tip of the tube reaches the oropharynx. Then, direct laryngoscopy is performed (in case of under direct vision nasal intubation) in the usual fashion. After that the tip of the ET tube which is seen in the oropharynx is directed into the glottis by holding and manipulating the machine end of the tube from outside of the nose.

Table 20.11: Risks factors for aspiration of gastric contents

Full stomach
< 8 hours fasting in solid food
< 6 hours fasting in milk
< 4 hours fasting in breastfeeding
< 2 hours in clear fluid
Pregnancy, obesity
Trauma
Intraabdominal pathology Intestinal obstruction
Gastric paresis (peritonitis, infection, diabetes, drugs, uremia)
Oesophageal diseases
Symptomatic reflex
Motility disorders
Uncertainty about intake of food and drink

If this is not possible then a Magill forcep may be used through oropharynx to direct the tip of the ET tube into the glottis, often with the help of an assistant who will push the nasal end of the tube. If the glottis can not be visualised by direct laryngoscopy, then the Magill forcep can still be used to guide the tip of ET tube blindly into the area of the glottis.

Blind nasal intubation is usually done in an anaesthetised spontaneously ventilated patient where spontaneous respiration facilitate the intubation blindly. This is described below. While the patient is taking spontaneous respiration, under deep sedation or anaesthesia (to prevent laryngospasm) or proper topical anaesthesia the tube is gradually inserted through the nasal cavity and then through the nasopharynx, oropharynx and laryngopharynx until the maximum breath sounds are heard from the outer end of the tube. It implies that the tip of the tube is just above the glottis. The tube is then inserted blindly into the glottis during next inspiration which tend to be deepest immediately following a cough. During forward movement of ET tube through laryngopharynx. If breath sound through the tube disappears, then it should be thought that the tube has passed into the oesophagus or pyriform fossa and must be withdrawn slightly above the level of the glottis. It is then reintroduced blindly into the larynx again and such several attempts can be tried. If still the tube does not enter the glottis, the patient's head should be extended, flexed or turned to guide the tip of the ET tube into the glottis. Usually, the tip of the tube enters into the oesophagus and extension of head is useful. If still, intubation is not possible, then help of direct laryngoscopy or bronchoscopy should be taken. As in blind procedure the entry of ET tube into the glottis is not seen directly, so it is helpful to have capnographic or bronchoscopic confirmation for endotracheal placement of the tube. Because at times, all the indirect signs of intubation may be misleading.

Blind nasal intubation in anaesthetised, apnoeic and paralysed patient may also be attempted. But as in this case there are no spontaneous breath sounds to help the placement of tube in the larynx, so this is only guided by the external observation of the tip location in the larynx.

INTUBATION FAILURE

Despite the most meticulous preoperative assessment of the airway, sometimes few patients present sudden and great difficulty during intubation. No matter how skilled, every practitioner have to encounter such patients in his practising life. So, induction of anaesthesia and use of muscle relaxant should be approached with this possibility in mind, as if a clear plan of action can be persuaded without unnecessarily panicking, if intubation failed.

These patients may be of elective or emergency cases. Failed intubation in emergency case is potentially life threatening. Because, there is a greater possibility of hypoxia both from regurgitation with aspiration (as these patients are not properly prepared by restricting the intake of food) and failed intubation. The cardinal rule under such condition is oxygenation first and everything else, i.e. regurgitation, aspiration, etc. are secondary. In such cases the majority of opinion is that, it would be wiser to allow the patient to come back to spontaneous respiration or even better to regain consciousness. Then, as the surgery is emergency and unavoidable, so one can review, rethink, plan and proceed again. The objective for these difficult patients should be not to use muscle relaxant producing apnoea until intubation has been successfully accomplished at the beginning of any anaesthesia or intubation has failed and patient is backed to spontaneous respiration. For such patients, conscious or 'awake' intubation by topical / infiltration local anaesthesia or intubation under spontaneous respiration under deep sedation or GA is ideal.

Indications for awake intubations are: (i) previous history of difficult or failed intubation, (ii) findings on physical examination that can indicate difficult or failed intubation and (iii) severe risk of aspiration. Actually, the term 'awake intubation' is applied to intubation on nonanaesthetised conscious emergency patient outside the operating room. But, this term is misnomer in OT where it is used after appropriate sedation, topical anaesthesia and/or nerve blocks to avoid laryngeal reflexes. If awake intubation has to be performed due to severe risk of aspiration, then narcotics and other IV sedatives should be used sparingly (Fig. 20.40).

Promoting local anaesthesia for awake intubation, the nerves that need to be blocked are trigeminal (nasal cavity and oral cavity) glossopharyngeal (nasopharynx, oropharynx, and laryngopharynx), vagus (supraglottic and infraglottic region). Woods and Lander describe a technique of glospharyngeal nerve block that only anaesthetizes the sensory supply

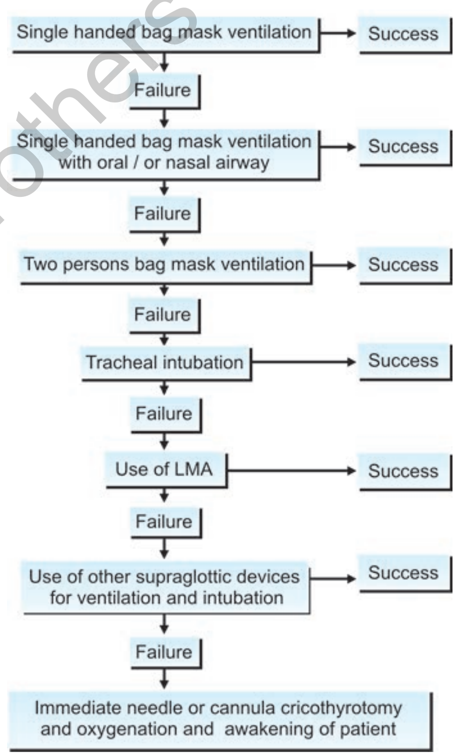


Fig. 20.40: Strategy in case of predicted or unpredicted difficult bag-mask ventilation

over the area of the back of the tongue which is innervated by this cranial nerve (glossopharyngeal IX). For this technique, by a 24 G needle, 2 ml anaesthetic drug is injected at the junction where the base of the tongue opposes with the palatoglossal fold. This causes local anaesthesia of the base of the tongue and does not appear to affect the airway integrity when performed bilaterally. This block is acceptable with full stomach also. This type of local anaesthesia allows a more comfortable laryngoscopy with lower doses of sedation. It has also been seen that if larger volume of local anaesthetic is given at that site then superior laryngeal nerve (SLN) which is the branch of vagus will also be blocked with glossopharyngeal nerve, because both the nerves lies in the same tissue plane. SLN innervates the epiglottis, aryepiglottic fold and the laryngeal structure up to the false vocal cords. This nerve can also be blocked isolatedly by giving injection of 2 to 3 ml local anaesthetic agent percutaneously between the greater cornu of the hyoid bone and the thyroid cartilage. But this block is contraindicated in full stomach patient as it impairs the protective mechanism of airway and cannot prevent the regurgitation and aspiration of stomach contents, if vomiting occurs. So, in full stomach where regurgitation and aspiration have possibility, then surface anaesthesia and analgesia of larynx (both supraglottic and infraglottic area) is the rule. For surface anaesthesia, 'spray-as-you-go forward' technique or certain variations of it, with or without cricothyroid puncture can be employed. The specific nerve blocks associated with surface anaesthesia is restricted only to the superior laryngeal nerve which can either be blocked percutaneously near the greater cornu of the hyoid bone where internal branch traverses the pyriform fossa before entering the larynx. A cricothyroid puncture for surface anaesthesia below the vocal cord is usually performed with the patient in semirecumbent position and local anaesthetic solution is injected or sprayed in the trachea usually at the end of expiration.

The difficulty of glottic exposure in laryngoscopy can be graded ranging from 1 to 4 : in grade 1, no difficulty of viewing the glottis; in grade 2, only posterior extremity of glottis is visible; in grade 3, only epiglottis is seen; in grade 4, no recognisable structure. When intubation fails by initial attempt, mask ventilation (if muscle relaxant is used) should be resumed and situation is reassessed. As long as oxygenation is maintained by mask ventilation, the problem is not an emergency one except if the patient is not in full stomach. During mask ventilation, cricoid pressure should be maintained if the stomach is full. However, in case of topical anaesthesia and / or nerve block if awake intubation is failed, then patient's spontaneous respiration is maintained only by giving 100% O_2. After that slight sedation can be added and fibre-optic intubation can be tried.

During reassessment of upper airway after a failed intubation in first attempt, the following things that should be brought in mind and correction should be done are: Head position, laryngoscopy technique, change of the shape (curved to straight) and size of blade, etc. If repeated laryngoscopy by an experienced practitioner is unsuccessful, then the first aim should be efficient mask ventilation (obviously in paralysed patient) to prevent hypoxia and attempts to bring back the patient to the spontaneous ventilation. If mask ventilation is efficient then before bringing back to spontaneous ventilation the anaesthesiologist can also again try intubation by the help of stylet, bougie, flexi tip laryngoscope, lightwand (trachlight), etc. LMA aided intubation, indirect rigid fibre-optic laryngoscope assisted intubation, pharyngeal airway Xpress aided intubation, etc. also can be tried. If all the previous methods are failed then patient should be brought back to the spontaneous ventilation. After resumption of spontaneous ventilation, there are three options: One, the patient may be allowed to awaken and the procedure is postponed if the case is not emergency; second, the patient is awakened and intubation is further attempted with topical anaesthesia if the case is emergency; three, after resumption of spontaneous respiration, not awakening the patient, try again to intubate the patient by previously described methods such as using styllate, bougie, fibre-optic bronchoscope, blind oral or nasal intubation, etc. then the muscle relaxant can be used if the operation is emergency. Actual life threatening emergency condition arises when after the use of muscle relaxants the tracheal intubation is failed and mask ventilation is also ineffective. The management of this extremely emergency condition is discussed later.

All anaesthetist should develop skill for conscious oral intubation with direct laryngoscopy. Blind nasal intubation that avoids the discomfort of laryngoscopy is also equally important to learn.

Intubation Failed – Mask Ventilation is Effective or Patient is Breathing Spontaneously (No Hypoxia – Oxygenation is Maintained) Operation is Urgently Needed

This group of patients can be managed by the following way:

i. If the manual mask ventilation is effective enough and the anaesthetist think that he will be able to carry on the operation by only mask ventilation with muscle relaxation (if that operation needs relaxation), then he can procede.

ii. Operation also can be carried out in anaesthetised spontaneously ventilated patient through mask if muscle relaxant is not needed to complete that surgical procedure. So after muscle relaxation and failed intubation, when spontaneous respiration is re-established, the anaesthesia can be continued with volatile inhalational agents by mask without muscle relaxant.

iii. After re-establishment of spontaneous respiration in anaesthetised patient, if the patients fall in the group where operation is urgent and the full muscle relaxation is required for completion of the surgical procedure and mask ventilation is though effective, but cannot be carried out for prolonged period or the surgical site does not allow the mask ventilation, then the patients should be managed by intubation first after re-establishment of spontaneous respiration and later followed by full muscle relaxation. Intubation in this group of patients is tried first with the help of different intubation accessories. In such situation there is another option that is use of LMA. By LMA we can maintain anaesthesia by spontaneous ventilation with the inhalational agents or we can ventilate if muscle relaxant is needed. Mask ventilation or ventilation with LMA (spontaneous or IPPV) is usually satisfactory for short minor procedures, such as cystoscopy, EUA, inguinal hernia repair, etc. but not for long complicated procedures or where high pressure for IPPV is needed.

Accessories for Intubation

(a) Using stylet

Difficult orotracheal or nasotracheal intubation can be performed by employing direct laryngoscopy and using stylet which is passed though the ET tube. ET tube is directed anteriorly with the stylet.

(b) Difficult oral intubation using bougie

Difficult oral intubation may also be attempted by gliding ET tube over a long flexible 'bougie', inserted blindly into the glottis under direct laryngoscopy. Sometimes, the subsequent passage of an ET tube by gliding over the bougie is difficult. In such situation, laryngoscope should be kept in position and the tracheal tube is rotated 90° anticlockwise, in order to prevent the 'fork' created by the bevelled end

Table 20.12: Recognition of correct placement of ET-tube

- Direct visualisation of tube passing through the larynx.
- Auscultation of chest.
- Asucultation of epigastrium.
- Observation of chest movement.
- Observation of abdominal movement.
- Tension of CO_2 in expired air, confirmed by capnography.T
- Observation of condensation of water vapour in expired air in PVC ET-tube.
- Movement of reservoir bag in up paralysed spontaneously breathed patient.

of the tube and the bougie, from impacting on the posterior rim between the aryteroid cartilages. A white (Table 20.12) plastic bougie with a soft metal core is said to be easier most to place in the glottis than the older gum elastic bougie. Advancement of the distal end of the bougie over the tracheal rings produces a clicking sensation and confirms its placement in trachea. If the bougie is hollow, then jet ventilation can also be done through this channel or capanography can be attached with it which will show the characteristic pattern of PCO_2 in expired air associated with the breathing.

(c) Using light wands

Light wand was originally introduced for blind intubation, but it can be used with direct laryngoscope also (semi-blind technique). If the light at the distal end of the tracheal tube is seen to transilluminate brightly through the cricothyroid membrane, then it is confirmed that the endotracheal tube is in the larynx. If no transillumination is seen, then the tube is considered to be in the oesophagus. The advantages of light wand or trach light are: easy technique, relatively inexpensive, useful adjunct in difficult airway, does not require much neck manipulation, useful in cervical spine injury, useful in patient with limited mouth opening, less traumatic than blind nasal intubation, presence of secretion is of no problem etc. The disadvantages of light wand are: should not be used with laryngeal or tracheal polyps, tumours, inflammation, retropharyngeal abscess, foreign body, etc. In morbidly obese patients, the ability to see the glow of light may be diminished. On the contrary, in thin and frail patients some transilluminations may also occur, even when the tube tip with the light source is in the oesophagus and will confuse the anaesthetist.

(d) Blind nasal intubation

For blind nasal intubation the patient should normally have the head and neck, placed in the classical 'sniffing the morning air' position. The anaesthetist will have to first decide which of the nasal passage is to be used. Then as a first step a well lubricated nasal tracheal tube is gradually passed along the floor of the nose into the nasopharynx, oropharynx, and hypopharynx (as the patient is breathing spontaneously). After that it is ultimately introduced blindly into the trachea. But unfortunately this is very uncommon, and commonly these tubes end up in either of the pyriform fossae or in the oesophagus. In such circumstances several blind attempts with or without the help of any accessories are tried. Occasionally, they can also cause various degrees of haemorrhage. Chances of successful blind nasal intubation can be increased by the following methods :

i. Listening to the proximal end of the nasal tube and feeling the air being breathed out of the tube.
ii. Using capanography to guide the distal end of the tube into the larynx.
iii. Using the light wand which can be manipulated, so that the long shaft of the wand follows the contours of the upper nasal passage and enter the larynx.
iv. A fiber-optic laryngoscope or bronchoscope can be passed through the nasal tube to guide it into the larynx.

(e) Using LMA

LMA has also been used on many occasions for difficult intubation. It has enabled effective oxygenation by spontaneous ventilation or manual positive pressure ventilation. LMA has also enabled the passage of bougie and/or fibre-optic scope into the trachea which is again followed by the passage of an ET tube in trachea with the help of these bougies or fibre-optic scope. There is also a special type of intubating LMA (ILMA) which is called 'Fastrach LMA'. It consists of an anatomically curved, short, wide bore tube and a laryngeal cuff with a guiding stainless steel handle. It has a single moveable epiglottis elevation bar in the place of fixed aperture bars. It is available in 3 sizes and can accomodate 7, 7.5 and 8 mm ET tube within its wide bore tube for intubation (Fig. 20.41).

(f) Combitube

The most recent method of accomplishing emergency intubation–or more correctly ventilation–is the use of combitube. This is the modern version of the older oesophageal obturator airway. The principle of combitube is that this tube is inserted blindly and artificial ventilation is started through any one of the distal two ports. Depending on the results of auscultation,

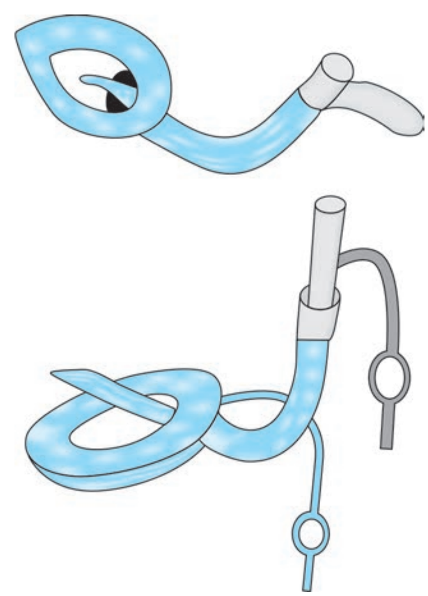


Fig. 20.41: Intubating LMA (ILMA)

any one of the two tubes is selected to ventilate the lungs.

(g) Fibre-optic instruments

Recently fibre-optic laryngoscope or bronchoscope have become an extremely important piece of instrument in the management of difficult airway. Due to their extreme flexibility, they easily can be passed either through the nose or through the mouth into the trachea and assist in intubation. The observer can also see the tip of the ET tube in trachea with the help of fibre-optic scope and confirm intubation.

When used for nasal intubation, the fibre-optic laryngoscope or bronchoscope with an ET tube can be passed through the nose into the larynx followed by the tracheal tube. Alternatively, the nasotracheal tube or airway can be passed into the pharynx and the fibre-optic scope is passed through it into the larynx, followed by the tracheal tube. The latter technique is used to prevent the tip of the fibrescope from toileting with blood, secretions or water vapour condensation to get a clear view. By contrast, the usual practice of fibre-optic scope through the oral route is to pass it first using the conventional laryngoscope, followed by an endotracheal tube. Once the intubation has been accomplished by either of these two routes or methods, the fibre-optic scope can also confirm the ET tube in the trachea by observing the tip of the tube against the tracheal ring or wall.

One of the disadvantages of fibre-optic techniques for intubation is that the instrument is delicate and expensive and can be quite easily damaged. Even in experienced hands, an intubation using these instruments can take duration which is three times longer than that of the conventional method and may be associated with marked cardiovascular resposes to intubation. It is reported that blood pressure and heart rate remain higher for a considerably longer period compared with following a normal intubation.

When Intubation is Failed and Also Ventilation By Mask is Ineffective or Not Possible

The patient who is a truly impossible candidate for mask ventilation after failed intubation presents really a life threatening emergency condition. Always the best treatment of such condition is prevention, like the other branches of medicine. So, an anaesthetist must always carefully evaluate the airway to determine the safest plan for intubation and the plan if both intubation and mask ventilation failed, before instituting muscular paralysis and general anaesthesia. In the patient who has been thoroughly de-nitrogenated by pre-oxygenation, there should be adequate time to institute one of the following procedures before serious O_2 de-saturation and consequent haemodynamic deterioration happen if such condition appears. In reality, when such circumstances will arrive, then everybody has to thought that he is often dealing with a severely anoxic patient who has suffered or is near to the brim of cardiac arrest. So, it is critical to start one of the following procedures before irreversible cardiac arrest or brain damage has ensured. The interventions during failed to intubate and failed to ventilate by mask conditions are the followings:

i. Establishment of emergency non-surgical airway and ventilation:
   After mask LMA or combitube will probably become the next non-surgical airway intervention for emergency ventilation.
ii. Establishment of emergency surgical airway and ventilation.

Emergency surgical airways can be established by many ways. These are: needle cricothyroidotomy, cannula cricothyroidotomy, surgical cricothyroidotomy, percutaneous tracheostomy (PCT), conventional surgical tracheostomy (ST), etc. Among these, the needle and cannula cricothyroidotomy is done during emergency condition when an anaesthetist 'cannot intubate and cannot ventilate by mask' the patient. Through these needle or cannula of cricothyroidotomy jet ventilation is performed for oxygenation of patient. So, this procedure may be called as the transtracheal jet ventilation (TTJV). Actually, the term 'jet ventilation' means introduction of gas (oxygen) into the tracheobronchial tree under high pressure and speed and has been used in different forms. For example, this technique may also be used during anaesthesia for bronchoscopy or laser surgery on the larynx. During anaesthesia for bronchoscopy as laser surgery on the larynx, jet ventilation via a needle, placed within the lumen of an otolaryngological laryngoscope permit oxygenation of patient without a tracheal tube intubation.

Trans-tracheal jet ventilation (TTJV) through needle cricothyroidotomy

In such TTJV a 12 to 18G needle (12 or 14G for adults and 16 or 18G for paediatric patients) is inserted through the cricothyroid membrane and is attached to a high pressure O_2 source via a low compliance circuit. For high pressure O_2 source, anaesthetic machine can also be used. For that an adaptor of ET tube of 5 mm ID which is attached to the low compliance O_2 supply tubing is inserted to the fresh gas outlet of the anaesthetic machine. At the other end of the low compliance O_2 tube (i.e. between O_2 tube and 16 G or 14 G cannula) a three way stop-cock is attached and then this stop-cock is connected to the translaryngeal 16 G or 14 G cannula. The three way stop-cock helps by preventing excessive pressure to build-up by releasing the aperture to the air in between jet inspiration. Before starting artificial jet ventilation, it is wise to fix the tube. Otherwise, high pressure through a narrow tube will tend to force the tube out of its position. It is essentially a blind technique and incorrect placement or excessive pressure can produce pneumothorax, pneumomediastinum, pneumotrachea, pneumolarynx, or pneumomediastinum. In this era

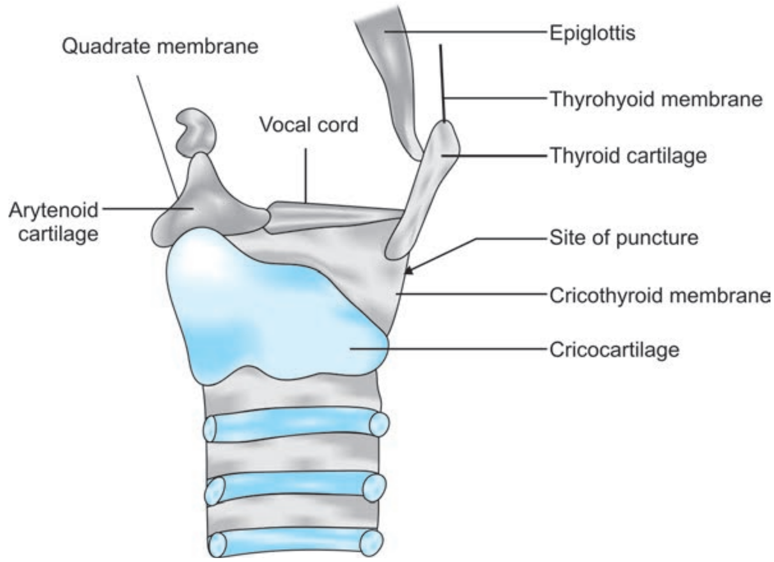


Fig. 20.42: The anatomy of cricothyroid membrane

of technological advances, flexible fibre-optic endoscope, Bullard laryngoscope, noninvasive light wand and different intubation guides are also recommended (Fig. 20.42).

This needle TTJV provides adequate ventilation as well as oxygenation and serves as an alternative emergency procedure for those who are planning to assemble a standard TTJV system through cannula cricothyroidotomy by modified Seldinger technique. TTJV, either by needle or cannula, only provides emergency oxygenation. So, always the successful TTJV should be followed up by provision of making a definite airway and ventilation by tracheotomy (precutaneous or classical) or endotracheal intubation or waking up the patient and resumption of the normal airway. In the technique of cannula cricothyroidotomy, after a needle is introduced into the tracheal lumen, a wire is passed downwards. Then the needle is withdrawn and a dilator is passed over the wire which is followed by an cannula. The advantages of this technique are that it is quick and relatively easy to perform. It is important to comment that neither TTJV or cricothyroidotomy can relieve obstruction which occur below the first few tracheal cartilages.

Surgical Cricothyroidotomy

In the 'cannot ventilate, cannot intubate by mask' condition, a classical tracheostomy cannot be performed quickly enough to save the life. In such situation emergency surgical cricothyroidotomy can also be employed to insert a small endotracheal or tracheostomy tube. Truly speaking, this surgical cricothyroidotomy is also time consuming (more than 5 minute) and may not be able to save the apneic patient's life.

For surgical cricothyroidotomy a stab incision by a short scalpel blade is made through the skin and cricothyroid membrane and the trachea is opened. Then, the incision is enlarged by using hook to pull the cricoid cartilage caudally. This helps to insert an ET tube of 5 to 6 mm ID (Table 20.13).

FIBREOPTIC SCOPE

There are some elective situations where direct laryngoscopy with a rigid laryngoscope is undesirable or impossible or if possible still the laryngeal inlet is completely out of view with this type of rigid laryngoscope. Examples of few such situations are: patients with unstable cervical spines, very poor range of motion of the temporomandibular (TM) joint, severe burn contracture of neck, certain congenital or acquired upper airway anomalies, etc. In such situations direct visualisation of larynx by fibreoptic scope and intubation with the help of it is the only answer. But, in contrast to conventional laryngoscope, its use needs intense practice. Intubation by fibre-optic scope requires longer time. So, it has no role in emergency situation where airway has to be established rapidly in the face of severe hypoxia. When the fibreopticscope aided intubation is anticipated for the elective management of a more difficult airway, then the fibre scope should be employed first, before visualisation of larynx is obscured by oedema, secretions and / or haemorrhage due to previous repeated attempt and failed intubation.

The fibre-optic scope is consist of a collection of thin glass fibres whose diameter vary between 5 to 25 μm. These collection of thin glass fibres are divided into two groups each containing 10,000 to 15,000 fibres. Among these two groups

Table 20.13: Difficult airway algorithm

1. Assessment
   - Assessment for difficult mask ventilation.
   - Assessment for difficult intubation.
   - Assessment for difficulty for patient co-operation and consent.
   - Assessment for difficulty for tracheostomy.
   - Assessment of opportunities for delivery of supplemental oxygen throughout the process of difficult airway management.
2. Consider the relative merits and demerits of the basic choices of management
   - Preservation of spontaneous ventilation vs Ablation of spontaneous ventilation.
   - Awake intubation vs Intubation after induction of GA.
   - As an intial approach for intubation taking the help non-invasive technique vs Invasive technique.
3. Difficult airway-recognised or unre-cognised.
4. Develop some other primary and alternative strategies.

one group transmits image from the target object to our eyes and another transmits light from a powerful source. In addition to all these fibreoptic scope consists of: (i) wires which control the angulation of the tip of fibres and (ii) ports for suction, injection of local anaesthetics and delivery of oxygen.

The keys to successful elective intubation by fibreoptic scope include control of secretions, adequate topical anaesthesia, proper sedation, proper defogging of lens and aligning of the scope in midline. As during any manipulation of airway, pulse oximeter is also mandatory during this procedure to detect hypoxia. During the use of fibre-optic scope aided intubation, the use of anticholinergic is strongly recommended, because excessive secretions in the upper airway may obscure the view. The tip of the scope should be defogged intermittently and frequently with warm soapy water and the entire length should be lubricated by K-Y jelly to facilitate the passage of scope through the ET tube. A patent suction port is important and a 10 ml syringe filled with 1% lignocaine solution can be attached for further topical spray through the scope. If O_2 insufflation is desired, then an appropriate source adaptable to the bronchoscope port should be available. This is useful in keeping the secretions off the tip of the fibre-optic scope and diminishing fogging as well as providing a source of 100% O_2. Preventing hypoxia during the fibreoptic scope aided intubation.

The elective intubation by fibre-opticscope may be oral or nasal and can be employed on conscious or anaesthetized patient. But among the oral or nasal route, the nasal route and among the sedated unparalysed and paralysed patient, the intubation in unparalysed patient by fibre-optic scope is technically more easier. On the otherhand, through oral route on a sedated paralysed patient fibre-optic intubation is the most difficult of the four possible technique such as oral or nasal fibre-optic intubation in sedated unparalysed or paralysed patient. During oral intubation by fibre-opticscope on a sedated unparalysed patient, an endoscopic oral airway or a bite block should be used to protect the scope from biting by teeth. Among the oral airway PatilSyracuse airway or Williams airway or ovassapian airway has some advantages. It prevents the dorsal displacement of the tongue and keeps the instrument in midline and guides the scope past the epiglottis into the larynx (Table 20.14).

As a first step, the base of the tongue, the oropharynx and the laryngopharynx is anaesthetised topically by 10% lignocaine spray or by nebulisation of 4% lignocaine. This is done in a completely conscious patient or with minimum sedation. Then an intubating airway is inserted through mouth after topicalisation. After that the ET-tube is inserted into the mouth about 8 to 10 cm through this airway and fibre-optic scope is passed through the ET-tube. The base of the toungue, epiglottis and finally glottis is visualised in proper sequence. If tip of the scope is obstructed by the posterior pharyngeal wall (which is diagnosed by pink blurr vision), it should be turned down to visualise the glottis. If the epiglottis obstructs the vision, then the scope should be manipulated, so that the vocal cords can be seen. After visualisation of the vocal cord, the ET tube is introduced into the glottis.

Table 20.14: Possible contents in an emergency difficult airway unit

1.	Rigid laryngoscope blades of different sizes and designs.
2.	Endotracheal tube of different sizes and shapes.
3.	Different ET tube guides, such as stylets of different sizes with or without hollow inside for jet ventilation, gum elastic bougies, light wands, forceps to manipulate the patient's end of the tube in the larynx.
4.	Various supraglotic airway devices :
	LMA of different sizes and types
	Combitube
5.	Fibre-optic intubation device.
6.	Set of a transtracheal jet ventilation.
7.	Set for emergency cricothyrotomy and ventilation.
8.	Set for retrograde intubation.
9.	Capnometer for detection of CO_2 in expired air.

Fibre-optic intubation in anaesthetised patient may also be done under spontaneous or controlled ventilation in a nonparalysed and paralysed patient respectively. It is obvious that the fibre-optic intubation under spontaneous ventilation in an anaesthetized patient is more technically easier and advantageous than the controlled ventilation. But, in spontaneous ventilation, diminished anaesthetic level causing cough, vomiting, laryngospasm, bronchospasm, etc. is the definite disadvantage. On the other hand, fibre-optic intubation under controlled ventilation, apnoea is the major headache. Patient should be ventilated with 100% O_2 by mask in between the intubation attempts by fibre-optic scope or patient should be ventilated with special endoscopic mask with a sealing port (through which endoscope is introduced) that allows for the continuous use of mask and ventilation during the attempts of intubation by fibre-optic scope. During endoscopy, additional O_2 from the separate source can be administered through the injection port of the fibre-optic scope.

Nasal intubation by fibre-optic scope has the advantage that the instrument can easily be positioned directly through nasal route into the hypopharynx to visualise the glottis. If the patient is not anaesthetized, tongue causes less interference when this route is used. On the contrary, anaesthetized intubation by fibre-optic scope through nasal route is less difficult due to less soft tissue upper airway obstruction caused by anaesthesia. In anaesthetized patient a standard nasal airway or a split nasal airway can be used to keep the tongue away from the posterior pharyngeal wall. Usually, the patient is not anaesthetized for fibre-optic scope to visualise the glottis. But, only anaesthesia is employed where patient is un-cooperative and keeping in mind that intubation by fibre-optic scope under anaesthesia is usually more difficult. This is because of the development of the upper airway obstruction by falling tongue. If there is any doubt about the ability to maintain ventilation by mask during fibre-optic laryngoscopy under anaesthesia and paralysis, then fibre-optic aided intubation should always be preceded with conscious sedation and/or topical anaesthesia instead of full anaesthesia. In topical anaesthesia, for nasal fibre-optic intubation the supraglottic, glottic and tracheal areas may be anaesthetized with 1% lignocaine, sprayed through the injection port. After awake sedation, and application of topical anaesthesia and vasoconstrictor on nasal mucosa, an nasal ET tube or split nasal airway is passed through any nares into the nasopharynx and oropharynx. Then fibre-optic scope is passed through it. Thus, in vast majority of cases glottis can be seen by this scope with minimal tip manipulation. After visualisation of glottis, it is very easy to push the tip of ET tube in the larynx with the tip of fibre optic scope inside it.

OTHER SURGICAL AIRWAY TECHNIQUE

Other surgical airway techniques except the needle cricothyroidotomy, modified cricothyroidotomy by Seldinger technique (cannula cricothyroidotomy) and surgical cricothyroidotomy are percutaneous tracheostomy (PCT) and conventional surgical tracheostomy (ST). But none is performed under emergency 'cannot ventilate and cannot intubate' (CVCI) condition. Because all these procedures are time consuming (more than 5 minutes) and may not be able to save the apnoeic patient's life. By these above mentioned cricothyroidotomy techniques (including needle, cannula and surgical cricothyroidotomy) O_2 can be provided on a short-term basis until a definite airway can be placed or the patient resumes spontaneous breathing or wakes up. So, for a definite airway PCT is most commonly performed in ICU on patients who need prolonged ventilatory support for more than 3 weeks by ET tube.

Chevalier Jackson in 1909, first defined the method of surgical tracheostomy. Before that a patient remains intubated through larynx till he becomes conscious and cannot maintain his own airway. But, prolonged intubation through larynx has many disadvantages. So, if one thinks that a prolonged intubation is needed (more than 10 days) or if it is apparent that the patient is unlikely to maintain his airway independently within 3 weeks, then tracheostomy should be done. Usually, there are two types of tracheostomy – PCT and ST. The PCT has several advantages over conventinal surgical tracheostomy. These advantages are: (i) reduced wound complications such as haemorrhage and infection, (ii) improved cosmetic results, (iii) can be easily done at the bed side in ICU, (iv) reduced duration of the procedure and (v) it can be performed by non surgeons. The disadvantages of PCT over ST is that due to narrow tract and lack of formal stoma formation in PCT, there is increased risk of delayed airway loss. Without a formal stoma and with only a narrow tract between the airway and the skin, tracheostomy tube may be displaced which can lead to death.

First PCT was reported in 1955 by Sheldon. But because of high complication rate in this technique adopted by Sheldon, Ciaglia in 1985 modified this technique and called it as percutaneous dilatational tracheostomy (PDT). PCT differs from conventional ST in that in PCT a puncture is made on the trachea in between cartilages (usually between 1st and 2nd or between 2nd and 3rd) by needle or scalpel and subsequently the puncture is dilated over a flexible guiding catheter to intorduce a small tracheostomy tube or a small endotracheal tube. Whereas in conventional ST the tracheal cartilages are dissected and cut by the scalpel. On the other hand, in cricothyroidotomy the site of puncture is cricothyroid membrane and not the tracheal cartilages. Other different techniquees of performing PCT are : Grigg's technique, White tusk / Blue Rhino technique, Pere Twist technique and Trans Laryngeal Tracheostomy Technique (TLT).

PCT is performed in the intercartilagenous area between the 1st and 2nd tracheal rings or 2nd and 3rd tracheal rings. There is increased incidence of subglottic stenosis when it is performed above the first ring. The area below the third ring is generally avoided to minimise the potential trauma of the isthmus of thyroid and to prevent the accidental injury of the inominate artery.

In conventional ST the tracheostomy tube should be placed so that it does not erode the ring and press against the cricoid cartilage. In addition, the opening should not be placed too low, so that the tip of the tube or its cuff will be too close to carina. Low placement of tracheostomy tube is also hazardous, because the innominate artery crosses anterior to the trachea low in the neck. During ST any segment of trachea should not be removed, because this might lead to greater loss of tracheal wall stability and predispose to stenosis, once healing is accomplished after removal of the tube.

SUPRAGLOTTIC AIRWAY DEVICES

These are the devices which lying above the glottic opening help in ventilation and avoid the 'tube within tube' situation that is produced by intubating the trachea by an ET tube. It provides a better unobstructed airway during spontaneous respiration than the oropharyngeal or nasopharyngeal airway. It also help in controlled ventilation if needed. LMA is such the first supraglottic airway device and has been in practice nearly 20 years, since Dr. Archie Brain in UK had first introduced it. The LMA has been used for more than 150 million times world wide, but without a single death attributed to its use. So now, LMA has a well established role in the management of patient with normal or difficult airways.

Thus, the amazing success trail of LMA has spurred the introduction over a dozen of different supraglottic airway devices other than LMA to remove the disadvantages of it. But, only some have stood the test of time, while others have dwindled into the oblivion. Some of the supraglottic airway devices which have stood the test of time include: Combitube, soft seal and laryngeal airway device, laryngeal tube suction (LTS), cobra perilaryngeal airway (cobra PLA), pharyngeal airway Xpress (PAX), streamlined linear of the pharyngeal airway (SLIPA), cuffed oropharyngeal airway (COPA), glottic aperture seal airway (GOS airway).

All the supraglottic airway devices produce minimal to nil haemodynamic instability during their placement in larynx as they avoid stimulation of the infraglottic structures. They offer minimum resistance to the patient's airway. Other advantages of supraglottic devices are: Easy insertion and smooth awakening, no inadvertent bronchial intubation, no vocal cord injury, no translocation of oral or nasal bacterial colony and no secretions into the lower respiratory tract. Among all the above mentioned supraglottic devices, LMA and combitube have been recommended as the rescue of airway in 'cannot ventilate, cannot intubate' situations. Again LMA has been recommended at five places in the ASA Task force Algorithm for the management of difficult airway, either as a ventilating devices or as a conduit for endotracheal intubation.

However, today these devices (LMA and combitube) are not only used during emergency situations, but also during elective management of the patient's airway. Ambulatory or day case surgery for patients of ASA I and II grade (ASA I patients only according to some anaesthetist) are one of the most suitable candidates for the use of these supraglottic devices. These include short procedures, not requiring controlled ventilations with muscle relaxant such as surgeries of the upper and lower limb, ear and nose surgeries, ophthalmic surgeries, short gynaecological procedures, etc. These devices are also recommended in patients with ischaemic and other heart diseases, coming for short surgical procedures under general anaesthesia, as their use is associated with lesser haemodynamic changes compared to tracheal intubation. At the end of neurosurgery, but prior to termination of anaesthesia, ET tube can be replaced with LMA as a preventive strategy against hypertension, coughing, bucking, etc. which are associated with extubation and smoother emergence. For these reasons, supraglottic devices also are used during ophthalmic surgery to prevent risk from sudden rise in IOP during intubation and extubation. The supraglottic devices are also extremely popular in patients, undergoing minor therapeutic and diagnostic surgical procedures outside the OT complex. These include: Radiotherapy, diagnostic and interventional radiology, endoscopy, ECT, cardioversion, etc. In the ever expanding horizons of the supraglottic devices, more and more number of the routine general anaesthesia, lasting for 2 to 3 hours are now also being administered using these devices. Even surgeries associated with increased intra-abdominal pressure (Laproscopic surgeries) are now being safely done using proseal LMA, LTS or combitube.

Factors which prevent the use of supraglottic airway devices include: Small oral opening and any pharyngeal pathology which prevents the proper fitting of it at the laryngeal inlet. For example, pharyngeal mass and oesophageal pathology including caustic injury contradicts the use of supraglottic airway devices like combitube and laryngeal tube suction. All the supraglottic airway devices do not offer reliable protection against regurgitation and aspiration of stomach contents, except combitube and LTS. So, they should not be used in patients with the possibility of reflux of gastric contents and aspiration of it or where retained gastric contents may be present.

These conditions include:

i. When fasting is not confirmed
ii. Morbid obesity
iii. Pregnancy where there is delayed gastric emptying
iv. Others conditions associated with delayed gastric emptying such as history of gastroesophageal reflex, hiatus hernia, etc.
v. Multiple or massive injury.
vi. Acute abdominal or thoracic injury.

But, we have to keep in mind that these above mentioned conditions are not the absolute contraindications for the use of supraglottic devices.

Supraglottic airway devices also have the limited value in patients with poor lung compliance as they cannot withstand the high inflation pressure. But, it is noted that only the proseal LMA can withstand the peak inflation pressure of 35 to 38 cm of H_2O without leak from sides.

Individual Supraglottic Device

There are many supraglottic devices, among them which are commonly used are described below.

LMA

Previously it has been already discussed.

Soft seal and laryngeal airway devices

both the soft seal and the laryngeal airway device are quite similar to the LMA of unique variety in regards to structure and single use concept. But, one major difference between the LMA of unique variety and the soft seal or laryngeal airway device is the removal of the aperture bars from both of these later devices and a softer cuff of the soft seal. So, the latter confers a better periglottic seal, which can withstand the higher inflation pressure than the LMA classic.

Laryngeal tube suction (LTS) device

LTS is basically a shorter version of combitube. It is a newly developed, multiuse, latex free, double lumen, silicon tube. Like combitube, it has both oropharyngeal and oesophageal low pressure cuffs, a ventilation outlet in between them and a second

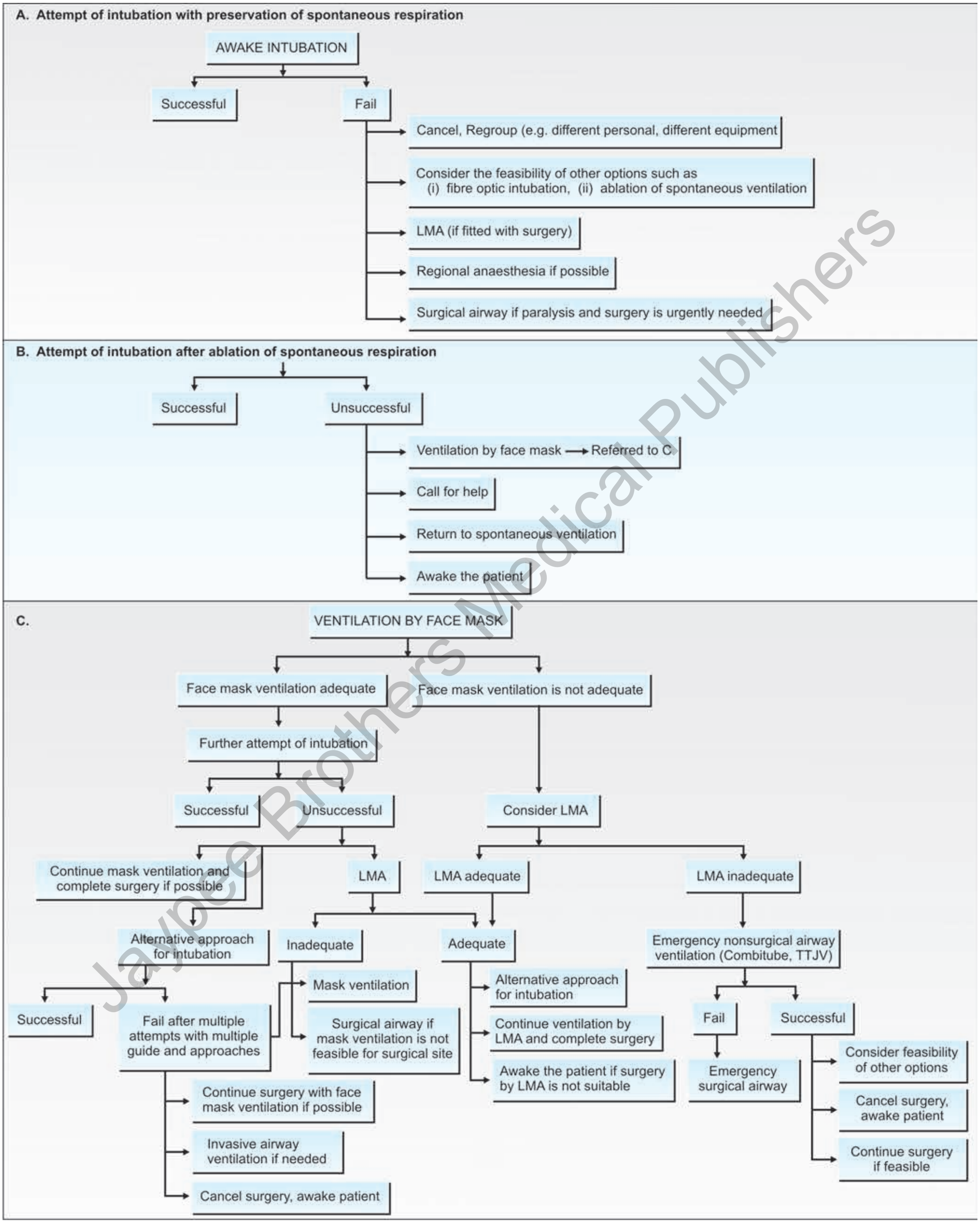


Fig. 20.43: Algorithm of airway management

tube placed posteriorly. The second tube is situated posterior to the respiratory lumen. The same inflation assembly inflates the two cuffs at a time. When correctly placed, the distal tip along with its opening and the cuff lies in the oesophagus. This effectively separates the oesophagus from the rest of the airways. Being shorter and blunder, the possibility of the oesophageal portion of the tube entering the trachea is non-existent. Laryngeal tube (LT) which is precursor to LTS has no second tube. So, it has now been replaced by LTS. Method of insertion of LTS is same as combitube. Due to the specially designed inflation line, the proximal cuff is inflated first and stabilizes the tube. Then once the proximal cuff has adjusted to the anatomy of the pharynx of the patient, the distal cuff will be inflated automatically. It is usually recommended to use a cuff pressure below 60 cm of H_2O. Like combitube there is no need to connect both the lumen alternatively for confirmation of ventilation. If ventilation is not adequate, then position of the tube can be changed by pushing it either distally or pulling it proximally according to patient size. The fine drained tube allows the insertion of a gastric tube.

Cobra Peri-laryngeal Airway (Cobra PLA)

It is a new device in the field of supraglottic airways. It consists of a tube, a cuff and a 15 mm standard adaptor for attachment with the anaesthetic machine. Distally, the tube ends at an opening with cobra head design which holds both the soft tissues and the epiglottis out of the way. Thus, it facilitates the ventilation though the slotted opening. The cuff when is inflated gently seals off the upper airway and allows improved positive pressure ventilation. Cobra PLA is usually used as an alternative to face-mask and certainly does not protect the airway from the effects of vomiting, regurgitation and aspiration.

Pharyngeal Airway Xpress (PAX)

PAX is a sterile, latex free, single use supraglottic airway device. It is used as an alternative to face-mask, LMA, Cobra PLA. The PAX supra glottic device consists of a tube, a cuff and a soft-flexible-gilled tip and is made of medical grade PVC. The tube has a standard 15 mm connector at its proximal end for attachment with anaesthetic machine. The soft, flexible, gilled tip is tapered to guide the device and help to rest the device within the cricopharyngeal recess, above the oesopharyngeal sphincter. The gilled tip is made of thermoplastic elastomer. A high volume, low pressure cuff which volume is 60 ml stabilizes the PAX within the oropharynx. Approximately, placed cuff lies just below the uvula and pushes the tongue forward for improved ventilation. An open hooded window is situated between the cuff and the gilled tip for aligned to the glottic opening. The hood is designed to lift the epiglottis forward. An anatomically curved tube can accept 7.5 mm ET tube if tracheal intubation is indicated.

Streamlined Linear Pharyngeal Airway (SLIPA)

The SLIPA is a hollow, preformed, boot-shaped airway. It is made of soft plastic and blow molded to the shape of the pressurized pharynx. As it is fitted tightly in the pharynx, no cuff is provided to seal the device in the pharynx. SLIPA is looked like a boot with 'toe bridge and heel' prominences. It is used as an inexpensive single use alternative to the LMA and to decrease the risk of aspiration if limited volume regurgitation should occur. It is available in different sizes to match the patient size (Fig. 20.43).