Evolution of Airway Devices

Vaishali Chandrashekhar Shelgaonkar, Kavita Udaykumar Adate, Archana Jeevan Shinde

ABSTRACT

Maintenance of patent airway is essential for adequate oxygenation and ventilation. Failure, even for a short period can be life-threatening. So expertise in airway management is essential in every medical speciality. Management of the airway has come a long way since the endotracheal intubation done by MacEwan (1880) to present day use of modern and sophisticated devices. The wide variety of airway armamentarium is available today. Since, time available to secure airway is short one has to be optimally prepared with proper selection of equipment, technique and participation of personnel experienced in doing it. This is a brief review of evolution of airway devices.

Keywords: Airway management, Airway devices, Routine, Advanced and sophisticated.

How to cite this article: Shelgaonkar VC, Adate KU, Shinde AJ. Evolution of Airway Devices. Int J Periop Ultrasound Appl Technol 2012;1(2):54-64.

Source of support: Nil
Conflict of interest: None declared

INTRODUCTION

Regardless of the variety of treatment sought by the patient, whether it is in operation theatre, labour suite, casualty department, critical care unit or even any scene of resuscitation, a single and important priority will always take precedence is airway management. There has been lot of awareness regarding airway and difficulty faced during its management in last decade due to increased incidence of morbidity and mortality. This has led to evolution of an array of devices which can result in better anticipation and decision-making.1

HISTORICAL ASPECT AND EVENTS

Endotracheal intubation provides an artificial conduit between the atmosphere and trachea for the purpose of alveolar gas exchange or protection of lungs from extraneous substances.2 Medical histories abound with an occasion on which the trachea was intubated via tracheostomy or larynx in an attempt to provide an airway for an asphyxiated or dead animal or human. Very few events had bearing on anaesthetic practice; otherwise it was taking place only for resuscitation specially asphyxiated neonates. Joseph O’Dwyer’s pioneering work with intubation of larynx in children with diphtheria paved the way for the acceptance of intubation in medical practice.3

Management of airway has come a long way, more than 1000 years old. The major stages of development in technique and devices are mentioned in Table 1.4-9

CLASSIFICATION

Conventionally, laryngoscopy and intubation that is visualisation of larynx or glottic opening and passage of tube collectively is known as airway management. Equipments used for this purpose are known as airway devices. They can be classified as follows:
1. Devices aiding to visualise airway or glottic opening, i.e. laryngoscopes.
2. Devices aiding to maintain patent airway.
3. Devices used when conventional aids fails.
4. Devices used to achieve airway surgically.

Devices Aiding to Visualise Airway or Glottic Opening—Laryngoscope

These are designed to examine directly the interior of larynx, specially the vocal cords for endotracheal intubation without any obstruction from tongue.

Rigid laryngoscopes have a handle which accommodates batteries for power source and a hook on blade with light
bulb in its distal third. The blade has three distinct parts; the spatula which compresses tongue in submandibular space, a flange to deviate the tongue leftward and the blunt tip which elevates the epiglottis.\textsuperscript{10}

Magill’s handle, curved and straight blade laryngoscope designed by Macintosh and Miller respectively are commonly used (Figs 1A and B).

Cardiff laryngoscope blade is blend of both the straight and curve blade, proximal 60\% is straight and distal 40\% is curves which terminate with a thickened, transverse bed to minimised mucosal damage.

Several variety of straight and curve blade with different size to suit patient of all age groups are designed for easy and successful laryngoscopes and improved visualisation of glottic opening.

**Devices Aiding to Maintain Patent Airway**

The wide variety of airway armamentarium available today, may broadly classified as follows:

1. Extraglottic or supraglottic airway devices
2. Intraglottic airway devices
3. Alternative airway devices
4. Specialized and newer airway devices. These are used to protect the airway in both elective as well as emergency situations.

**Supraglottic Airway Devices can also be classified on the Basis of Lumens Present in IT**

i. Single lumen devices—LMA classic, LMA unique, LMA flexi, ILMA, C trach, soft seal, etc. (Figs 2A to E)
ii. Double lumen devices—Proseal LMA (PLMA), combitube, laryngeal tube suction, etc. (Figs 3A to C).
iii. Triple lumen devices—Elisha airway device (Fig. 4).

**Intraglottic Airway Devices**

The airway devices which pass the glottis opening and enters trachea are labelled as intraglottic devices. They are synonymously called as endotracheal tubes.

The basic indications for endotracheal intubation are as follows:

i. Airway protection
ii. Pulmonary toileting
iii. Application of positive pressure ventilation
iv. Maintenance of adequate oxygenation

Endotracheal tubes are made up of various substances like synthetic rubber, silicone, nylon, teflon, polyethylene; red rubber and polyvinyl chloride (PVC) are most commonly used. Ideal ETT should be nontoxic, nonallergic, smooth and nonreactive to lubricants. All ETTs must confirm to American society for testing materials (ASTM) standards.

ASTM standards include aspects, such as inside (ID), outside diameter (OD), distance marking from tip, material toxicity testing, angle and direction of bevel tip, radius of curvature and size and shape of Murphy’s eye (Fig. 5).

The standard ETT tube described is not only sufficient, but also appropriate for majority of clinical situations but still for some situations specialized tubes are used.\textsuperscript{9}

They are described as follows:

a. **Spiral embedded (flexometallic or armoured) tubes** (Fig. 6A): These are metal or nylon spiral reinforced tubes covered internally or externally by rubber, PVC or silicone. They are resistant to kinking or compression, so they are used in patients undergoing head, neck and neurosurgical procedures where kinking of conventional ETT are possible.

b. **Ring-Adair Elwyn (RAE or preformed) tubes** (Fig. 6B): These tube have a preformed bend either south or north
Figs 2A to E: Single lumen supraglottic airway devices: (A) LMA classic, (B) LMA unique, (C) LMA flexible, (D) LMA fastrach, (E) LMA CTrach

Figs 3A to C: Double lumen supraglottic airway devices: (A) Proseal LMA, (B) combitubes, (C) laryngeal tubes
intended to maintain the tube’s position away from the surgical field. They are available for both nasal and orotracheal intubation and indicates to improve exposure during orofacial, neck and neurosurgical procedure.

c. **Cole tubes**: They have been recommended for resuscitation in paediatric patients but for short-term intubation. It has small bore patient end and wide bore machine end. Nasal intubation is not possible with this tube.

d. **Laser resistant tubes (Fig. 6C)**: Standard PVC tube may ignite and catches fire during the laser surgery on airway. Laserflex tube (Mallinckrodt) is an airtight tube formed from a stainless steel spiral that contains two sequential saline inflatable PVC cuffs.

e. **Parker flexs-tip tube**: This tube is designed with tip that reduces the gap between fibrescope and inside of the tube so reduces the risk of impinging on laryngeal structures during insertion of tube during fibreoptic tracheal intubation.

f. **HI-LO Evac ETT with evacuation lumen**: Used for patients who are on ventilator therapy. Due to evacuation lumen, aspiration of oropharyngeal secretion and reflux gastric contents in intubated patient is possible which helps to reduce the incidence of nosocomial infections.

g. **HI-LO Jet tracheal tube (Fig. 6D)**: It is variety of endotracheal tube designed for jet ventilation and allows accurate monitoring from the distal tip which provides most precise measurements.

h. **Microlaryngeal tracheal tube (MLT) (Fig. 6E)**: Its tube length, cuff size with smaller ID and OD helps to provide greater access to surgical field during microlaryngeal surgery.

i. **Laryngectomy tube (Fig. 6F)**: Its peculiar designed helps to keep circuit away from field and is useful during laryngeal surgery.

j. **Double lumen tubes (Fig. 6G)**: Isolation of normal lung from infective lung and haemorrhage to facilitate surgical exposure in thoracic surgeries, pulmonary surgeries or oesophagial operative procedure is important. This is possible only with double lumen tube. At the same time adequate and effective ventilation can be done.

k. **Bronchial blocking tubes (Figs 6H and I)**: These are used with conventional endotracheal intubation to separate the diseased lung from normal. It has to be advanced under guidance of fibreoptic bronchoscope. They are univent and Arndt WEBT (wire guided endobronchial tube).

l. **Combitube or oesophageal tracheal combitube (ETC)** (see Fig. 3B): These are indicated in elective or emergency situations like cardiopulmonary resuscitation, trauma and predicted and unpredicted difficult airway.

**Alternative Airway Devices**

These airway gadgets help in the maintenance of a patent airway and allow the passage of anaesthetic gases or oxygen. They are as follows:

i. **Face masks**: It allows administration of gases from breathing system without introducing into oral cavity. They are made up of clear plastic, PVC, rubber or elastomeric material and available in various sizes and shape (Fig. 7).

ii. **Airways**: It provide an unobstructed airway orally or nasally. The purpose is to lift the tongue and epiglottis away from posterior pharyngeal wall (Figs 8A and B).

**Newer Supraglottic Airway Devices**

Invention of LMA (laryngeal mask airway) by Archie Brain, 1983, has revolutionised airway management. Since, then various efficient airway devices are made and introduced into the array of airway devices which are even safer in...
Figs 6A to I: Specialised endotracheal tubes: (A) Flexometallic tubes, (B) RAE tubes, (C) Laser flex tracheal tube, (D) Hi-Lo jet tracheal tube, (E) microlaryngeal tracheal tube, (F) laryngectomy tube, (G) DLT-Robertshaw, (H) Univent tube, (I) Arndt wire-guided endobronchial blocking tube

Fig. 7: Various types of face masks

inexperienced hands due to its easy insertion techniques with added patients safety and comfort (Fig. 9D).

i. **Elisha airway device (see Fig. 4):** It is helpful for ventilation, gastric tube insertion and blind or fibreoptic aided intubation without affecting ventilation due to its triple lumen.

ii. **Cobra perilyngeal airway (see Fig. 9A):** It consists of breathing tube with wide distal end and cuff attached just proximal to wide port. It is an alternative in difficult to intubate and ventilate condition.

iii. **Streamlined pharynx airway liner (SLIPA) (Fig. 9B):** It looks like a slipper with toe, bridge and heel. Due to its peculiar shape it does not require cuff.

iv. **Laryngeal tube (see Fig. 3C):** It is multiuse, latex free, single lumen silicone tube with oropharyngeal and oesophageal low pressure cuff. It has aspiration protection too.

v. **Pharyngeal airway Xpress (Fig. 9C):** It is flexible gilled is fitted in to hypopharynx above oesophageal sphincter and high volume low pressure cuff is positioned just below the uvula to provide an effective airway seal within hypopharynx. It is suitable for spontaneous and controlled ventilation.

vi. **Glottic aperture seal airway (GASA):** It is capable of achieving a highly effective seal against larynx. It consists of curved a tubular component which ends in
elliptical foam cushion at 60° angle having flexible plastic backing. It is under prospective clinical trial.

**Devices used when Conventional Aids Fails or can not be Used**

In order to achieve successful endotracheal intubation, glottis opening has to be in sight of making three axis in one plane. This leads to inevitable distortion of upper airway anatomy, which may not be possible or not advisable in certain clinical situations.

Inability to secure the airway can lead to catastrophic results and airway mismanagement remains an important cause of mortality and morbidity in anaesthetic practice.

---

**Figs 8A and B:** Airways: (A) Nasopharyngeal airway, (B) oropharyngeal airway

**Figs 9A to D:** Newer devices: (A) Cobra perilaryngeal airway, (B) SLIPA, (C) Pharyngeal airway Xpress, (D) LMA supreme
Conventional rigid direct laryngoscopy aids tracheal intubation in 98.1% cases but even in most experienced hands it may lead to difficulty. So, there must be alternative techniques and equipments for these 1.9% cases.

The options available in such clinical conditions are as follows:
1. Flexible fibreoptic intubation
2. Intubating LMA (Fastrach™) assisted intubation
3. Lightwand (Trachlight™) aided intubation
4. Indirect fibreoptic laryngoscope aided intubation (Bullard™, Upsher scope™ or Wu-scope)
5. Gum elastic bougie aided intubation
6. Retromolar scope guided intubation (Bonfils)
7. C-arm guided endotracheal intubation
8. Supraglottic airway guided intubation

**Fibreoptic Intubation**

The use of fibreoptic instruments to help in airway management is a relatively recent event, but it was as early as 1967, when Dr P Murphy was the first to use a fibreoptic instrument for the control of airway for a nasal intubation under general anaesthesia for a patient with advance still’s disease using choledoscope.

The fibreoptic scope is a flexible instrument which is capable of transmitting an image from the distal tip to the proximal end. The motion of the tip of fibrescope can be controlled which enables the operator to direct the scope in any desired fashion (Fig. 10). The combined characteristics of controllability, flexibility and image transmission permit anaesthesiologist to employ the fibrescope as an aid to tracheal intubation.

**Technique of fibreoptic intubation:**

- Nasal route
- Oral route

Nasal route is easier and has higher success rate. This approach is straight route to larynx and trachea and stability of endotracheal tube is better once secured in position.

Nasal approach is used in dental, maxillofacial procedure and in temporomandibular ankylosis.

Oral route is comparatively difficult because of greater angle between the oral cavity and laryngeal inlet and difficult to keep insertion tube in midline. Oral fibreoptic intubating aids like Ovassipian’s airway, Berman’s airway or bite block can be used to aid intubation.

Fibreoptic intubation can be facilitated under local or general anaesthesia. Nasal or oral, spray or nebulisation, cricothyroid puncture or transtracheal puncture and local spray and internal laryngeal nerve blocks are commonly used methods for awake intubation under local anaesthesia. Asleep intubation can be performed under general anaesthesia with or without muscle relaxants techniques.

**Intubating LMA—Fastrach-Assisted Intubation**

Classic LMA was not ideally suited to aid tracheal intubation, so a new intubating LMA was introduced in 1997 which consist of three parts, ILMA itself, tracheal tube and stabilising rod.

It is rigid, anatomically curved airway tube made up of stainless steel with a standard 15 mm connector. The tube is wide and short enough to accommodate ETT and ensure its passage beyond vocal cord. It has a single flap, the epiglottis elevating bar. A rigid handle attached to the tube facilitate one handed insertion, removal and adjustment of devices position, so as to direct aperture directly opposing larynx (see Fig. 2D). It is available in three sizes (3, 4 and 5). It is also possible to connect ILMA directly to the breathing circuit.

LMA C’ trach is the modification of the blind on blind technique of LMA fastrach with integrated fibreoptics.
(see Fig. 2E). Due to which a direct view of larynx with real time visualisation of the tracheal tube passing through vocal cords is possible.\textsuperscript{19-22}

LMA proseal is the most complex of the specialised LMA devices with a improved ventilatory characteristics and offered protection against regurgitation and gastric insufflations. Indications are similar to classic LMA but preferable whenever a better seal, better airway protection and access to the gastrointestinal tract are required (see Fig. 3A).

**Lightwand (Trachlight\textsuperscript{TM}) Aided Intubation\textsuperscript{23,24}**

It is an alternative semiblind technique of endotracheal intubation where transillumination of the soft tissue of the neck using lightwand is possible (Fig. 11).

The Trachlight consist of three parts as follows:

a. A reusable handle with alkaline batteries
b. A flexible wand transmitting light
c. A stiff retractable stylet shaped in field—hockey stick

It is easy to use, inexpensive and useful in difficult airway. It is useful in poor or irregular dentition, cervical spine instability and limited mouth opening. It is less traumatic and presence of secretion or blood is of no hindrance while using this instrument. Shikani optical styllet system (SOS) and flexible airway scope tool (FAST) is a newer lighted styllet.

**Indirect Fibreoptic Laryngoscope Aided Intubation\textsuperscript{25,26}**

*Bullard laryngoscope (BL):* It is a valuable aid for the management of predicted as well as unanticipated difficult tracheal intubation.

BL is a curved rigid fibreoptic intubation device with conventional laryngoscope battery, handle with light source and unique anatomically shaped blade. The laryngoscope has fibreoptic bundle for both airway illumination and transmission of the view from the distal tip to the proximally located eye piece. BL comes in three sizes, paediatric, paediatric long and adult. It includes 3.7 mm working channel which permits suctioning and administration of oxygen and local anaesthetics (Fig. 12A).

Bullard elite with detachable metal styllet is the most recent version.

*The upsher laryngoscope:*\textsuperscript{27} It is a steel C shaped laryngoscope with an integrated fibreoptic system and light channel for viewing. Its power handle is capable of attaching any light source (Fig. 12B).

**Wuscope:** The design is similar to bullard except the blade portion has a three detachable stainless steel ports that require assembling. For better view of object it has a very advanced optic system (Fig. 12C).

**AirTraq optical laryngoscope:** It is a new intubation aid for routine as well as difficult airways.

The curvature of blade and well-design optical components helps in visualisation of the glottis without the need for aligning three airway axes. The curved blade has two side by side channels, one as a conduit for ETT and other channel contains series of lens, prism and mirror that transfer the image from illuminating tip to a proximal view finder. The optics is so arranged that one gets a good quality view of glottis, adjacent structure as well as the tip of ETT.

*Indications:*
i. Predicted difficult intubation
ii. Failed intubation scenario
iii. Unstable cervical spine

*Contraindications:*
i. Blood and secretion in the upper airway
ii. Distorted upper airway anatomy
iii. Foreign body in upper airway

*Advantages:*
i. Sturdy as compared to flexible fibrescope
ii. Can control soft tissue better
iii. Allows better management of secretions
iv. Portable and less costlier than flexible fibrescope

*Disadvantages:*
i. Can damage teeth and soft tissue
ii. Nonmalleable metal

**Gum Elastic Bougie Aided Intubation (GEBI)\textsuperscript{28}**

GEBI is a standard technique for intubation in difficult airway management. It can be used blindly or along with indirect laryngoscopy with a laryngeal mirror or even with LMA.

Two types of GEB are available. One is straight while other is angled distally. Straight GEB is longer (70 cm), with 15 French diameter is basically tube exchanger. It is not recommended for difficult airway manoeuvres. Angled GEB is ideal for endotracheal intubation in difficult airway. It is 60 cm long with 15 French diameters. The angulation at its distal end is approximately 5 cm from tip and permits the tube to be steered around obstacle when GEB’s shaft is rotated (Fig. 12D).

The Augustine guide is a variant of GEB for aiding blind orotracheal intubation in adult patients. It can be used for
intubation in neutral position. Thus, useful in variety of location, such as field ambulance, etc.

**Retromolar Scope Guided Intubation (Bonfils)**

Akidikmen SA in 1966 was the first person to describe a paraglossal technique of intubation which was refined and named retromolor technique by Bonfils P in 1983.

Bonfils retromolar intubation fibrescope is 5.0 mm optical, distally curved stylet which accommodates 6.00 mm ID or longer ETT. This equipment has a fixed distal curved of 40p. It is available with or without 1.2 mm working channel. It has an adapter for fixing the ETT and permits continuous oxygen insufflations during procedure. It is provided with a movable eye piece that permits ergonomics work during intubation. It is also available with wide modules that permit image display without the use of separate camera (Fig.12E).

Brambrink intubation endoscope (manufactured by Karl Storz) is similar to Bonfil’s. It incorporates high resolution semiflexible fibreoptic stylet that has 40p distal curvature and 40 times magnification.

**Retrograde Intubation (RI)**

RI technique is an accepted mode of establishing airway in difficult airway scenario.

The first stage includes retrograde passage of a catheter or a long guide wire from larynx to the mouth or nose. The second stage consists of railroading of ETT over guide wire or catheter (Fig. 12F).

Though readymade sets are available 18 gauge epidural catheter or ‘J’ tipped vascular guide wire can serve the purpose of catheter. A hybrid technique of lightwand guided RI is also reported which increase the speed and success rate of correct intubation.

**C-arm Guided Endotracheal Intubation**

C-arm guided endotracheal intubation is also an alternative in difficult intubation but in presence of various other choices it is not very practical.

**Supraglottic Airway Guided Intubation**

Supraglottic airway devices like C Trach or intubating LMA, cobra PLA, pharyngeal airway Xpress are useful an intubating devices.

---

**Figs 12A to F:** Indirect fibreoptic scope: (A) Bullard laryngoscope, (B) Upsher laryngoscope, (C) Wu scope, (D) Retrograde wire intubation, (E) Bonfils scope, (F) Gum elastic bougie
Devices or Technique used to Achieve Airway Surgically

In airway management, to achieve surgical airway is the ultimate choice when all other techniques fails or it is not at all possible to achieve conventionally or nonconventionally, e.g. large oropharyngeal tumour.

This can be done electively or in emergency life-saving situations.

**Tracheostomy**

Italian surgeon Sanctorium was probably the first to describe the technique of surgical tracheoctomy in the 16th century. But it has appeared as pictures date back in Rigvedas.

Chevalier Jackson in 1909 was the first person to define surgical tracheostomy. It is a procedure where the incision is made over the trachea followed by insertion of a tube so as to maintain the patency of the opening temporarily or permanently.

Tracheostomy tubes are available in various sizes and styles. They can be either metal or plastic. Metal tube are constructed of silver or stainless steel, but not used nowadays because of its rigid structure and being not cuffed.

PVC or silicone tubes both cuff or noncuff are used commonly as per patients need. As they are nontraumatic, confirms to patients tracheal anatomy and centering the distal tip in trachea (Fig. 13A).

While selecting the size of tube, the ID (internal diameter), OD (outer diameter), its curvature, proximal and distal length must be considered.

**Fenestrated tracheostomy tubes:** It is similar in construction to standard tracheostomy tubes with the addition of an opening in the posterior portion of the tube above the cuff with inner cannula removed, cuff deflated, the tracheostomy air passage occluded, the patient can inhale and exhale through fenestrations. This allows assessment of patient’s ability to breathe through the normal oral/nasal route.

**Mini-tracheostomy tubes:** It is small bore (4.0 mm ID) cannula inserted in to trachea through the cricothyroid membrane or tracheal stoma after decannulation. It can be used for oxygenation or bronchial lavage.

**Percutaneous Dilational Tracheostomy (PCT)**

First modern PCT was reported by Sheldon in 1955, but Ciaglia in 1985 described a new wire guided technique for PCT. It has become preferred choice of tracheostomy in ICU.

**REFERENCES**


ABOUT THE AUTHORS

Vaishali Chandrashekhar Shelgaonkar (Corresponding Author)
Associate Professor, Department of Anaesthesiology, Indira Gandhi Government Medical College, Nagpur, Maharashtra, India
e-mail: vas717@yahoo.com

Kavita Udaykumar Adate
Assistant Professor, Department of Anaesthesiology, Smt Kashibai Navale Medical College and General Hospital, Pune, Maharashtra, India

Archana Jeevan Shinde
Senior Resident, Department of Anaesthesiology, Smt Kashibai Navale Medical College and General Hospital, Pune, Maharashtra, India