Review article

Difficult airway in intensive care unit

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Abstract

Airway management in critically ill patients is often difficult and is associated with complications. Knowledge of airway anatomy, its change during laryngoscopy and physiology of oxygen transport is essential for predicting difficult airway and in planning the management. Optimal assessment of the airway anatomy to predict difficulty, formulating a plan of action, and an alternate plan, assembling the required equipment and personnel, keeping the difficult airway trolley ready, preparation of the patient by preoxygenation and proper positioning are some of the measures to decrease complications. Adequate training to develop cognitive and procedural skill for managing difficult airway is very important. All physicians involved in airway management should update their skills by involving in simulation excercises and workshops.

Keywords: Airway in critically ill, difficult airway, hypoxia.

Introduction

Airway management in the intensive care unit (ICU) is more challenging than in the Operating room (OR). The cause for this could be due to the ongoing critical illness in patients who often have associated faciomaxillary and cervical spine injuries and who may be at increased risk of aspiration. The limited availability of equipment and physician's expertise in airway management also contribute to the challenge.[1]

Preparing the patient and a plan for airway management and good communication between the members of the team who possess adequate skills to manage the airway help to overcome these challenges.

Difficult airway in ICU

The incidence of difficult airway is approximately twice as high as in the OR.[1] Shwartz and colleagues reported an incidence of 12% in 297 patients requiring emergency intubation in the ICU.[2] Similarly, Martin *et al* reported an incidence of 10% in 3423 emergency intubations in the ICU.[3] The incidence of other complications such as severe hypotension, hypoxaemia, aspiration, oesophageal intubation and cardiac arrest were also high.[1-3]

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Lessons from audits

Fourth National Audit Project (NAP4) conducted by the Royal College of Anaesthetists and Difficult Airway Society in the United Kingdom (UK) reported the complications due to airway management.[4] They found that deaths and severe hypoxic brain damage were more frequent in the ICU. Various factors contributed to these complications and they could be divided into patient, equipment and operator related. Patients receiving oxygen supplementation, noninvasive or invasive ventilator support, renal replacement therapies, vasoactive medications, those with multiorgan failure and body mass index (BMI) > 30 kg/m^2 were at increased risk for complications. Equipment related factors such as nonavailability of an organised difficult airway trolley, capnography and tracheostomy tube of appropriate size/type also contributed to complications. Other factors were delay in formulating a plan for airway management,

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extubation and postextubation care. Lack of sufficient experience in airway management or absence of an experienced anaesthesiologist were the operator-related factors responsible for the complications.

The NAP4 team suggested certain preventive measures to avoid complications associated with airway management. The recommendations were for the operator competence, equipment required, and planning and organisation. The operators must be sufficiently trained in airway management with special emphasis on use of difficult airway algorithms capnography and in achieving surgical access to airway. A preprocedure checklist including management details on drugs, equipment, personnel required and alternate plan if difficulty is anticipated should be prepared in each hospital and implemented before every airway procedure. The primary plan, backup plan in case of difficulty and the personnel notified for help in case of difficulty should be documented. Fibreoptic bronchoscope and an organised difficult airway trolley should be kept accessible before the procedure.

Review of relevant anatomy

Airway anatomy and physiology of oxygen transport forms the basis for airway management including difficult airway. Thus understanding the relevant anatomy and physiology is vital for appropriate management. Important points of anatomy and pathophysiology in the critically ill patient will be reviewed here.

Many studies have assessed the anatomy of the airway and its dynamic nature during manipulation. The old idea that alignment of oral, pharyngeal and laryngeal axis during sniffing position and laryngoscopy facilitates intubation is being challenged (*Figure 1, 2*).[5] Greenland and colleagues[6] have proposed a new model where they described the airway with the help of two curves *viz.* primary curve –the oropharyngeal curve (which extends from the mouth opening along the tongue to the pharynx) and secondary curve– the pharyngo-glotto-tracheal curve (which extends from hypopharynx through the glottis into the trachea *(Figure 3)*. The tangent drawn at the point where the two curves meet (called the point of inflection) defines the axis of the laryngeal vestibule. A successful direct laryngoscopy and intubation requires alignment of the two curves and the alignment of the axis of the laryngeal vestibule and visual axis. Flexion at the lower cervical joints flattens the secondary curve, and extension at the upper cervical joint flattens the primary curve. Laryngoscopy pushes the tongue into the submandibular space and puts tension on the hyoepiglottic ligament. This displaces the tongue and the epiglottis from the line of vision, flattens the primary curve further and aligns the visual axis with that of the laryngeal vestibule.

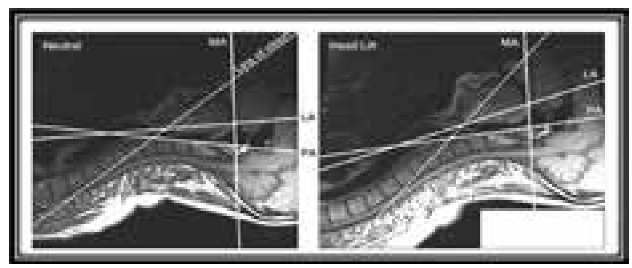

Figure 1: Pharyngeal (PA), laryngeal (LA) and mouth (MA) axes superimposed on MRI images (sagittal section) of head and neck region with head in neutral and lifted position (neck flexed). Dotted line-the line of vision.[5]

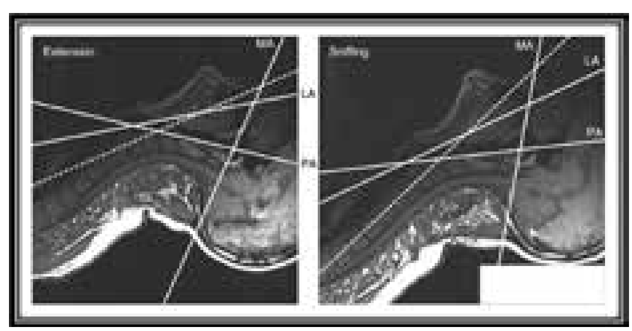

Figure 2: Pharyngeal (PA), laryngeal (LA) and mouth (MA) axes superimposed on MRI images (sagittal section) of head and neck region with head in extension and sniffing position. Dotted line-the line of vision.[5]

From this model we can understand that any variation in the anatomy which prevents adequate flexion and extension of the spine and anterior displacement of the jaw and related structures during laryngoscopy will lead to difficulty in visualisation of the vocal cords which in turn will lead to difficulty in intubation.

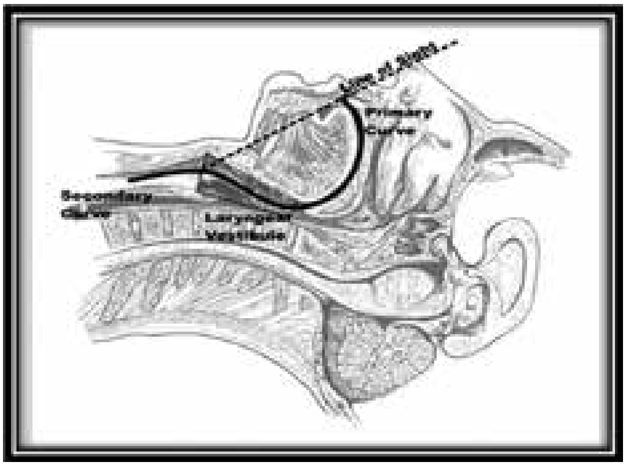

Figure 3: Figure showing the primary curve, secondary curve, laryngeal vestibule and the line of vision.[5]

Assessment of the airway can also be based on this model.[7] The airway can be divided into three columns for the purpose of assessment *viz.* anterior, middle and posterior. The posterior column refers to the cervical spine which is assessed by its range of motion. The middle column consists of the air passage from the mouth to the trachea. Its assessment involves looking for any lesion which compromises the air passage or causes signs of obstruction. The anterior column is defined as an imaginary pyramidal space formed with its apices at the two temporomandibular joints (TMJ) and the midpoint of hyoid bone. Assessment of this column involves looking for volume and compliance of the submandibular space and tethering of any of the three apices of the pyramid *viz.* the two TMJ and hyoid bone and its attachments.

Physiology and pathophysiology

The goal of airway management is to deliver oxygen to the alveoli and further into the blood and to the metabolising tissues. The oxygen delivery to the alveoli can be accomplished by passive insufflation, mass movement of oxygen and positive pressure ventilation. The transfer of oxygen further depends on the distribution of ventilation and ventilation-perfusion ($\dot{V}/\dot{Q}$) matching, binding of oxygen to haemoglobin, cardiac output, distribution of the blood flow and release of oxygen to the tissues.[8] Many of these processes are altered in critically ill patients, for example, $\dot{V}/\dot{Q}$ matching and diffusion of oxygen is altered in patients with pneumonia, atelectasis and ARDS, cardiac output is decreased in patients with shock. Also anaesthetic drugs and muscle relaxants adds to the $\dot{V}/\dot{Q}$ mismatch and haemodynamic derangement. Thus, airway management in critically ill patients is challenging, gives the operator less time for intervention and can lead to grave complications.

Goals of airway management

Alveolar oxygen delivery is the primary goal of airway management which involves maintenance of airway patency and delivery of oxygen. In addition, the critical care physician has other goals to achieve which are secondary, such as airway protection, airway security, carbon dioxide (CO_2) elimination, applying PEEP and regulating the inspiratory time. When faced with a difficult airway situation, maintaining airway patency and alveolar oxygen delivery become the prime priority and some of the secondary goals such as airway protection and security, CO_2 elimination may have to be compromised. These priorities should be made clear mentally before proceeding with the intervention and subsequent decisions should be in alignment with our priorities.

Assessment of the airway

Understanding the anatomy and its changes during laryngoscopy forms the basis for airway assessment and predicting difficulty. The patient should be assessed for difficulty in performing any of the following procedures – mask ventilation, intubation, fibreoptic bronchoscopy, videolaryngoscopy, supraglottic airway device insertion and surgical access to airway.

Difficult mask ventilation (DMV) has been defined as the inability of a trained anaesthetist to maintain the oxygen saturation greater than 90% using a face mask for ventilation and 100% inspired oxygen, provided that the pre-ventilation oxygen saturation level was within the normal range. Five criteria are recognised as independent factors for a DMV (age >55, BMI >26 kg/m^2, beard, lack of teeth, history of snoring), with the presence of two indicating high likelihood of DMV (sensitivity, 0.72; specificity, 0.73).[9]

Difficult laryngoscopy is defined as inability to visualise even a portion of the vocal cords after multiple attempts and difficult intubation is defined as one which requires multiple attempts for success.[1] Difficult laryngoscopy can be assessed with the help of the three column approach as defined by Greenland and others.[7]

The posterior column can be assessed by looking for flexion at the lower cervical joint and extension at atlanto-occipital joint. The angle between extremes of flexion and extension should be 90^0 and a lesser angle leads to a difficulty in laryngoscopy and intubation. The qualitative assessment of the length and circumference of the neck also predicts restriction of neck mobility.

The middle column which consists of the air column is assessed by looking for any difficulty in breathing, noisy breathing, examination of the neck to look for any masses compressing the trachea and larynx. In case of suspicion further investigation with a nasopharyngeal endoscopy and indirect or videolaryngoscopy can be performed. Presence of any lesion causing obstruction of the middle column should be assessed for its severity and usually intubation is performed in awake state.

The anterior column consists of the imaginary pyramid with its three apices situated at the two TMJ and at the midpoint of hyoid bone. Assessment of this column consists of the assessment of the volume and compliance of the submandibular space and assessment of movement at the two TMJ and of the hyoid bone and its attachments. The volume of the submandibular space is assessed indirectly with the help of modified Mallampati grade and the mentohyoid distance. Also, crowded teeth anteriorly on the mandible, narrow anterior mandible and high arched palate also predict a relatively narrow submandibular space. Mobility of the TMJ is assessed by the ability to open the mouth (< 6 cm is associated with difficulty) and to perform the upper lip bite test or to protract the mandible. Presence of protruding incisors and the position of the mandible in relation to the maxilla affect the mouth opening. Calcification of stylohyoid ligament tethers the hyoid bone *i.e.*, the third apex of the pyramid and restricts the displacement of the hyoid bone and tensing of the hyoepiglottic ligament during laryngoscopy.

Christie and others recapitulated several clinical indicators to predict difficult laryngoscopy and intubation which are mentioned in the table below.

Table 1: Predictors of difficult laryngoscopy and intubation.[10]

Airway exam component	Nonreassuring finding
Length of upper incisors	Relatively long
Relation of maxillary and mandibular incisors during normal jaw closure	Prominent overbite (maxillary incisors anterior)
Relation of maxillary and mandibular incisors during voluntary protrusion	Patient cannot bring mandibular incisors anterior to maxillary incisors
Interincisor distance	<3 cm
Visibility of uvula	Not visible when tongue is protruded with patient in sitting position
Shape of palate	Highly arched or very narrow
Thyromental distance	Less than three ordinary finger breadths
Length of neck	Short
Thickness of neck	Thick
Range of motion of neck	Patient cannot touch tip of chin to chest or cannot extend neck

Another quick method for airway assessment which is useful especially in the emergency department is the LEMON method.[11] The criteria included are:

L - Look externally. Look at the patient externally for characteristics that are known to cause difficult laryngoscopy, intubation or ventilation (long incisors, beard, large tongue and facial trauma)

E - Evaluate the 3-3-2 rule. The distance between the patient's incisor teeth should be at least 3 finger breadths (3), the distance between the hyoid bone and the chin should be at least 3 finger breadths (3), and the distance between the thyroid notch and the floor of the mouth should be at least 2 finger breadths (2).

M - Mallampati The hypopharynx should be visualised adequately.

O - Obstruction. Any condition that can cause obstruction of the airway will make laryngoscopy and ventilation difficult. Such conditions are epiglottitis, peritonsillar abscesses and trauma.

N - Neck mobility. It can be assessed easily by getting the patient to place their chin down onto their chest and then to extend their neck so they are looking towards the ceiling.

The LEMON criteria has been assessed for its ability to predict intubation difficulty in the emergency department. In a study by Reed MJ *et al*, the authors proposed a score to predict difficult intubation using the LEMON criteria. They gave 1 point to each of the unfavourable criteria and found that a median score of 2 was a good predictor of difficulty.[12]

Similarly, El-Ganzouri and associates proposed a multivariate risk index called Airway Score (AS). They also recommended the management based on the AS as described below.

AS of 0: Proceed with routine management

AS of 1 to 2 points: Proceed with routine management, check availability of fibreoptic laryngoscope, and prepare a special plan B.

AS of 3 to 4 points: Have the fibreoptic scope on standby at bedside, and call for help; prepare for asleep or awake fibreoptic intubation.

AS > 5 points: Perform awake intubation (most practitioners prefer awake fibreoptic intubation)

It can be clearly seen that difficult airway predictor scores which incorporate tests to assess all the three columns of the airway are the ones which have high sensitivity and specificity. Although none of the scoring systems show good statistical probability to predict difficulty but they certainly provide a warning so that an alternate plan can be ready and additional help can be summoned.

***Table 2*: Airway score.**[13]

S.No	ASSESSMENT	0 POINTS	1 POINT	2 POINTS
1	INTERINCISOR GAP	> 4 cm	< 4 cm	Cannot open mouth
2	MALLAMPATI CLASS	CLASS I	CLASS II	CLASS III
3	HEAD/NECK MOVEMENT	> 90 degrees	90 degrees	< 90 degrees
4	TEETH	Prognathic or edentulous	Can approximate teeth only	Cannot approximate teeth
5	THYROMENTAL DISTANCE	> 6.5 cm	6 – 6.5 cm	< 6 cm
6	BODY WEIGHT	< 90 kg	90-110 kg	> 110 kg
7	HISTORY OF DIFFICULT INTUBATION	None	Questionable	Definite
	Airway score (AS) Range – 0 -14	0	7	14

Predictors of difficult videolaryngoscopy/ fibreoptic laryngoscopy

Cormack-Lehane Grade 3 or 4 view at direct laryngoscopy, abnormal neck anatomy, including radiation changes, neck scar, neck pathology, and thick neck, limited mandibular protrusion, decreased sternothyroid distance are some of the factors which can lead to difficulty in videolaryngoscopy and fibreoptic laryngoscopy.

Difficult supraglottic airway device insertion

Reduced mouth opening, supra- or extraglottic pathology (*e.g.*, neck radiation, lingual tonsillar hypertrophy), glottic and subglottic pathology, fixed cervical spine flexion deformity, applied cricoid pressure, male sex, increased body mass index, poor dentition are the factors which have been found to be associated with difficulty in supraglottic airway (SGA) insertion.

Difficult surgical access

Female sex, age < 8 years, thick/obese neck, displaced airway, overlying pathology (*e.g.*, inflammation, induration, radiation, tumour), fixed cervical spine flexion deformity are factors associated with difficult surgical access. If difficulty is anticipated, the site for cricothyroidotomy should be marked or a cannula should be inserted before proceeding for the primary plan of management.

Management

All patients in the critical care unit should be treated as difficult airway and appropriate preparation and planning should be done prior to the procedure. Preparedness is the key to success and in minimising complications. Preparation involves proper positioning and preoxygenating the patient, arranging appropriate drugs and equipment and availability of help in case of difficulty. Pre-procedure checklists are useful to eliminate human errors in planning. One such checklist is presented here.

Table 3: Emergency intubation checklist

Prepare patient	**Prepare equipment**	**Prepare team**	**Prepare for difficulty**
1. Is preoxygenation optimal? • ETO_2 >90% • Consider CPAP	1. What monitoring is applied? • Capnography • SpO_2 probe • Blood pressure • ECG	1. Allocate roles Team leader • First intubator • Second intubator • Cricoid pressure • Intubator assistant • Drugs • MILS • Rescue airway	1. If the airway is difficult could we wake up the patient?
2. Is patient's position optimal? • Consider head up	2. What equipment is available and checked? • Self-inflating bag • Suction • 2 tracheal tubes • 2 laryngoscopes • Bougie • Supraglottic airway	2. How do we contact further help if required?	2. What is the plan for difficulty? • Plan A - RSI • Plan B - *e.g.,* BMV • Plan C - *e.g.,* PLMA • Plan D – *e.g.,* front of neck
3. Can patient's condition be optimised any further before intubation?	3. Do you have all drugs required? • Consider ketamine • Relaxants • Vasopressors		3. Where is the relevant equipment including alternate airway? • Do not start till available
4. How will anaesthesia be maintained ?			4. Are any specific complications anticipated?

Equipment

The difficult airway trolley or cart which is a portable trolley to hold various airway equipment is popular in the operation theatre. The intensive care unit should also have such a trolley to manage difficult airway. The trolley should be well organised and the contents of each drawer should as per the sequence of plan of management. The operators must be familiar with the organisation of the trolley. The trolley should be labelled appropriately, checked regularly and before each use and the used equipment should be replaced immediately after use. The American society of Anesthesiologists and the Difficult Airway Society, UK have suggested contents for such a trolley.

Table 4: Suggestions by DAS.[15]

Recommended equipment for routine airway management	**Recommended equipment for management of unanticipated difficult intubation**
Facemasks	DAS guidelines algorithm flowcharts
Oropharyngeal airways: three sizes	Equipment list for re-stocking
Nasopharyngeal airways: three sizes	At least one alternative blade (*e.g.,* straight, McCoy)
Laryngeal Mask Airways	Intubating Laryngeal Mask Airway (ILMA) set (size 3, 4, 5 with dedicated tubes and pusher)
Tracheal tubes in a range of sizes	Tracheal tubes – reinforced and microlaryngeal size 5 & 6 mm
Two working laryngoscope handles	Flexible fibreoptic laryngoscope
Macintosh blades: Sizes 3 & 4	Proseal Laryngeal Mask Airway
Tracheal tube introducer ("gum-elastic" bougie)	Cricothyroid cannula (*e.g.,* Ravussin) with High pressure jet ventilation system (*e.g.,* Manujet)
Malleable stylet	Large bore cricothyroid cannula (*e.g.,* Quicktrach)
Magill forceps	Surgical cricothyroidotomy kit (Scalpel with no.20 blade, tracheal hook, 6/7 mm tracheal and tracheostomy tubes)
	• Bullard type laryngoscope • Trachlight • Aintree Intubation Catheter • Combitube

***Table 5*: Suggestions by ASA.[14]**

Rigid laryngoscope blades – other than routinely used, may include rigid fibreoptic laryngoscope
Videolaryngoscope
Tracheal tubes of assorted sizes
Tracheal tube guides - Semirigid stylets, ventilating tube changer, light wands, forceps to manipulate tip of tracheal tube
Supraglottic airways- LMA or ILMA of various sizes
Flexible fibreoptic intubating equipment
Equipment for emergency invasive airway access
Exhaled carbon dioxide detector

Personnel

Adequate number of people should be available for helping the operator during airway management. The primary plan and alternate plan should communicated to all the members of the team and each member should be assigned with clear roles such as administration of drugs, monitoring vital signs and assisting the operator with airway instrumentation, performing manoeuvres such as cricoid pressure, manual inline stabilisation, *etc*. A senior staff, usually an anaesthetist should be informed when a difficult airway is anticipated. Additional help if required should be kept informed.

Preoxygenation and positioning

Preoxygenation fills the body stores with 100% oxygen and thus provides oxygen to the body while the patient is apnoeic during airway instrumentation till ventilation or spontaneous breathing is resumed. This can be performed by providing 100% oxygen *via* a face mask for 3 minutes while the patient takes normal breaths or for 30 seconds while the patient takes deep breaths. Applying PEEP of 10 cm H_2O is another method to improve the lung oxygen stores. Administering oxygen *via* nasal cannula during apnoea period allows mass movement of oxygen and helps in preventing desturation.

Weingart *et al* have suggested a simple protocol for preoxygenation in patients with different pre-procedure SpO_2. The authors suggested a combination of different techniques to prevent desaturation during emergency intubation.[16]

Head elevated position is beneficial in all patients and if it is not possible due to cervical spine injuries, a reverse Trendelenberg position can be given.

Patients with SpO_2 96-100% can be managed with preoxygenation with 100% O_2 for 3 minutes without any other method. Patients with SpO_2 91-95% or patients receiving oxygen with high FiO_2 are best benefited by preoxygenation with 100% O_2 for 3 minutes along with a PEEP of 10 cm of H_2O and oxygen insufflation by a nasal cannula during the apnoea period. Patients with $SpO_2 < 90\%$ should receive all the measures as in the previous subset of patients and should also receive positive pressure breaths during the apnoea period when the muscle relaxant achieves its peak action.

Sedation and analgesia

Opioids such as fentanyl and remifentanil, short acting benzodiazepines such as midazolam and intravenous anaesthetics such as ketamine, propofol, dexmedetomidine and etomidate have all been used alone and in combinations to facilitate laryngoscopy and intubation.[1] Ketamine and etomidate are usually the induction agents of choice in critically ill patients. Succinyl choline and rocuronium are the most popular muscle relaxants used to provide optimal intubating conditions.[1]

Patient's cooperation is very important for success of awake intubation. Hence, they should be counselled appropriately. Anxiolytic drugs such as midazolam or dexmedetomidine can be useful in anxious patients. Regional anaesthesia can be very useful to facilitate awake intubation. The ethmoidal nerves in the nasal cavity can be blocked by packing with pledgets soaked in local anaesthetic solution, the pharynx can be anaesthetised with local anaesthetic in the form of aerosol, gargle or spray. The larynx and trachea can be anaesthetised with superior laryngeal nerve blocks and the transtracheal block.[17]

Rapid sequence induction

Rapid sequence induction is a standard procedure for emergency intubation which involves a series of steps to intubate the trachea and secure the airway, simultaneously preventing aspiration and desaturation. The steps involve positioning with head elevation, preoxygenation, rapid administration of anaesthetic agent, paralytic agent and application of cricoid pressure which is followed by a period of apnoea till the muscle relaxant achieves peak effect followed by tracheal intubation.[18] Many modifications for this technique have been suggested to cater to different clinical situations. Use of intravenous lignocaine, mask ventilation during the apnoea period, releasing the cricoid pressure, modifying the dose and rate of administration of the anaesthetic agents and paralysing agents are the modifications done to suit patients with head injury, septic shock, difficult airway, *etc.*[18] Rapid sequence induction technique is the technique of choice for emergency intubations as its success rate is better than that with other techniques.[19]

Anticipated difficult airway

Various techniques and laryngoscopes have been used for different clinical situations and no single technique is found to be the best in all situations. In every case the primary plan (or PLAN A) for instrumentation and alternative plans (B, C and D) in case the primary plan fails, are made. Appropriate help and equipment are arranged and kept ready. The three column model for airway assessment by Greenland *et al*, can also be used to choose the appropriate instrument for laryngoscopy and intubation.[20] Airway management of patients with anterior column problems excluding severe deformity such as TMJ ankyloses should be attempted with Macintosh laryngoscope with a bougie assisted intubation as the primary plan. Alternate plans for such cases should be

A. Use of a Miller's laryngoscope in the patient with neck extension alone and the operator in sitting position
B. Inserting a classic LMA and then an Aintree intubating catheter (AIC) over a fibreoptic bronchoscope (FOB) through it. Then rail road the endortracheal tube (ETT) over the AIC
C. Using a videolaryngoscope such as Airtraq or Glidescope.

In patients with posterior column problems, the primary plan can be to use a Macintosh laryngoscope and do a bougie assisted intubation. The alternate plan could be

A. to use a McCoy laryngoscope,
B. a video laryngoscope and
C. inserting a classic LMA and then an AIC over FOB and then the ETT over the AIC.

Patients with middle column problems have some soft tissue lesion which obstructs the air passage and the use of anaesthetic agents can worsen this obstruction. Hence, intubation in an awake and spontaneously breathing state is always desirable. The primary plan can be to provide local anaesthesia and attempt direct laryngoscopy with the Macintosh laryngoscope and the alternate plans can be

A. to use a video laryngoscope,
B. FOB guided intubation
C. classic LMA insertion, then AIC over FOB with intubation over the AIC.

Unanticipated difficult airway

An unanticipated difficult airway can put the operator under sudden stress which may affect his/her decision-making adversely and may delay intervention putting the patient at risk of grave complications.

Having a mental plan as to what steps to take in such a situation and executing such a plan in simulated difficult airway situations helps the operator to remain calm and take quick decisions when faced with real difficulty. The plan to deal with such situations should be simple, easy to remember and execute. It is also very important to communicate to the team members and assign clear roles to each one of them, at the same time be open to suggestions from them.

In a situation of unanticipated difficult airway, the primary goal of alveolar oxygenation takes priority over the secondary goals such as airway protection and controlling the ventilation.

Airway patency can be achieved nonsurgically with bag and mask (BM), supraglottic airway (SGA) device and endotracheal tube (ETT), and surgically with needle or surgical cricothyroidotomy.

A simple scheme to maintain alveolar oxygen transfer and secure the patency as soon as possible in presented below.[21]

Step 1 – Optimal attempt to achieve airway patency nonsurgically (BM, SGA, ETT).
Step 2 – Surgical airway in case of failure.
Step 3 – Optimize SpO_2, mobilise resources, consider other options.
Step 4 – Definitive airway.

Optimal attempt to secure airway patency nonsurgically

All the three methods to secure airway patency *i.e.*, BM, SGA and ETT should be attempted with three attempts at each method. Each attempt with each method should be optimised and each subsequent attempt should be improvised. Methods to optimise can be either related to position of the operator and the patient, change in type, size or position of the device used, use of airway adjuncts to facilitate each method, use of suction and manipulating the pharyngeal muscle tone.

Achieving 'sniffing' position or ramp up position in obese patients, giving jaw thrust, optimising the height of the table and optimal external laryngeal manipulation all facilitate BMV, SGA and ETT insertion. Use of two operators for BMV and twisting the SGA are some of the manipulations to achieve adequate alignment for ventilation. Airway adjuncts such as oropharyngeal airways and nasopharyngeal airways can facilitate BMV. Similarly laryngoscope, bougie and introducers can act as adjuncts to SGA. Stylets, lighted stylets, airway exchange catheters and bougies help in ETT intubation. Change in size or type of device can be helpful. Optimal size of mask or SGA helps in achieving adequate seal. Change in the laryngoscope to Miller's type or to one of the videolaryngoscopes, fibreoptic bronchoscope or using a combination of devices can be beneficial for better visualisation of vocal cords and intubation.[14,15]

Suction can be useful to clear out the blood and secretions in the airway and improve visibility. Increased tone of the pharyngeal and laryngeal muscles is a very important cause of difficulty to perform instrumentation for intubation. Any instrumentation is best done with complete neuromuscular blockade or in completely normal tone with local analgesia as a state of partial paralysis impedes optimal airway manipulation. Thus, in a patient with partial paralysis during the attempts to secure the airway, further instrumentation should be attempted after repeating a bolus of muscle relaxant or after awakening the patient. The decision to reverse or deepen the block also depends on the type of instrumentation being done, findings during the previous attempts and the state of oxygenation.

Surgical airway

A failure to secure the airway nonsurgically should prompt us to quickly move to a surgical method without waiting for the oxygen saturation to fall.[15] Cricothyroidotomy and tracheostomy are the two surgical methods to achieve airway access. Cricothyroidotomy is faster to perform as the cricothyroid membrane is very superficial and more easily accessible as compared to tracheostomy. Cricothyroidotomy is of three types: needle, percutaneous and open surgical. The needle technique involves insertion of a wide bore cannula in to the trachea and connecting it to the jet ventilator for ventilation. The percutaneous technique involves insertion of tracheostomy tube through the cricothyroid membrane by Seldinger technique. The open surgical method involves exposing the cricothyroid membrane surgically, cutting it open and then inserting a tracheostomy tube through it.

Considering other options and definitive care

Once primary goal of alveolar oxygenation is achieved either by surgical or nonsurgical technique, further help should be called for so as to evaluate the nature of difficulty and decide on the subsequent course of management. Procuring additional equipment or calling an ENT surgeon for tracheostomy can be done as per the decision of the experts. Cricothyroidotomy is associated with subglottic stenosis. Hence, it best serves as a temporary measure to achieve oxygenation, provides time to think and decide on the best method to secure the airway in that situation.

Brief review of the techniques and equipment supraglottic airways

The laryngeal Mask Airway (LMA) is a prototype of the supraglottic airway devices. It consists of a mask which covers the laryngeal opening, and a tube which fits in the curve of the oropharynx and connects the mask to the ventilator. The LMA was initially used in the OR and then used in resuscitation as an easier alternative to endotracheal intubation as it could be used by paramedical professionals with minimal training. Several variants have been invented since then to improve the ease of insertion, to decrease the time for insertion, to prevent aspiration of gastric contents and to allow endotracheal intubation through them.[20] Of all the variants, the oesophageal tracheal combitube, easy tube and I-gel were found to have highest success rate for providing rescue ventilation in mannikin and human studies.[1,22,23]

Laryngoscopes

Videolaryngoscopes such as flexible fibreoptic laryngoscope, rigid fibreoptic laryngoscope, prism based videolaryngoscopes are some of the alternatives to the traditional Macintosh laryngoscope. Videolaryngoscopes have higher overall success rate and success rate at first attempt for intubation compared to the Macintosh laryngoscope. However, the time taken for laryngoscopy is generally longer. A straight blade laryngoscope and rigid scopes such as Bullard's or Wu's laryngoscope can be useful in specific situations.[14,20]

Airway adjuncts

Optical stylets, intubating catheter or tube exchange catheters are useful adjuncts in patients with difficult airway. However, they should be used with caution as they can cause trauma to airway and the lung.[14]

Surgical techniques

Surgical airway is the final pathway in most difficult airway algorithms. Thus, the physician involved in airway management should be trained adequately to perform cannula / surgical cricothyroidotomy. TTJV provides oxygenation and thus provides sufficient time to make a decision on further management and perform procedures such as FOB guided intubation. The cannula insertion and subsequent transtracheal jet ventilation (TTJV) is associated with several complications. Hence, many authors recommend open surgical technique over it in emergency situation. Data comparing percutaneous Seldinger technique and open surgical method are insufficient to make recommendations. However, all the surgical techniques require sufficient training on manikins and human cadavers and the choice of technique depends on the skill of individual operator, local hospital policy and equipment available.[1,4,24]

Confirmation of tracheal intubation

Appropriate placement of the tracheal tube can be assessed clinically, radiographically and with monitoring devices. Passing the tube between the vocal cords under vision, adequate chest movement with ventilation, fogging in the tracheal tube, bilateral audible breath sounds are some of the clinical criteria used. Oesophageal detector device, fibreoptic bronchoscopy, colorimetric and waveform capnography are some of the monitoring devices used. X-ray and ultrasound are the radiographic methods for confirming correct tracheal tube placement. Among all the methods, passing the tube between the vocal cords under vision, sustained presence of waveform capnography, observing the tracheal rings and the carina by passing the fibreoptic bronchoscope into the tube are the only methods which confirm the tracheal placement of the tube unequivocally. [25,26]

Training and education

Inadequate training and poor judgment in crisis are important issues leading to patient morbidity and mortality. Many anaesthesia training programs are now changing from "learning by experience" to "proactive learning". These models require the competencies to be defined and use of various techniques to teach the trainees for developing cognitive and motor skills for airway management. The training methods are updated and are based on the latest research on medical education. Training is an ongoing process and the expertise is achieved with dedication to achieve excellence and a desire to learn continuously. Airway anatomy and physiology, assessment of the airway, technical skills such as laryngoscopy, videolaryngoscope, fibreoptic laryngoscope, use of supraglottic airway device, use of capnography, surgical access to airway (any one method) are the practical skills to be acquired. Similarly, cognitive skills such as planning the management in anticipated and unanticipated difficult airway, applying the difficult airway algorithm, how to think quickly and communicate with team members during crisis and planning for extubation are some of the core skills which are usually included in the airway training programmes. Use of mannikins and simulation of various difficult airway situations are some of the teaching methods utilised for training.[27]

References

1. Ruetzler K, Krafft P, Frass M. Airway Management in Intensive Care Medicine. In: Hagberg CA, editor. Benumof and Hagberg's Airway Management. Philadelphia: Saunders, Elsevier; 2013. p. 916-54.
2. Schwartz DE, Matthay MA, Cohen NH: Death and other complications of emergency airway management in critically ill adults: a prospective investigation of 297 tracheal intubations. *Anesthesiology* 1999;**82**:367–76.
3. Martin LD, Mhyre JM, Shanks AM, Tremper KK,Kheterpal S. 3,423 Emergency tracheal intubations at a university hospital: airway outcomes and complications. *Anesthesiology* 2011;**114**: 42–8.
4. Cook TM, Woodall N, Harper J, Benger J. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments. *Br J Anaesth* 2011;**106**: 632-42.
5. Adnet F, Borron SW, Dumas JL, Lapostolle F, Cupa M, Lapandry C. Study of the "Sniffing Position" by Magnetic Resonance Imaging. *Anesthesiology* 2001;**94**(1):83-86.
6. Greenland K B, Edwards M J, Hutton N J, Challis V J, Irwin M G, Sleigh J W. Changes in airway configuration with different head and neck positions using magnetic resonance imaging of normal airways: a new concept with possible clinical applications. *Br J Anesth* 2010;**105**(5):683-690.
7. Greenland KB. Airway assessment based on a three column model of direct laryngoscopy. *Anaesth Intensive Care* 2010; **38**:14-19.
8. Wilson WC, Benumof JL. Physiology of the Airway. In: Hagberg CA, editor. Benumof and Hagberg's Airway Management. Philadelphia: Saunders, Elsevier; 2013. p. 118-158.
9. Langeron O, Masso E, Huraux C, *et al*: Prediction of difficult mask ventilation. *Anesthesiology* 2000;**92**:1229–36.
10. Christie JM, Dethlefsen M, Cane RD: Unplanned endotracheal extubation in the intensive care unit. *J Clin Anesth* 1996; **8**: 289–93.
11. Walls RM, Luten RC, Murphy MF, Schneider RE, eds. Manual of Emergency Airway Management. Philadelphia: Lippincott Williams & Wilkins, 2000.
12. Reed MJ, Dunn MJ, McKeown DW: Can an airway assessment score predict difficulty at intubation in the emergency department? *Emerg Med J* 2005;**22**:99–102.
13. El-Ganzouri AR, McCarthy RJ, Tuman KJ, *et al*: Preoperative airway assessment: predictive value of a multivariate risk index. *Anesth Analg* 1996;**82**:1197–204.
14. Practice Guidelines for the Management of the Difficult Airway: An updated report by the American Society of Anesthesiologists Task Force on the Management of the Difficult Airway. *Anesthesiology* 2003;**98**:1269–77.
15. Henderson JJ, Popat MT, Latto IP, Pearce AC. Difficult Airway Society guidelines for management of the unanticipated difficult intubation. *Anaesthesia* 2004;**59**:675–94.
16. Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. *Ann Emerg Med* 2012;**59**(3):165-175.
17. Artime C A, Sanchez A. Preparation of the patient for awake intubation. In: Hagberg CA, editor. Benumof and Hagberg's Airway Management. Philadelphia: Saunders, Elsevier; 2013. p.243-64.
18. El-Orbany M, Connolly LA. Rapid sequence induction and intubation: Current controversy. *Anesth Analg* 2010;**110**(5):1318-25.
19. Sakles JC, Laurin EG, Rantapaa AA, Panacek EA. Airway management in the emergency department: a one-year study of 610 tracheal intubations. *Ann Emerg Med* 1998; **31**:325–32
20. Baker P A, Flanagan B T, Greenland K B, Morris R, Owen H, Riley R H. Equipment to manage a difficult airway during anaesthesia. *Anaesth Intensive Care* 2011; **39**:16-34.
21. Chrimes N, Fritz P. The Vortex Approach: Management of the Unanticipated Difficult Airway. Monash Simulation, 2013.
22. Hubble MW, Wilfong DA, Brown LH, Hertelendy A, Benner RW. A metaanalysis of prehospital airway control techniques. Part II:

Alternative airway devices and cricothyrotomy success rates *Prehospital Emergency Care* 2010; **14**(4): 515-30.

23. Duckett J, Fell P, Han K, Kimber C, Taylor C.Introduction of the i-gel supraglottic airway device for prehospital airway management in a UK ambulance service. *Emerg Med J*. 2014; **31**(6): 505-7.
24. Smith RB, Babinski M, Klain M, *et al*: Percutaneous transtracheal ventilation. *JACEP* 1976; **5**:765–70.
25. Grmec S. Comparison of three different methods to confirm tracheal tube placement in emergency intubation. *Intensive Care Med* 2002;**28**:701–4.
26. Knapp S, Kofler J, Stoiser B, *et al.* The assessment of four different methods to verify tracheal tube placement in the critical care setting. *Anesth Analg* 1999;**88**:766–70.
27. Baker PA, Weller JM, Greenland KB, Riley RH, Merry AF. Education in airway management. *Anaesthesia* 2011;**66** (Suppl. 2): 101–11.