COMPLICATIONS OF ENDOTRACHEAL INTUBATION AND OTHER AIRWAY MANAGEMENT PROCEDURES
Dr. Divatia J. V.¹  Dr. Bhowmick K.²

Introduction
Airway management is a fundamental aspect of anaesthetic practice and of emergency and critical care medicine. Endotracheal intubation (ETI) is a rapid, simple, safe and non surgical technique that achieves all the goals of airway management, namely, maintains airway patency, protects the lungs from aspiration and permits leak free ventilation during mechanical ventilation, and remains the gold standard procedure for airway management. There are also several alternatives to ETI, both for elective airway management as well as for emergency airway management when ETI is difficult or has failed. These devices include the laryngeal mask airway and the combitube. Both ETI and the use of the other airways are associated with complications, some of them life threatening. It is essential for anaesthesiologists to be aware of these complications, and to have an effective strategy to prevent and manage these complications when they arise. A large number of complications have been described. It is beyond the scope of this article to deal with each in detail; emphasis will be laid on the major, potentially life threatening and preventable complications.

Complications associated with ETI
Predisposing factors for complications¹
The incidence and occurrence may depend on several factors. These include:

Patient factors
1. Complications are likely in infants, children and adult women, as they have a relatively small larynx and trachea and are more prone to airway oedema.
2. Patients who have a difficult airway are more prone to injury as well as hypoxic events.
3. Patients with a variety of congenital as well as chronic acquired disease may experience either difficult intubation or may be more prone to physical or physiological trauma during intubation.
4. Complications are more likely during emergency situations.

Anaesthesia related factors
The anaesthesiologists:
1. The knowledge, technical skills and crisis management capabilities of the anaesthesiologists play a vital role in the occurrence and outcome of complications during airway management.
2. A hurried intubation, without adequate evaluation of the airway or preparation of the patient or the equipment is more likely to cause damage.

Equipment
1. The shape of the standard endotracheal tube (ETT) results in maximal pressure being exerted on the posterior aspect of the larynx. The degree of damage to these areas depends on the size of the tube and the duration of intubation.
2. Use of stylets and bougies predispose to trauma.
3. Additives to plastic may provoke tissue irritation.
4. Sterilization of plastic tubes with ethylene oxide may lead to production of toxic ethylene glycol if adequate time for drying has not been allowed.
5. Cuff related injuries might occur with the use of high pressure cuffs or inappropriate use of low pressure cuffs.

Complications that may be associated with ETI² are listed in Table 1. Flemming classifies hazards of ETI as those that require immediate recognition and management, those related to tissue erosion and healing, and those of lesser significance such as minor trauma.³

I. Complications requiring immediate recognition and management
Failed intubation
The difficult airway and failed intubation encompass a spectrum including difficult mask ventilation, difficult laryngoscopy, difficult intubation and failed intubation. The most dreaded situation is a cannot-ventilate-cannot-
Table 1: Complications of ETI

<table>
<thead>
<tr>
<th>At the time of intubation</th>
<th>While the ETT is in place</th>
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<tbody>
<tr>
<td>Failed intubation</td>
<td>Tension pneumothorax</td>
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<tr>
<td>Spinal cord and vertebral column injury</td>
<td>Pulmonary aspiration</td>
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<tr>
<td>Occlusion of central artery of the retina and blindness</td>
<td>Airway obstruction</td>
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<tr>
<td>Corneal abrasion</td>
<td>Disconnection and dislodgement</td>
</tr>
<tr>
<td>Trauma to lips, teeth, tongue and nose</td>
<td>Tracheal tube fire</td>
</tr>
<tr>
<td>Noxious autonomic reflexes</td>
<td>Unsatisfactory seal</td>
</tr>
<tr>
<td>Hypertension, tachycardia, bradycardia and arrhythmia</td>
<td>Leaky circuits</td>
</tr>
<tr>
<td>Raised intracranial and intracocular tension</td>
<td>Swallowed ETT</td>
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<tr>
<td>Laryngospasm</td>
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<tr>
<td>Bronchospasm</td>
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<tr>
<td>Laryngeal trauma</td>
<td></td>
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<tr>
<td>Cord avulsions, fractures and dislocation of arytenoids</td>
<td></td>
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<tr>
<td>Airway perforation</td>
<td></td>
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<tr>
<td>Nasal, retropharyngeal, pharyngeal, uvular, laryngeal, tracheal, oesophageal and bronchial trauma</td>
<td></td>
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<tr>
<td>Oesophageal intubation</td>
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<tr>
<td>Bronchial intubation</td>
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</table>

During extubation After intubation

<table>
<thead>
<tr>
<th>Difficult extubation</th>
<th>Sore throat</th>
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<tbody>
<tr>
<td>Cuff related problems</td>
<td>Laryngeal oedema</td>
</tr>
<tr>
<td>ETT sutured to trachea or bronchus</td>
<td>Hoarseness</td>
</tr>
<tr>
<td>Laryngeal oedema</td>
<td>Nerve injury</td>
</tr>
<tr>
<td>Aspiration of oral or gastric contents</td>
<td>Superficial laryngeal ulcers</td>
</tr>
</tbody>
</table>

intubate (CVCI) situation in an apnoeic anaesthetized patient. This is a brain and life threatening emergency occurring in about 1 in 10,000 anaesthetics. Failure to achieve oxygenation will result in death or hypoxic brain damage. Repeated attempts at intubation result in more morbidity, and the number of attempts should be restricted to three. In an analysis of 1541 claims, there were 522 (34%) adverse respiratory events. Death or brain damage occurred in 85% of these cases. The main problems were inadequate ventilation (38%), substandard care (90%), oesophageal intubation (18%) and failure to identify problem (48%). The approach to a difficult airway and the management of the difficult airway as well as failed intubation has been outlined in the ASA difficult airway algorithm. It is beyond the scope of this article to discuss the algorithm in detail. Methods of emergency ventilation in a CVCI situation include use of the laryngeal mask, combitube or transtracheal jet ventilation. Cricothyrotomy (not tracheostomy) is the preferred method of surgical access to the airway in an emergency such as a CVCI problem. Complications associated with the laryngeal mask and combitube are detailed in a later section. The major problem with jet ventilation is the risk of barotrauma due to pressure of the oxygen jet. The risk increases if the airway is obstructed. The ventilatory rate should be restricted to the minimum required to prevent life threatening hypoxia (4-6/min) and a cricothyrotomy or tracheostomy undertaken without delay. A second 20G cannula can be inserted to vent the expired gases.

Oesophageal intubation

Prompt recognition of oesophageal intubation is vital to prevent hypoxia in the apnoeic patient. It may be recognized by gurgling sounds over the epigastrium on auscultation, abdominal distension and absence of breath sounds on the thorax. However all such clinical tests are flawed, and precious lives and brains have been lost by relying on clinical signs of oesophageal intubation. The only certain method of confirming correct placement of the ETT is to visualise its passage though the vocal cords; unfortunately this is not possible during a difficult intubation, a common situation in which oesophageal intubation occurs. End tidal CO2 monitoring is essential to confirm tracheal placement of the ETT. Passage of a fibreoptic bronchoscope through the ETT and visualization of the tracheal rings and carina also confirms tracheal placement, but is not universally available. Hypoxemia occurring soon after ETI may be due to unrecognised oesophageal intubation. Every attempt should be made to confirm correct placement. There may sometimes be difficulty in deciding whether the tube has been correctly placed; if there is any doubt, the tube should be withdrawn and reintroduced. The old maxim "when in doubt, take it out" still holds true.

Bronchial intubation

Endobronchial intubation occurs if too long a tube is used and inserted into one of the mainstem bronchi. Endobronchial intubation is most common when the distance for the tube tip to be placed properly above the carina yet
Spinal cord and vertebral column injury

Extension of the cervical spine during laryngoscopy may cause trauma to the spinal cord resulting in quadriplegia. This is more likely in patients with cervical spine fractures or mutilations, tumours or osteoporosis. In patients with suspected instability of the cervical vertebrae, the head must be maintained in a neutral position during laryngoscopy and intubation at all times; hyperextension is strictly avoided. The head may be stabilised by in-line manual stabilisation by an assistant. Alternative techniques of airway management that do not involve neck manipulation, such as fibreoptic intubation may be considered.

Noxious autonomic reflexes

Hypertension, tachycardia, arrhythmias, intracranial and intraocular hypertension

Laryngoscopy and ETI produce reflex sympathetic stimulation and are associated with raised levels of plasma catecholamines, hypertension, tachycardia, myocardial ischemia, depression of myocardial contractility, ventricular arrhythmias and intracranial hypertension. Hypoxia and hypercarbia aggravate the autonomic response. The magnitude of the pressor response is related to the duration of laryngoscopy, and may be severe during a difficult intubation with multiple, prolonged attempts at laryngoscopy and intubation. These responses may be particularly deleterious in patients with hypertension, IHD, myocardial dysfunction and raised intraocular and intracranial pressure. In patients with limited coronary or myocardial reserve, myocardial ischemia or failure may follow. The patient with limited intracranial compliance or an intracranial vascular anomaly may suffer serious intracranial hypertension or haemorrhage.

These responses, which also occur during tracheal extubation and suction, can be minimized by rapid, smooth ETI with adequate topical anaesthesia, analgesia, sedation and perhaps the use of muscle relaxants to prevent coughing and bucking during the procedure.

Drugs that tend to block the response to airway instrumentation may be used to blunt these noxious reflex responses. These include fentanyl 3 to 4 mgkg$^{-1}$, alfentanil, lignocaine 1.5 mgkg$^{-1}$ i.v., a small dose of beta antagonist, sublingual nifedipine or intravenous nitroglycerine

Bronchospasm

The presence of an ETT in the trachea produces reflex bronchoconstriction. Bronchospasm may be especially severe in the lightly anaesthetized patient with reactive airways. Bronchospasm may be blunted by the prior administration of anticholinergics, steroids, inhaled $\beta$-agonists, lignocaine (topical, nerve block, intravenous), and narcotics. After intubation, deepening anaesthesia with intravenous agents and the administration of inhaled or intravenous b-agonists are helpful. It is important to ensure that the audible wheezing is not due to mechanical obstruction of the tube or other causes, such as tension pneumothorax, or heart failure.

Drying of mucosa and effects on mucociliary function

The ETT bypasses the humidifying mechanisms in the nose and upper trachea. Inadequate humidification leads to drying of secretions, depressed ciliary motility and impaired mucous clearance. The ETT also provides a surface for pathogenic organisms from the gastrointestinal tract and oropharynx to adhere to and provides direct access for these organisms into the respiratory tract.

Laryngospasm

This may result from attempted intubation of the trachea under light anaesthesia. This can result in hypoxia, inability to ventilate the lungs and hypoxia, and must be corrected by rapidly deepening the plane of anaesthesia or by giving a muscle relaxant.

Acute traumatic complications

Injury to the lips, teeth, tongue, nose, pharynx, larynx, trachea and bronchi can occur during laryngoscopy and intubation. Traumatic complications have been extensively described in two excellent reviews. Most traumatic complications do not result in major morbidity or mortality. However, some require immediate recognition and management. In a review of closed 4,460 claims, airway injuries accounted for 6%. The most frequent sites of injury were larynx (33%), pharynx (19%), and oesophagus (18%). Tracheal and oesophageal injuries were more frequent with difficult intubation. Difficult intubation, age
older than 60 yr and female gender were associated with claims for pharyngo-oesophageal perforation.

**Oesophageal, tracheal and bronchial perforation**

Oesophageal perforation can occur with attempts at intubation, especially in patients with a difficult airway or multiple attempts. Subcutaneous emphysema may be noticed soon after intubation. Later, neck pain, difficulty in swallowing, neck erythema, and oedema may occur. Mediastinitis leading to sepsis may result in death or serious morbidity. Placement of a nasogastric tube has also been associated with oesophageal perforation.

Tracheal laceration may occur due to overinflation of the ETT cuff, multiple intubation attempts, use of stylets, malpositioning of the tube tip, tube repositioning without cuff deflation, inadequate tube size, vigorous coughing, and nitrous oxide in the cuff. The risk is also greater in patients with tracheal distortion caused by neoplasm or large lymph nodes, weakness in the membranous trachea (seen in women or the elderly), chronic obstructive lung disease, and corticosteroid therapy.

Endobronchial injury can occur with instrumentation of the bronchi. Endotracheal tube guides or tube changers have been associated with endobronchial rupture. Placement of double-lumen ETTs has also been associated with tracheobronchial rupture.

Airway perforation may occur anywhere from the nose to the trachea. It may admit air into unusual locations and manifest as subcutaneous emphysema, pneumomediastinum and pneumothorax. When these occur, a search must be made for such perforations, including by bronchoscopy. Nitrous oxide should be discontinued when pneumothorax or pneumomediastinum is suspected. In awake patients, cough, hemoptysis and cyanosis may occur.

**Tension pneumothorax**

This can lead to severe hypoxia and hypotension, and can occur after airway perforation during intubation or due to barotrauma during IPPV. It must be suspected either when there is unexplained hypoxia and hypotension, or when they occur with any of the signs of airway perforation. Airway pressure is increased, ventilation of the lungs may be difficult, breath sounds are absent on the affected side with a mediastinal shift to the opposite side, there is a hyper resonant note on percussion, and breath sounds are diminished or absent. An urgent X-ray chest confirms the diagnosis, but in the presence of cardiorespiratory compromise, the pneumothorax must be urgently decompressed by inserting a wide bore cannula in the 2nd interspace on the affected side.

**Disconnection and dislodgement**

Accidental dislodgment of the ETT during anaesthesia is a potentially lethal complication. Extension of the neck may cause cephalad movement of the ETT tube. Poor or loose fixation of the tube, excessive movement of the head during surgery, inadequate access to the tube during head and neck surgery or neurosurgery and heavy connectors producing drag on the circuit and ETT may lead to dislodgement. It can be detected rapidly if airway pressure and capnography are being continuously monitored. In the intensive care unit, the longer a tube stays in-situ, the greater the chances of kinking, blockade and unplanned extubation, leading to hypoventilation and hypoxia. Unplanned extubations have reported an incidence ranging from 0.3–30 %. Inadequate sedation, agitation, inadequate nursing supervision and inadequate fixation of the ETT predispose to accidental extubations in the ICU.

**Failure to achieve satisfactory seal**

Inadequate cuff seal is a common problem, leading to hypoventilation during Mechanical Ventilation (MV) and aspiration of gastric contents. The common causes of leak during MV and their solutions are outlined in Table-2. More serious causes include tracheomalacia and tracheo-oesophageal fistula (TEF). Inflation of the cuff leads to weakening of tracheal cartilage and widening of the trachea. Progressively increasing volumes of air are then required to maintain cuff seal.

**Table - 2 : Common problems leading to leak during mechanical ventilation.**

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
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<tbody>
<tr>
<td>Eccentric cuff inflation</td>
<td>Check cuff before insertion</td>
</tr>
<tr>
<td>Incorrect cuff position, cuff at or above vocal cords</td>
<td>Check and adjust ETT position, ensure cuff is in mid-trachea</td>
</tr>
<tr>
<td>Size of ETT is too small</td>
<td>Change ETT, insert a larger ETT</td>
</tr>
<tr>
<td>Leak in inflation valve</td>
<td>Attach 3-way stopcock and keep closed to maintain seal</td>
</tr>
<tr>
<td>Leak in pilot balloon or valve</td>
<td>Cut the connecting tube distal to leaking porthousing and insert 22G needle with 3-way stopcock into remaining tubing</td>
</tr>
<tr>
<td>Leaking cuff, usually damaged by teeth, nasal bone or Magill forceps</td>
<td>Change ETT</td>
</tr>
</tbody>
</table>

**Obstruction of the tube**

This can be due to a number of reasons:

1. Biting of the ETT.
2. Kinking of the ETT.
3. Obstruction by material in the lumen of the tube. This includes inspissated secretions, blood clots, nasal turbinates, adenoids or a variety of foreign bodies.
4. Defective spiral embedded tubes. During manufacture, air bubbles may form between layers. Blebs form when these are steam sterilized with vacuum. Diffusion of nitrous oxide into these blebs causes dissection of the walls with compression of the lumen.

5. Impaction of the tip of the tube against the tracheal wall may result in respiratory obstruction, particularly where the trachea contains a sharp bend, such as the thoracic inlet. The Murphy's eye, incorporated into many modern tubes, permits airflow to take place, even if this has occurred.

6. Herniation of the cuff over the lumen of the tube may occur if the cuff of an old, perished tube is over inflated. This, again, will cause respiratory obstruction.

7. Compression of the lumen of the tube by the cuff may be caused by over inflation of the cuff or by gradual diffusion of nitrous oxide onto the cuff during the course of anaesthesia. This problem is more common when silicone rubber tubes are used.

Obstruction of the ETT may manifest as increased resistance to ventilation, high airway pressures and ‘wheeze’. A blocked tube is an important cause of intraoperative bronchospasm and must be ruled out before bronchodilator therapy is given. ETT obstruction may be prevented by careful attention to the type of ETT, inspection and checking of the ETT and cuff prior to use, and by humidification of inspired gases. When ETT obstruction is diagnosed, visual inspection, passage of a suction catheter (or preferably a fiberoptic bronchoscope) along with cuff deflation and 90° rotation of the tube will rule out several of these possibilities. If patency cannot be restored, the ETT should be removed and replaced, if necessary over a tube exchanger.

Aspiration of gastric contents

While a cuffed tube protects the lungs from aspiration of foreign material, aspiration does occur. The high volume low pressure cuff has folds even after inflation through which fluid can pass into the trachea and lungs. The presence of spontaneous ventilation, accumulation of fluid above the cuff, a head up position and the use of uncuffed tubes or cuff leakage increase the chances of aspiration.

Fire during laser surgery

Fires are a danger associated with the increasing use of lasers for airway and oral surgery. Steps that may be taken to reduce this extremely serious hazard include:

1. Using special laser tubes, which may be made of jointed metal or clear plastic (with no radiopaque strip), or a plain red rubber tube, but not a conventional plastic tube.

2. Wrapping exposed portions of the tube with aluminium tape.

3. Inflating the cuff of the ETT with saline instead of air.

4. Packing wet pledgets between the ETT and larynx and covering the external part of the ETT with wet drapes.

5. Use of helium-oxygen mixtures that are less supportive of combustion than oxygen alone or oxygen-nitrous oxide mixtures.

When a fire in the airway occurs, the flow of oxygen must be immediately stopped, saline poured on the ETT and the trachea extubated. Surgery is stopped, the trachea is reintubated and the patient given humidified oxygen. The airway should be examined for burn injury and for any missing fragments of the ETT or its wrapping.

Difficult extubation

1. The cuff may fail to deflate. It can be punctured by a needle placed through the cricothyroid membrane after the cuff is raised to this level.

2. More serious and somewhat unusual causes of difficult extubation include fixation of the ETT or pilot tube by a Kirshner (K) wire used in head and neck surgery or a suture placed from the pulmonary artery through the trachea into the ETT. The nature of the surgical procedure must be kept in mind when a tube will not come out after cuff deflation or rupture, so as to avoid trauma from vigorous extubation attempts. Direct or fiberoptic examination may be required.

Complications of extubation

Airway obstruction, laryngospasm, and aspiration can occur. After intubations lasting 8 hours or more, airway protection may be impaired for 4 to 8 hours.

Sore throat is a complication of anaesthesia that may have pharyngeal, laryngeal, and/or tracheal sources and may occur in the absence of ETI. Factors that may affect the incidence of sore throat include area of cuff trachea contact, use of lignocaine ointment and size of the ETT, and the use of succinylcholine. Cuffs with a longer cuff trachea interface appear to cause a higher incidence of sore throat. The incidence of sore throat may also be related to intracuff pressures. The mechanism for succinylcholine-related sore throat is postulated to be myalgias due to fasciculations of periharyngeal muscles. Sore throat is a minor side effect that should resolve within 72 hours; it should not be a factor in determining whether ETI is required.

Hoarseness is another minor side effect correlated with ETT size that should be investigated if persistent.
Laryngeal oedema

Subglottic oedema is particularly more common in children, as the nonexpandable cricoid cartilage is the narrowest part of the pediatric airway. Oedema may also be uvular, supraglottic, retroarytenoid, or at the level of the vocal cords, and is manifested by inspiratory stridor. Diminished stridor may represent total airway obstruction and movement of air must be repeatedly confirmed. The contributing factors to the production of laryngeal oedema include too large a tube, trauma from laryngoscopy and/or intubation, excessive neck manipulation during intubation and surgery, excessive coughing or bucking on the tube, and present or recent upper respiratory infection. The prophylactic use of steroids before extubation to reduce oedema is an unproven but frequently utilized treatment if the likelihood of postextubation stridor is suspected. Treatment includes warmed, humidified oxygen, nebulized racemic epinephrine (0.25 to 1 ml), and i.v. dexamethasone (0.5 mg kg\(^{-1}\) up to 10 mg). If obstruction is severe and persistent, reintubation must be considered.

Acute traumatic complications of lesser significance

Dental injury

Incidence of dental injury ranges from 1:150 to 1:1000, to as little as 1:9000.\(^{22}\) The upper incisors are usually involved. Risk factors include preexisting poor dentition and one or more indicators of difficult laryngoscopy and intubation.\(^{23}\) When dental trauma occurs, the loose tooth should be recovered to ensure that aspiration of the tooth does not occur. The avulsed tooth should be placed in saline and immediate dental consultation should be obtained for possible reimplantation. A partial or complete dental fracture should be evaluated by an oral surgeon postoperatively. Details of the injury should be well documented in the anaesthetic record and chart and the patient informed of the injury.

Nasal injury

Nasotracheal intubation is frequently used in head and neck surgery. Patients with basilar skull fractures or severe facial trauma should not have nasal tubes passed as there exists a danger of inadvertent cranial intubation. Epistaxis is a common problem, caused by the tip of the ETT traumatizing nasal and pharyngeal mucosa. This may be more common and dangerous in patients with coagulopathy or those receiving anticoagulants. Nasal intubation is relatively contraindicated in such patients.

Attempted passage of a nasotracheal tube can create false submucosal passages. These can progress to retropharyngeal abscesses.

Turbinates, adenoids, and tonsils can also be traumatized. Prolonged nasal intubation can lead to pressure necrosis of the nostrils and septum. Nasal septal abscesses, retropharyngeal abscesses and paranasal sinusitis can occur after intubation. Paranasal sinusitis\(^{24}\) occurs due to injury to the sinus ostia followed by oedema, obstruction and infection. It may present as unexplained fever or purulent discharge, is often refractory to antibiotics and may lead to intracranial infection or septicaemia.\(^{25}\)

Pharyngeal trauma

Necrosis and perforation of the pharynx may present in the immediate postoperative period with subcutaneous crepitus, fever, tachycardia, and odynophagia. Most lacerations of the oropharynx can be treated conservatively. A haematoma should be treated with antibiotics, but if it is large, consideration should be given to drainage. The patient must avoid oral feeds for at least 48 hours and intravenous broad-spectrum antibiotics should be prescribed. Larger perforations may need surgical repair.

Temporomandibular joint injury

Patients tend to be healthy females below 60 years of age. Preexisting temporomandibular disease may be present in a small percentage. The dislocation usually is detected at the time of procedure and the jaw is locked in an open position and cannot be closed. Immediate reduction of the dislocated TMJ should be performed and this can be achieved easily. Patients with continual symptoms referable to the joint should receive an oral surgery consultation for possible treatment with an occlusal appliance.

Tongue injury

Macroglossia occurs due to prolonged compression by an ETT or oral airway, leading to ischemia and venous congestion. Obstruction of the submandibular duct by an ETT may lead to massive tongue swelling.\(^{26}\) Compression injury to the lingual nerve during difficult intubation leading to loss of sensation has been reported.

Laryngeal trauma

Vocal cord paralysis

In the subglottic larynx, an anterior branch of the recurrent laryngeal nerve enters between the cricoid and the thyroid cartilage, innervating the intrinsic muscles of the larynx. An inflated cuff at this location can compress the nerve between the cuff and the overlying thyroid cartilage, causing injury.\(^{27,28}\) Bilateral injuries present considerably more risk and frequently require emergency reintubation or tracheostomy. Unilateral injury to a
recurrent laryngeal nerve prevents abduction of the ipsilateral vocal cord; therefore, it becomes fixed in the adducted position. This is associated with hoarseness, usually noted immediately in the postoperative period. Recurrent nerve injury can be prevented by avoidance of overinflation of the ETT cuff, and prevention of excessive tube migration during anaesthesia. Vocal cord paralysis is usually associated with spontaneous recovery over days to months.

**Arytenoid injury**

Arytenoid dislocation is another well described cause of laryngeal injury that can occur after traumatic intubation as well as with routine elective intubation. This results in immobility of the true vocal cords, which lead to hoarseness. Indications of arytenoid dislocation can include the onset of hoarseness, dyspnea, stridor, fever, and sepsis. Arytenoid dislocation can be managed with conservative measures or surgical intervention. An arytenoid dislocation can be diagnosed using direct laryngoscopy, laryngeal stroboscopy, or bronchoscopy.

### II. Complications related to tissue erosion and healing

**Laryngeal injury**

Laryngeal injury occurs due to ischemic injury resulting from high pressures generated when the round ETT presses on the pentagonal structure of the larynx, especially at the vocal processes of the arytenoids and the cricoid ring. Ulcerations or erosions of the larynx are common even after a short duration of intubation, and progress with the length of intubation. They are most commonly found on the posterior part of the larynx and anterior and lateral aspects of trachea, corresponding to the position of the convex curve of the ETT, the tip and the cuff. Superficial ulcers heal rapidly. Deeper ulcers may result in scarring or erosion of a blood vessel and haemorrhage.

**Ulcerations or erosions of the larynx**

Ulcerations or erosions of the larynx are not only common but also significant causes of laryngeal complications. They can be treated with topical medications or surgical intervention. Ulcerations can be prevented by minimizing the pressure on the larynx and using lubricated cuffs.

**Granuloma of the vocal cords**

Granulomas of the vocal cords may develop from an ulcer, when granulation tissue forms and forms a sessile lesion. The incidence varies from 1: 800 to 1: 20000. Patients may be asymptomatic, or have hoarseness, pain and discomfort in the throat, chronic cough and haemoptysis. Persistent symptoms after intubation need an ENT consult and strict voice rest. Granulomas usually heal spontaneously. Surgical intervention is required only if the lesion is pedunculated or the patients develops respiratory obstruction.

**Laryngotracheal membrane**

Laryngotracheal membrane is an uncommon but potentially fatal complication due to respiratory obstruction. The symptoms of respiratory obstruction occur 24-72 hours after extubation. Diagnosis is made by direct laryngoscopy or bronchoscopy. Treatment is removal by suction.

**Delayed tracheal injury**

Delayed tracheal injury is almost always cuff related, and can be minimized by use of low pressure cuffs and meticulous cuff management. The incidence of laryngotracheal complications can be further reduced by use of appropriate sized ETTs made of nontoxic plastic. Drag on the ETT by ventilator tubing should be avoided and excessive ETT movement reduced by use of swivel connectors. Local and systemic sepsis should be aggressively treated and corticosteroids used only when indicated.

**Tracheal stenosis**

Tracheal stenosis is a complication of tracheostomy. It occurs when the ETT cuff is inflated and the pressure is transmitted laterally against the wall of the trachea. Ischemia and eventual necrosis occur when the lateral tracheal wall pressure exceeds the capillary perfusion pressure of about 25 mmHg. Necrosis of the tracheal mucosa leads to sloughing and ulceration of the mucosal membrane, exposing the tracheal cartilage. Continued ischemia may be followed by partial or complete destruction of cartilaginous tracheal rings and loss of the structural integrity of the affected tracheal segment, leading to tracheal dilatation. Healing of the injured tracheal segment during any stage of this process may lead to a tight fibrous stricture (tracheal stenosis). These can be prevented by proper management of low pressure cuffs. Only high volume, low pressure cuffs must be used, and the cuff inflated to pressure not exceeding 25 mmHg or 30 cm H2O. Overinflation of these cuffs causes them to function just like high pressure cuffs. It is therefore essential to inflate only as much air as is required to just seal the air leak during IPPV (minimal inflation technique), and to check the intracuff pressure with a cuff-pressure manometer.

### Complications of tracheostomy

Two types of tracheostomy (TR) are now performed – open or surgical tracheostomy, and percutaneous tracheostomy. The complications of TR are summarized in Table 3. Some of these are:

<table>
<thead>
<tr>
<th>Table - 3 : Complications of tracheostomy</th>
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<tbody>
<tr>
<td><strong>A. Complications during surgery</strong></td>
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<tr>
<td>Haemorrhage</td>
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<tr>
<td>Pneumothorax and pneumomediastinum</td>
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<td>Cardiorespiratory arrest</td>
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<tr>
<td>Recurrent laryngeal nerve injury</td>
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<tr>
<td><strong>B. Immediate postoperative complications</strong></td>
</tr>
<tr>
<td>Haemorrhage</td>
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<tr>
<td>Subcutaneous emphysema</td>
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<tr>
<td>Displacement and obstruction of the tube</td>
</tr>
<tr>
<td>Swallowing problems</td>
</tr>
<tr>
<td><strong>C. Late complications</strong></td>
</tr>
<tr>
<td>Tracheal stenosis: at the stoma or at the level of the cuff</td>
</tr>
<tr>
<td>Tracheomalacia</td>
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<tr>
<td>Tracheo-oesophageal fistula</td>
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<tr>
<td>Tracheo-innominate fistula</td>
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1. **Pneumothorax**: Occurs in about 4% of adult TRs and is more common during emergency or difficult TR, especially when the airway is obstructed and the patient's inspiratory efforts draw in a large volume of air into tissue planes. False passage of the tracheostomy tube (TT) in the anterior paratracheal tissue followed by mechanical ventilation (MV) leads to similar complications. Tension pneumothorax may lead to cardiac arrest. A chest X ray must be taken after TR and if pneumothorax is present, it should be promptly treated by drainage and underwater seal. Subcutaneous emphysema can be prevented by using a cuffed TT and by not suturing the wound very tightly.

2. **Cardiorespiratory arrest**: The respiratory drive and massive sympathetic stimulation occurring due to hypercarbia and hypoxia in patients with severe airway obstruction are suddenly removed when TR is performed, leading to respiratory arrest and cardiovascular collapse. The patient usually recovers completely with MV, fluid resuscitation and inotropic support. Negative pressure pulmonary oedema may also occur minutes to hours after airway obstruction is relieved by TR (or ETI). It responds well to treatment.

3. **Inability to insert the TT**: Can result in severe hypoxia and death. During TR, the ETT should never be withdrawn completely from the larynx until it is confirmed that the TT is in the trachea. The TR tract takes 37 days to form. If in this period, the TT needs to be reinserted, there is a real danger of being unable to reinsert the tube or of inserting it into the paratracheal space. A pad must be placed under the shoulders to bring the trachea up in the neck and a tracheal dilator used to introduce the TT. ETI may be necessary to secure the airway if the TT cannot be replaced. A Bjork flap [an inverted ‘U’ shaped flap of anterior tracheal wall cut and sutured to the skin] may permit easier reinsertion of the TT before the tract has formed, but may be associated with a higher incidence of stomal stenosis.

4. **Trachea stenosis and tracheomalacia**: Can be prevented by proper management of low pressure cuffs. The incidence of stomal stenosis can be reduced by not making a large stoma and by use of lightweight, mobile, swivel connectors to minimize mechanical trauma.

5. **Tracheo-oesophageal fistula**: May occur due to injury to the posterior tracheal wall during TR, but is more often the result of high cuff pressures, and is often aided by a nasogastric tube pinched between the oesophagus and posterior tracheal wall.

6. **Tracheo-innominate fistula**: Is a dreaded complication of TR, the patient exsanguinating to death in minutes. It is a major cause of haemorrhage occurring 48 hours after TR and occurs either due to direct contact between the innominate artery and TT in case of low TR [below the 4th tracheal ring] or to high cuff pressures leading to necrosis of the anterior tracheal wall followed by erosion of the arterial wall. Major haemorrhage may be preceded by ‘warning bleeds’ and the TT may be seen to be pulsating. Haemorrhage may be controlled by hyperinflating the cuff to occlude the opening in the artery. If this is unsuccessful, the artery can be compressed anteriorly after incising the skin over the sternal notch while the patient is transported to the operating room. Immediate surgery is required to salvage the patient.

Complications of percutaneous tracheostomy

The incidence of complications reported with PCT varies from 3-25%. In three large series using the Ciaglia technique, perioperative complications were reported in 8-11% of patients. The published incidence of perioperative complications with the guidewire dilating forceps (GWDF) technique ranges from 0-24%. Fikkers and Ambesh found no major differences between the GWDF and the Blue Rhino techniques, except perhaps for a slightly increased bleeding with the GWDF. In a meta analysis of percutaneous tracheostomy trials (n=27; patients) 1817 perioperative complications occurred in 10%, including deaths in 0.44% and serious cardiorespiratory events in 0.44% patients, whereas postoperative complications occurred in 7% of patients. The main perioperative complications of PCT include bleeding, pneumothorax, and posterior tracheal injury. Posterior tracheal injury may be confined to the mucosa, or may involve the entire posterior wall, and more seriously, result in a tracheo-oesophageal fistula. It has been suggested that visualization by fibreoptic bronchoscopy of tracheal puncture and dilatation can substantially reduce the incidence of such complications. Endoscopic guidance ensures midline placement, prevents paratracheal tube placement and avoids inadvertent injuries. Complications during percutaneous tracheostomy have been classified as major, intermediate and minor (table 4).
Complications with the laryngeal mask airway

The laryngeal mask airway (LMA) has become an increasingly popular alternative to the face mask and ETT as a means of providing a secure airway for patients undergoing elective surgical procedures requiring general anaesthesia. However, the use of LMA is not free of complications. These have been reviewed by Pollack. Complications resulting from use of the LMA in the OR are known to be rare. In a series of more than 11,000 patients of all ages over a 2-year period, there was a 0.15% airway management complication rate, and none of these 18 patients required intensive care.

Malplacement and aspiration

The commonest and the most important are regurgitation of gastric content and chances of aspiration. Brimacombe conducted a meta analysis of the published literature and found an incidence of aspiration in 2/10,000 patients, which is similar to that recorded during general endotracheal anaesthesia. The LMA has been shown to cover both the laryngeal inlet and the oesophagus, thus forming a potential direct communication between the two. Moreover LMA does not reliably provide an airtight seal around the larynx and may not protect the airway from aspiration of gastric contents, if there is regurgitation into pharynx. The chance of regurgitation and aspiration while using LMA is present both during spontaneous and mechanical ventilation. The incidence of regurgitation varies from 0.08 to 23%. Mechanical ventilation with an LMA may encourage the risk of reflux and aspiration more, by causing gastric insufflations and increased intragastric pressure. Regurgitation is considered to occur more often during certain surgical procedures, such as laparoscopic surgery in gynaecological patients. This is thought to be due to lithotomy position with head down tilt which increases intra abdominal pressure, there is also the possibility that the LMA induces a reduction of lower oesophageal sphincter tone. Malplacement and improper seating of the LMA above the airway opening clearly increases the risk of gastric distension and subsequent aspiration, as does positive pressure ventilation through the LMA. There are case reports of aspiration even with Proseal LMA.

Inadequate patient anaesthesia may result in coughing, gagging, and bucking on attempted LMA insertion. This may be particularly hazardous in the patient with suspected intracranial or cervical spine injury. If coughing and gagging occur during attempted insertion, the mask should be removed and anaesthesia should be deepened. If they occur with the mask in situ, anaesthesia should be deepened and the mask should be left in place. Direct trauma to pharyngeal and upper airway structures typically may result from poor insertion technique.

Malplacement of the LMA, with migration of the LMA tip into the glottic aperture, may also induce bronchospasm. Ventilation through an LMA in these patients may be inadequate because high positive pressure ventilation results in air leak around the laryngeal mask.

Pressure induced lesions

The next important complication, which has been reported, is lingual nerve injury, both unilateral and bilateral. The course of lingual nerve after it branches out of posterior trunk of mandibular nerve is such that the various manoeuvres undertaken during the insertion of LMA and in maintaining its position can injure it. The nerve is vulnerable to compression as it travels between the pterygoids or between the medial pterygoid and the mandible. Compression injury between the pterygoids may occur secondary to mandibular retraction. Prolonged anterior displacement of the mandible, as in the jaw thrust manoeuvre, has also been implicated in lingual neuropaxia. The LMA can also cause nerve injury probably by direct compressions of the nerves. When the laryngeal mask is correctly placed, the distal tip lies in the hypopharynx at the upper oesophageal sphincter, the proximal base lies just under the tongue base with sides facing the pyriform fossa. In this position the cuff may compress the lingual nerves as they lie on the inner aspect of the mandible covered only by the mucous membrane.

Tongue cyanosis and swelling has also been reported after the use LMA. The probable cause may be occlusion of lingual artery bilaterally by the cuff of LMA when the arteries enter the base of tongue. It may be due to malpositioning or due to size of LMA.

The incidence of recurrent nerve paralysis has also occurred by the use of LMA. The probable cause may be the compression of the nerve by increased cuff pressure of the LMA at the point where the nerve enters into the larynx passing behind the thyroid and cricoid cartilage.

Cuff volume also influences postoperative sore throat and dysphagia. The incidence of sore throat has
also been found to be higher in case of LMA than that of ETT. It has been found that sore throat incidence is less with Soft-Seal LMA than classic LMA. Nitrous oxide tends to diffuse less into the Soft Seal cuff during anaesthesia.

**Complications of using the esophageal tracheal combitube (ETC)**

The combitube has been widely accepted as an airway device for out-of-hospital Cardio pulmonary and cerebral recurritation (CPCR) but has not been accepted into routine anaesthesia practice. The main limitation of the ETC in routine anaesthesia is the potential risk of trauma.

Oesophageal and pharyngeal perforation leading to subcutaneous emphysema, pneumomediastinum and pneumoperitoneum has been reported in association with out of hospital airway rescue. Bleeding (36-45%), sore throat (16-46%) and dysphagia (8-68%) have been reported in association with routine anaesthesia. Possible mechanisms for trauma are direct injury during placement or high pressures exerted against the surrounding mucosa.

The chances of direct injury during the placement of ETC are due to the following reasons:

1. ETC is a large and stiff tube with an anterior curvature, a design that might cause injuries by bulging the anterior wall of oesophagus. Laceration has been observed on the anterior wall only.

2. Technique of blind insertion with out visualization of the passage of the ETC into the pharynx and into the proximal oesophagus opening may also promote injuries.

The volume of both the proximal and the distal cuffs determines the pharyngeal, oesophageal and tracheal mucosal pressures. Pharyngeal mucosal perfusion is progressively reduced when mucosal pressure increases from 34 to 80 cmH$_2$O. In the pharynx and in the oesophagus the pressure will be highest posteriorly because the posterior surface is adjacent to the rigid vertebral bodies. In the pharynx the ETC can potentially impair the perfusion in the anterior, lateral and posterior wall when the proximal cuff volume increases from 40 to 70 ml, 50 to 80ml, and 30 to 50 ml respectively. These volume frequently exceed the minimal volume required to form an oropharyngeal leak pressure of 30 cmH$_2$O.

In the oesophagus perfusion would be potentially impaired in the anterior, lateral and posterior oesophagus when distal cuff volume increases from 12 to 18 ml, 12 to 20 ml and 4 to 8 ml respectively. Likewise tracheal mucosal perfusion is progressively reduced when mucosal pressure increases from 30 to 50 cmH$_2$O. Tracheal perfusion would be potentially impaired in the anterior, lateral and posterior trachea, when distal cuff volume increases from 4 to 6 ml, 8 to 10 ml and 10 to 12 ml, respectively. Thus at the recommended inflation volume for the pharyngeal (85 ml) and oesophageal cuffs (10-15 ml), mucosal pressure would be potentially higher than perfusion pressure posteriorly.

In the pharynx, the increased pressure may cause bleeding and sore throat and would perhaps predispose to pharyngeal perforation. Likewise, in the oesophagus these high pressures may cause dysphagia and may predispose to oesophageal rupture.

**References**


