Chapter 9: The obstructed airway

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Attempts to save man’s life from suffocation have been made from ancient times. These early attempts occasionally succeeded but more often failed. The ancient Egyptians, who established the first civilization, were pioneers in solving problems. Two engravings in the Abydos and Sakkara regions of Egypt (3600 BC) record the performance of a tracheostomy (Shehata, 1981). Homer around 1000 BC reported that Alexander the Great saved the life of one of his soldiers from suffocation, by making an opening in the trachea using the tip of his sword. Hippocrates (460-377 BC) suggested a type of pharyngeal intubation using a straight cannula passed orally to maintain an airway. In the tenth century, Avicenna (980-1037) advocated intubation of the larynx using bent tubes of silver and gold. Tracheostomy during this period was reserved for the hopeless cases.

Towards the end of the 19th century Schrotter (1876) and MacEwen (1878) revived the idea of peroral intubation and with the invention of the laryngoscope by Bozzini (1807) perfected by Kirstein (1895), techniques improved, many lives were saved, and inhalation anaesthesia became a possibility. In 1885 successful intubation of the larynx was performed in the USA by O’Dwyer (1841-1898) in preference to a tracheostomy for laryngeal diphtheria. The manufacture of the endotracheal tubes was modified and improved in the succeeding years, and the original hard metal tubes were replaced by a flexible metal one, introduced on a curved guide wire through the mouth. This was replaced in 1907, by Barthelemy and Dufour of France, by a rubber catheter which could be guided into the trachea by touch. In 1928, Magill, the father of endotracheal anaesthesia, published his experience of blind nasal intubations gained during World War I. After the Second World War, the attitude to intubation was radically altered by the use of muscle relaxants which made intubation relatively easy, quick and atraumatic. The Macintosh laryngoscope, introduced in 1943, has now come into daily and universal use. The added help of electric light and fibrooptic illumination and the Magill's intubation forceps have made laryngeal intubation a simple, safe and routine procedure.

Tracheostomy, derived from two Greek words meaning ‘I cut the trachea’, has probably been known for about 3,500 years (Frost, 1976). In 1833 Trousseau described 200 tracheostomies in patients with diphtheria. Fifty of these patients survived, and the operation of tracheostomy became a legitimate procedure with wide acceptance. However, it was not until the early 1900s when Chevalier Jackson attempted to standardize indications, techniques, and the instrumentation for tracheostomy, that the procedure became practical and relatively safe (Jackson, 1909). At present the mortality for tracheostomy as the primary operation varies from 0.5 to 3.0%. These variations can be explained by the differing ages and conditions of the patients, as well as by the urgency of the procedure and the skill of the personnel involved.

Clinicians who have to share the airway in the operating room, whether under routine or emergency circumstances, have come to appreciate the need to achieve and maintain a patent airway if the patient is to survive. It therefore behoves us all to have alternative methods available to achieve a patent airway and be willing to use these alternative methods with speed should the method being used fail. Otolaryngologist have, over the years,
accumulated much experience of the grave complications of emergency and long-term laryngeal intubation. The laryngologist functions as the primary source of expertise in the long-term management of the intubated airway and in the treatment and rehabilitation of the complications caused by artificial airways.

**Intubation of the larynx**

**Instruments**

Certain basic instrumentation is required for successful laryngeal intubation. The equipment should always be checked in advance if time and the needs of the patient allow. A source of 100% oxygen and a bag-valve assembly should also be available to ventilate the patient. Tightly-fitting anaesthetic face masks in a variety of sizes should be to hand to help gain initial control of the airway. Suction is essential and a large bore Yankauer tip type suction head is ideal to clear the airway of mucus, blood or vomit. The Macintosh laryngoscope must be available - the handle should be checked for battery integrity - with a variety of fitting blades. A selection of different sized endotracheal tubes should also be available, with a metal malleable stylet which may occasionally be needed to aid with the insertion of the tube. The Magill forceps is often invaluable in directing the endotracheal tube if any difficulties are encountered in finding or exposing the laryngeal inlet. The selection of the appropriate bore of endotracheal tube is based roughly on the patient's age, especially in children. An adult woman will usually accept a tube of internal diameter of 8.5 mm and a man, one of 9.5 mm. It is a mistake to select a small bore tube in the belief that it will be easier to insert. Not only is this usually incorrect, but there will be a large air leak past the tube, together with an increase in the resistance to spontaneous respiration should the latter be desired. On the other hand, an over-large tube inserted with force will damage the vocal cords with possible serious long-term results. The correct length of the endotracheal tube which will be required can be estimated by measuring the distance from the lobe of the ear to the angle of the mouth and doubling it.

**Indications**

**Absolute**

(1) Protection of the trachea from contamination in:

(a) non-anaesthetized patients with a depressed cough reflex, for example head injury, cerebrovascular accidents, overdoses and some central nervous system diseases;

(b) anaesthetized patients who are likely to vomit or soil the lower airway, for example obstetric patients or patients with intestinal obstruction;

(c) patients at risk of soiling the trachea or lower airway from an operative site, as in head and neck or dental procedures.

(2) Severe upper airway obstruction.
Relative

(1) To facilitate controlled ventilation.

(2) To facilitate tracheobronchial toilet.

(3) To maintain a clear airway under difficult circumstances, for example the prone position for neurosurgery.

(4) For diagnostic procedures - angiography or bronchography.

Technique

Careful but rapid preparation of the patient will aid intubation unless the situation dictates immediate action. The occiput is elevated about 4-6 cm off the table with a pad, providing that cervical spine injury is not suspected. The neck should be flexed on the trunk and the head extended on the neck in the 'sniffing position'. Pre-oxygenation of the patient should be performed with a tightly fitting anaesthetic mask and ventilation assisted as necessary by the bag-valve-mask assembly. Sedation or topical anaesthetic both can be used at this stage to decrease patient discomfort.

The head is placed so that the angle between the mouth and the trachea is reduced, until it forms, as near as possible, a straight line. It is a mistake to hyperextend both the head and neck, as this produces misalignment of the mouth and tracheal axes, so making intubation more difficult.

Endotracheal intubation in the hands of experts takes less than 10 seconds, however, the inexperienced may take much longer. Oxygen uptake continues during the period of intubation and the arterial oxygen tension declines. The lungs should therefore be inflated if possible with oxygen up to the moment when the laryngoscope is inserted into the mouth. Similarly, prolonged attempts at intubation must always be interrupted to prevent hypoxaemia.

To achieve the correct degree of extension at the atlanto-occipital joint, the forefinger of the right hand is applied to the patient's hard palate and the upper jaw is pulled towards the operator. The lips can then be pushed away from the teeth by the middle finger and thumb.

The laryngoscope is held in the left hand, and is introduced into the right side of the patient's mouth so that the tip of the blade approaches the midline from the right. The 'Z'-shaped cross-section causes the tongue to be pushed out of the way to the left.

The handle of the laryngoscope is lifted in the direction to which it points. It must not be rotated, as this movement will damage the teeth, gums and the mucous membrane of the pharynx. The uvula is seen at the tip of the blade which is advanced in the midline while elevation of the soft tissues is maintained. The tip will eventually come to lie in the valleculae between the tongue and the epiglottis. Elevation of the root of the tongue will indirectly elevate the posteriorly placed epiglottis, and the laryngeal opening will come into view ready for intubation.
The endotracheal tube is passed between the vocal cords. If the patient is making respiratory movements, the tube should be passed during inspiration when the cords are separated maximally. If the larynx is difficult to see anteriorly, it may be brought into view by an assistant gently pressing the thyroid cartilage posteriorly.

At this stage the cuff of the endotracheal tube should be inflated with air via a syringe until the tracheal leak is just eliminated.

The tube should be fixed to the head with a bandage or tape to prevent displacement.

Finally, the endotracheal tube is attached, as the situation demands, to an Ambu bag, ventilator or anaesthetic circuit.

Oral intubation is the most direct route, requires less time and is indicated in the moribund or apnoeic patient. An awake patient must be cooperative or adequately sedated to allow oral intubation because of the profound stimulation of the throat by direct laryngoscopy. Nasotracheal intubation is useful when the patient is uncooperative or if manipulation of the neck is considered unsafe (Danzl and Thomas, 1980). This technique can be used if the patient has trismus, severe mandibular injuries, cervical spine rigidity, distortion or masses in the oral cavity. The nasotracheal approach has disadvantages in that it demands greater technical expertise, and the patient must have good spontaneous respirations because the tube is guided by breath sounds. The complication rate of this procedure is less than 3%, but includes epistaxis, sinusitis, nasal necrosis, retropharyngeal lacerations and otitis media (Tintinallu and Claffey, 1981). Fibreoptic techniques can be used to aid oral and nasal intubation but are usually reserved for elective intubations because they require more expertise and time as the larynx can be easily obscured. Successful translaryngeal intubation is achieved if the clinician is flexible, comfortable with multiple techniques and is aware of the possible complications and difficulties that may be encountered with each technique used. Emphasis is placed on the expeditious control of the airway in a rapidly deteriorating patient. If the initial approach to intubation is unsuccessful, prompt use of alternative approaches must be instituted (Salem, Mathrubhutham and Bennett, 1976).

**Intubation difficulties**

Difficulties in intubation arise from three sources:

1. errors of techniques (*Table 9.1*);
2. anatomical variations;
3. transient physiological and structural abnormalities.

The incidence of difficult intubation has been estimated to be approximately 1:750 cases in experienced hands (Edems and Sia, 1981). Of these airways with difficulties, 90% can be anticipated and in the remaining 10% the problem is discovered unexpectedly.

Preintubation assessment can often identify high risk patients. Patients with head and neck problems sometimes have a number of factors which would suggest possible intubation
problems. A mass can alter the normal anatomy of the pharynx, larynx or trachea so that the glottis is impossible or extremely difficult to expose by direct laryngoscopy. Oedema and scarring of the airway secondary to radiotherapy or prior to surgery may interfere with the ability to expose the glottis directly. The presence of temporomandibular joint ankylosis, tumour, masseteric spasm or a small mouth with a large tongue will compromise adequate exposure. Lesions that limit neck mobility such as cervical spondylosis, Klippel-Feil syndrome, as well as congenital abnormalities which produce a very anteriorly placed larynx (micrognathia, Treacher Collins and Goldenhaar's syndromes) will make alignment of the laryngeal and oropharyngeal axes difficult (White and Kander, 1975).

Table 9.1 Common errors of orotracheal intubation

<table>
<thead>
<tr>
<th>Step</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning</td>
<td>Axes not aligned</td>
</tr>
<tr>
<td>Opening of mouth</td>
<td>Mouth not wide enough</td>
</tr>
<tr>
<td>Insertion of blade</td>
<td>Wrong size or type of blade</td>
</tr>
<tr>
<td></td>
<td>Blade badly positioned</td>
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<tr>
<td>Exposure of cords</td>
<td>Leverage rather than traction</td>
</tr>
<tr>
<td>Introduction of tube</td>
<td>Obscured line of vision</td>
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<tr>
<td></td>
<td>Failure to maintain natural curve</td>
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<td></td>
<td>Trachea angulated by traction.</td>
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Temporary abnormalities often present a problem in an emergency. These abnormalities include blood, vomit and foreign bodies that interfere with the view of the airway; trismus secondary to head injuries, seizures or drug ingestion; trauma of the mouth or face; a neck injury; and hypoxia caused by shock or drugs in a conscious but uncooperative patient.

Physicians who are likely to encounter emergency situations which require rapid control of the patient's airway should be able to secure an airway with techniques other than the standard oro- or nasotracheal intubation. Alternative techniques include the fibreoptic laryngoscope, guided retrograde transcricoid intubation, oesophageal devices, cricothyroidotomy, tracheostomy and transtracheal jet ventilation (Iserson, Saunders and Kaback, 1985). Many techniques and devices have been used to aid blind intubation including forceps, hooks, catheter, guides and drugs to increase the respiratory flow, and agents to sedate or paralyse the patients. The most frequently used device to facilitate the positioning of the tube during orotracheal intubation is the malleable guide wire. In its most common form the blunt ended wire is used to mould and hold the tube in a pronounced curve. However, this technique has the potential of lacerating the vocal cord or trachea.

More recently, the above techniques have been added to the flex-end tube or trigger tube. The tube is of standard design; the wall contains a wire that allows anterior flexion of the tip by means of a trigger at the proximal end. While internal guides are generally used in orotracheal intubation, external guides are most often employed in nasotracheal intubation. The most common external guide is the Magill forceps, an instrument that allows the distal end to be grasped and be positioned in the vocal cords under direct vision. The clear
polyvinyl chloride (PVC) tracheal tube is commonly used nowadays, and it allows the clinician to see the condensation of expired air on the inside of the tube.

However, at times oral and nasal intubation are difficult to achieve even with the techniques described. The fibreoptic laryngoscope has been used for difficult intubations since it was first described by Davis (1973), who reported it as an alternative to blind nasal intubation. The flexible fibreoptic laryngoscope is small enough to allow the adult endotracheal tube to be passed around the laryngoscope. The laryngoscope acts as an introducer and allows direct exposure of the larynx. The distal 5 cm of the scope can be manoeuvred in an anterior and posterior direction using the controller. Neither neck movement nor spontaneous respiration is required. With nasopharyngoscopes it is now possible to remove secretions which in the past interfered with the identification of structures (Davidson, Bone and Nahum, 1975).

**Correct placement of endotracheal tube**

In an emergency, and sometimes in difficult elective intubation, the endotracheal tube is occasionally misplaced in the oesophagus. If this situation is not recognized quickly the patient will die. There are very few absolute signs that the tube is in the trachea; in most cases reliance is placed on a good view of the larynx during intubation, the 'feel' of the lungs during bag compression, the presence of reasonable breath sounds, and the appropriate thoracic movements. The restarting of spontaneous respiration with the appearance of bag movements is reassuring. Bronchospasm or pneumothorax can confuse the picture, but the presence of these diagnoses should be accepted only on good evidence. Difficulty in ventilating is more likely to be a consequence of a tube in the oesophagus than because of bronchospasm. The detection of breath sounds is notoriously misleading, as these may be mistaken for the sound of air passing along the oesophagus. If a blue patient goes pink the tube is unlikely to be anywhere but in the trachea. Patients do not die from 'failure to intubate', they die either from failure to stop trying to intubate or from undiagnosed oesophageal intubation. If difficulty is encountered during intubation the airway can nearly always be maintained by an oral airway and a ventilating mask and bag.

**Preventing complications**

The design of the current plastic disposable endotracheal tubes has greatly reduced the risks of complications compared with the old cuffed, reusable, red-rubber types. The types of injury following endotracheal intubation have been well described (Blanc and Tremblay, 1974). The incidence and severity of mucosal damage correlates with the duration of the intubation. Minimal damage is reported in patients intubated for less than 48 hours. With longer intubation, the incidence of mucosal damage increases especially in the glottic and subglottic areas. Severe late complications of endotracheal intubation include glottic granulomata, laryngotracheal synechiae, vocal cord paralysis and, the most severe, tracheal stenosis. Tracheal stenosis, although uncommon has been reported in at least one in 342 long-term intubated patients (Hawkins and Luxford, 1980).

The risk of complications greatly increases after intubation for more than 48 hours (Johnsen, 1973; Kane et al, 1982). Major recent improvements that have reduced the complications of endotracheal intubation are an improved understanding of the pathogenesis
of intubation injuries and advances in mechanical ventilation, respiratory therapy and endotracheal tube design and care. Prevention of airway injury from prolonged intubation depends on preventing excessive pressure on the airway structures by the cuff, and developing preshaped endotracheal tubes which conform to the airway anatomy. Laryngeal injury from long-term nasotracheal intubation is lower than that of oral intubation, probably as a result of the smaller sized tubes and the greater stability which reduces the frictional forces of the tube in the larynx during positive pressure ventilation.

The incidence of tracheal stenosis produced by cuff-induced lesions has diminished significantly with the development of the high residual volume (high volume, low pressure, high compliance or 'floppy') cuff (Arola, Inberg and Puhakka, 1981). Problems reported with the high residual volume cuff include aspiration around the endotracheal tube, a higher incidence of sore throats as a result of the larger mucosal contact, increased difficulty of intubation because the cuff obstructs the view of the larynx during insertion, obstruction of the endotracheal tube lumen on account of overinflation of the cuff and high peak pressure during coughing, and increased incidence of postintubation stridor after prolonged intubation. Animal studies have shown that ventilation by endotracheal tube with low pressure, high volume cuffs causes different but significant tracheal damage when compared to the old tubes with high pressure, low volume cuffs (Sanada, Kojima and Fonkalsrud, 1982).

The advent of the CO₂ laser microlaryngeal surgery has made it imperative to protect the plastic intubation tubes from laser-induced ignition. Wrapping the tube in metal tape will protect the plastic sufficiently, as long as it is applied correctly. Even with these precautions lasers have caused fires by ignition of dry protective material, loose metal wrapping or inadequate wrapping of the endotracheal tube (Hirshmann and Smith, 1980).

Hoarseness after an operation is relatively common and has been reported in as many as 70% of patients after operation (Stauffer, Olson and Petty, 1981; Gleeson and Fourcin, 1983). Typically the hoarseness disappears after a few days and neither the patient nor the surgeon remains concerned about the quality of the voice. However, in some cases hoarseness or even aphonia persists associated with pain on swallowing. The following factors contribute to the development of postoperative hoarseness (Jaffe, 1972):

(1) the act of intubation;
(2) the endotracheal tube during the operation;
(3) the indwelling endotracheal tube after operation;
(4) intubation and concomitant bronchitis or bronchopneumonia;
(5) an allergic reaction involving the larynx;
(6) any operation in the neck or upper thorax.

Other symptoms may include sore throat, cough, sputum production and haemoptysis in descending frequencies ranging from 40% to 10% of patients studied. The incidence of
granuloma varies from one in 800 to one in 30 as reported in the literature, but most complications resolve spontaneously (Stauffer, Olson and Petty, 1981).

One-quarter of patients ventilated and intubated in intensive care units require ventilatory support for more than one week, and 10% require aid for more than 2 weeks. Any inflatable cuff, no matter how soft, is potentially hazardous when confined within the tracheal lumen without a safety mechanism. Pressure control is essential, preferably by some means that does not require much attention. Nasotracheal intubation is generally better tolerated than the orotracheal route and can usually be maintained for 3-4 weeks.

**Laryngotomy/cricothyroidotomy**

In an emergency, failure to clear or secure the airway with an endotracheal tube may result in the death of the patient. Entry into the airway can be achieved rapidly through the cricothyroid membrane because it is superficial and an easily identifiable landmark (Roven and Clapham, 1983).

**Indications**

**Emergency**

An emergency arises when an obstructed airway cannot be secured through the laryngeal route for whatever reason.

**Elective**

Cricothyroidotomy has been condemned because of the high incidence of subglottic stenosis. In the presence of laryngeal pathology and/or prolonged intubation the incidence of subglottic stenosis is high and cricothyroidotomy as an elective procedure should not be performed (Brantigan and Grow, 1982).

**Techniques**

There are three techniques for laryngotomy/cricothyroidotomy:

1. using an intravenous catheter;
2. using a cricothyrotome;
3. a formal surgical procedure.

The patient's head is placed in the extreme extended position by placing a pillow beneath the shoulders to provide better exposure. In an emergency, a 14-gauge intravenous needle can be inserted, through the cricothyroid membrane, into the trachea and is aspirated until air is returned to signify correct position. A catheter is then directed 45° caudally and advanced over the needle into the trachea. The cricothyrotome is used in a similar manner but it is usually not readily available. Sometimes a skin incision may need to be performed to make insertion easier. In the formal surgical procedure, the instruments needed are a scalpel,
an artery forceps and an endotracheal or tracheostomy tube. The operator steadies the thyroid cartilage with the thumb and middle finger using the non-dominant hand and the cricothyroid space is identified with the index finger. The scalpel should be inserted perpendicularly through the cricothyroid membrane. A stab and twist movement without reaching the posterior cricothyroid ring gains access to the airway. With the non-dominant hand the artery forceps is slightly opened and passed around the scalpel blade into the airway to widen the hole. The scalpel is exchanged for an endotracheal tube or a tracheostomy tube. If the cricothyroid membrane is cut transversely and parallel to the tracheal rings more bleeding can be expected because of the veins crossing this area.

After a surgical cricothyroidotomy when an endotracheal or tracheostomy tube has been placed, ventilation can be managed in the normal way using an Ambu bag and an adaptor. With the intravenous catheter or cricothyrotome with Luer connection two immediate problems arise - connection to an inflation device, and producing adequate gas flow through a small bore tube with high resistance. In the casualty or resuscitation environment several methods are available: a 3 mm endotracheal tube using a 3 mL Luer lock; a syringe with a 7 mm endotracheal tube adaptor inserted into the barrel; a 10 mL syringe with the endotracheal tube inserted into the barrel with the cuff inflated. Enough oxygen is then supplied for tissue oxygenation but CO₂ removal is inefficient. If the minute ventilation is inadequate, the surgeon can at least 'buy time' for the performance of a surgical cricothyroidotomy or tracheostomy. The resistance to flow through the small bore cannula can be overcome by a high pressure oxygen source (at least 400 kPa). Flow must be intermittent and allow adequate time for exhalation. The Jet-vent or a high pressure flow system is needed to overcome these problems. An obvious hazard is hyperinflation with high intrathoracic pressures, possibly leading to cardiac decompensation or pneumothorax. High-frequency jet ventilation is the safest way to solve the problems of hyperinflation and cardiac decompensation.

Once the emergency has been controlled, the clinician can convert to a translaryngeal tube or to a tracheostomy. The long-term management plan should be specific to the patient's needs (Weymuller and Cummings, 1982). Severe laryngeal injury should mandate a tracheostomy, whereas in an obstructed laryngeal lesion the blockage may be removable endoscopically.

Complications

Complications may occur during catheter placement or during ventilation. Haemorrhage may occur from an artery or vein during placement (McGill, Clinton and Ruiz, 1982). The main problems with ventilation are subcutaneous emphysema - if the catheter slips out of the trachea - and hyperinflation. Hyperinflation occurs when laryngeal obstruction limits expiration so that the chest becomes more expansive with each inflation. Subglottic stenosis may follow cricothyroidotomy, although its true incidence is difficult to assess. It is probably uncommon unless prolonged intubation in assisted ventilation is needed (Sise et al, 1984).

A 'minitracheostomy' or cricothyroidotomy has been suggested for patients who are at risk of sputum retention (Matthews and Hopkinson, 1984), which is a major cause of morbidity and mortality following thoracic surgery and in the chronic bronchitis patient. It
has been suggested that the use of the minitracheostomy allows permanent access to the trachea for suction, while avoiding the disadvantages of tracheostomy or endotracheal intubation. The minitracheostomy preserves the function of the glottis. Patients therefore retain an explosive cough with minimal loss of expiratory air volume. However, in a recent long-term follow-up of such patients (Gleeson et al, 1984), up to 75% had subjective and objective voice changes following minitracheostomy.

Tracheostomy

Indications

Tracheostomy may be performed for any of three basic reasons:

(1) ventilatory insufficiency as a result of secretions;

(2) mechanical respiratory insufficiency;

(3) upper airway obstruction - real or anticipated.

Ventilatory insufficiency may complicate many medical conditions including infections, congestive heart failure, pulmonary oedema, chronic lung disease, or bulbar disease secondary to cerebrovascular insufficiency complicated by pneumonia. Secretory ventilatory insufficiency is now the most common indication for tracheostomy. Acute respiratory failure requiring tracheostomy may occur with a variety of conditions, including drug intoxication, head and chest trauma, elective surgery, neuropaalytic disorders and chronic obstructive pulmonary disease. In these cases requiring long-term treatment, tracheostomy may provide the easiest means of providing ventilatory assistance; it eliminates upper respiratory 'dead-space' and allows frequent and accurate pulmonary aspiration and toilet. Upper airway obstruction is now the least common indication for tracheostomy. Infectious processes and cancer of the larynx and hypopharynx, foreign bodies of the trachea or larynx, subglottic oedema from any cause, and occasionally infections of the oropharynx may require a tracheostomy. Laryngeal trauma is also an indication for immediate tracheostomy.

In general, once the tracheostomy has been performed the underlying disease is no longer an immediate threat to the airway. Since Moser's dictum that 'the time to do a tracheostomy is when you first think about it', it has been well known that in upper airway obstruction, the operation should be performed if the patient has stridor at rest, is restless, cannot lie flat, is using accessory muscles of respiration or has a rising pulse rate. A tracheostomy is indicated in patients with respiratory failure if serial measurements of the vital capacity fall to 25% of normal value. The length of time to wait after oroendotracheal intubation before performing tracheostomy is controversial. In general with the new low pressure cuffed endotracheal tubes most clinicians would currently recommend a wait of 3 weeks. In contrast if prolonged intubation is expected, an early tracheostomy may be preferable.
Surgical technique

All tracheostomies should be performed in the operating room if possible. The procedure should be carried out under sterile conditions. If the tracheostomy is carried out with adequate preparation, meticulous surgical technique and excellent postoperative care, it is safe and reliable. The procedure can be performed under local anaesthetic, but if the patient's condition does not preclude an endotracheal intubation the procedure should be performed in an orderly controlled environment.

Exposing the trachea requires a skin incision between the lower border of the cricoid cartilage and the suprasternal notch. Excellent rapid exposure is obtained through a vertical midline incision. In an elective situation, a horizontal incision gives a better cosmetic result. Under emergency circumstances, cosmesis becomes a lesser consideration when rapid control of the airway is needed. One exception is the patient admitted with stridor secondary to laryngeal tumour who should have a high tracheostomy even if this involves going through the tumour (Stell, 1973). The tumour should then be removed as quickly as possible as the tracheostomy may become the site of tumour recurrence. After the skin has been opened the strap muscles can be separated by blunt dissection in a vertical plane through the linea alba. Dissection through this area should be relatively bloodless, although communicating venous channels may be encountered. All bleeding should be controlled at entry as identification of bleeding areas can be impossible once the tracheostomy is placed in position. The isthmus of the thyroid gland should be clamped with artery forceps, transected in the midline, and transfixed, exposing the trachea. The thyroid gland must be divided in the midline, as deviation from this can result in profuse haemorrhage and even recurrent laryngeal nerve damage. The technique of retracting the thyroid isthmus superiorly or inferiorly may be quicker, but the risk of airway obstruction during early tube change is real and this procedure should be avoided unless the surgeon carries out the first tube change.

The opening into the trachea should lie at the level of the second to the fourth tracheal ring to avoid damage to the cricoid cartilage which can result in subglottic stenosis. The tracheal incision should be of the type that least disturbs the tracheal anatomy (Bryant et al, 1978). The vertical incision is more than adequate for this purpose. Some surgeons recommend a superiorly or inferiorly based flap (Bjork) or even the removal of a segment of cartilage; these procedures are advised to facilitate retention and changing of the tube. However, the disadvantages of these procedures include tracheal stenosis, delayed healing after removal of the tube with the formation of a tracheocutaneous fistula which frequently requires formal closure. In the patient with a short fat neck the use of the cricoid hook to elevate and stabilize the trachea can be invaluable in making the tracheal incision. If the trachea is soft and malleable as in the young the insertion of laterally based stay sutures at the tracheal opening can be helpful and aid with changing the tube later. In the elderly, it may occasionally be necessary to use the Mayo scissors or even bone cutting forceps to open into the tracheal lumen. If the tracheal cartilages are found to be calcified it is better to remove an adequate portion of anterior tracheal wall to allow easy entry of the tracheostomy tube rather than outfracture the tracheal rings.

The tracheostomy tube should have been previously selected and checked for leaks in the cuff before insertion. In general, tubes of size 33 or 36F are suitable for women and tubes of 36-39F for men. Once the tube has been inserted into the trachea the obturator is removed
immediately, and the blood and mucus aspirated from the lumen. The wound must not be closed too tightly at the end of the operation, as this can lead to rapid development of alarming surgical emphysema of the neck. The flanges of the tracheostomy tube should be sutured to the skin using strong silk to prevent dislodgement. The wings or flanges of the plastic tracheostomy tube can be shortened so the tapes cannot be used during the initial recovery period. The practice of tying in the tracheostomy tube with a surrounding gauze pad should be discouraged for the first 24 hours, at least, as the pad may obscure any sign of bleeding and may even encourage surgical emphysema as the tissue become swollen.

**Emergency tracheostomy**

A tracheostomy performed in an emergency under local anaesthetic can be a harrowing experience for all concerned and should be avoided wherever possible by prompt decisions to perform elective procedures. However, the patient and the situation sometimes dictate otherwise, for example a cautious anaesthetist who is reluctant to attempt intubation in a stridulous patient with a known mass in the upper airway.

The patient should be placed in the usual position if possible with the head extended and the shoulder supported to give maximum exposure. Local anaesthetic (lignocaine 1%) should be injected into the incision area and into the strap muscles. Care should be exercised that the local anaesthetic is not placed into the trachea otherwise paroxysmal coughing may turn a semi-emergency into an absolute emergency. The local anaesthetic should not be placed in the paratracheal gutter as the recurrent laryngeal nerves may be paralysed, increasing respiratory distress. During the procedure the patient should be reassured that all is proceeding according to plan. When the trachea has been exposed the thyroid isthmus becomes a problem. There is a tendency to mobilize the thyroid off the trachea and move it upwards or downwards rather than dividing it. It is recommended that the thyroid isthmus be divided rather than mobilized as the thyroid can occlude the airway during early postoperative changing of the tube. It is important that the thyroid is divided in the midline as deviation from the path will cause torrential haemorrhage. The thyroid isthmus should be clamped in the midline using two artery forceps, it is divided and the cut ends transfixed by silk sutures. Once this stage has been carried out local anaesthetic should be instilled into the trachea to suppress the cough. The patient should be warned at this stage that he can no longer speak. This warning can help to minimize the panic that often accompanies this type of operation. If the patient becomes distressed or loses his airway during an emergency tracheostomy an airway must be secured without delay, otherwise the patient will die.

Once the skin has been incised, the trachea needs to be identified and stabilized using the thumb and the index finger of the non-dominant hand. Holding the scalpel in the dominant hand the strap muscles should be divided in the midline until the tracheal cartilages are identified. By retracting the skin and the strap muscles the trachea should be opened longitudinally. Using an artery forceps the trachea can be opened to allow the correct placement of the tracheal tube in the tracheal lumen. The cuff is then inflated to protect and control the lower airway. The emergency situation should now be controlled.

During an urgent tracheostomy the bleeding can be profuse and sometimes terrifying to the inexperienced. The surgeon must not waste time in attempting to stop the bleeding, but first secure the airway. To the surgeon's surprise the bleeding dramatically subsides once the
trachea is opened. It cannot be emphasized often enough that it is the surgeon's responsibility to make sure that the assistants do not retract the trachea from the midline during the surgery. The surgeon must dissect down on to the trachea because if exploration deviates from the midline major complications may result.

**The tracheostomy tube**

The selection of the tracheostomy tube is usually governed by the requirements of the operation and the postoperative care. Usually a plastic tube with an inner cannula and a built-in cuff is preferred if the patient requires protection of the lungs from aspiration or haemorrhage. If the patient requires controlled ventilation, a cuffed Shiley or Portex tube with a high volume, low pressure cuff system is satisfactory. A fenestrate tube permits the passage of air upwards through the glottis thereby allowing the patient to speak.

There are two types of tracheostomy tube.

**Metal tubes**

Metal tubes, whatever their design, have several basic common principles: an obturator, an outer tube, and an inner tube. The inner tube is always slightly longer than the outer tube so that crusts can collect on the protruding end. Cleaning of the inner tube can be performed unhurriedly because the outer tube maintains the patency of the airway. Newer tracheostomy tubes have a flange which is not rigidly attached, allowing free movement of the neck. In unusual situations special tubes are available - Koenig's tube for extensive and low narrowing of the trachea, and Durham's tube in which the position of the flange is adjustable, so that it can be used for patients with either thin or very fat necks. The main disadvantages of the metal tubes are that they do not have a cuff, and cannot therefore produce an airtight seal. If the metal tubes do not fit properly, the end of the tube can erode the anterior tracheal wall. It must be remembered that the metal tracheostomy tubes are manufactured and supplied as a ‘set’. Therefore only complete sets should be used otherwise complications may result.

**Non-metal tubes**

Non-metal tubes are made of rubber or silastic. Their advantage is that they almost all have an inflatable cuff and can be connected to an anaesthetic machine or a respirator. They do not produce mechanical damage to the trachea. Paradoxically the main disadvantage of these tubes is the inflatable cuff: it should be blown up to the point where there is a slight air leak past it and it should be deflated for 5 minutes in every hour. It is absolutely essential to maintain a permanent airtight seal, this can be achieved by the use of a Salpekar tube, which has two cuffs, one above the other, allowing alternate deflation and inflation of each cuff.

**Elective tracheostomy**

Any major operation on the mouth, pharynx and larynx always constitutes a danger to the airway, both as a result of direct surgical trauma and by physiological disturbance of the swallowing mechanism. In many of these patients with uncertain general condition,
particularly cardiovascular or pulmonary deficiency and advanced age, elective tracheostomy should be considered. Generally there is nothing to lose by its use - better too often than too late (Shaw, Stylis and Rosen, 1974).

Postoperative management

Much of the morbidity and some of the mortality attributed to tracheostomy can be prevented by meticulous postoperative care by the surgeon / physician in charge, the nursing staff, the patient and his family. Initially, frequent suction is necessary because the tracheostomy robs the patient of his ability to cough and he cannot clear the secretions from his tracheobronchial tree. The secretions are profuse for the first few days and may require a full time special nurse to perform very frequent suction if lower respiratory infections are to be avoided. The secretions result from the trachea being exposed to the cooler and drier air that it has been used to. The trachea therefore needs to be sucked out at frequent intervals. No specific time interval can be set and suction is required when indicated. The attending staff must obey the usual aseptic ritual: wash, wear gloves, and the suction tube should be sterile and preferably disposable. Changing the tracheostomy tube should not be necessary for at least 36-48 hours. At this time the tract will have epithelialized and the hole in the trachea will usually be readily found. However, even in experienced hands the trachea may occasionally be difficult to find, and therefore it is important that the surgeon who has performed the tracheostomy should do the first tube change. When the nursing staff are expected to do the tracheostomy changes the whereabouts of a medical staff member should be known in case the airway is lost.

Patients who are having their tube changed are placed in the tracheostomy position, that is lying flat and with the head extended. When the tube is withdrawn many patients experience paroxysmal coughing and the patient is therefore instructed first to inhale deeply, so that on removal of the tracheostomy tube all the secretions and debris are blown out rather than aspirated.

During the early postoperative phase the inspired air needs to be adequately humidified to prevent crusting. The use of saline or sodium bicarbonate instillations into the trachea, 1-2 mL/h, helps to reduce the likelihood of such complications and aids with suction clearance of the mucus secretions (Schild, 1970).

Complications

As with any other operation the complications of tracheostomy may be immediate, that is during or immediately after the operation; intermediate, happening during the rest of the patient's stay in hospital; or late, commencing after the patient has gone home (Conley, 1979). Table 9.2 lists some of the more common of these complications.

Immediate

Haemorrhage

Haemorrhage during the operation is frequent, arising from the anterior jugular veins or the thyroid gland. Bleeding should be controlled at once by diathermy or ligation. If the
bleeding is profuse and difficult to control digital pressure should be applied and the wound extended to allow a direct view of the bleeding area. Blind groping and grasping in a small hole is to be condemned as further bleeding and other tissue damage can result (Stemmer et al, 1976).

**Table 9.2 Complications of tracheostomy**

*Immediate*
Haemorrhage
  - thyroid veins
  - jugular veins
  - arteries
Air embolism
Apnoea
Cardiac arrest
Local damage
  - cricoid / tracheal cartilage
  - recurrent laryngeal nerves

*Intermediate*
Dislodgement / displacement of the tube
Surgical emphysema of the neck
Pneumothorax / pneumomediastinum
Scabs and crusts
Infection
Tracheal necrosis
Tracheoarterial fistula
Tracheo-oesophageal fistula
Dysphagia

*Late*
Stenosis of the trachea
Difficulty with decannulation
Tracheocutaneous fistula / scars.

**Air embolism**

Air embolism is a serious complication but fortunately is very rare. During surgery large neck veins can be inadvertently opened with large volumes of air sucked in and passing rapidly into the right atrium. This situation can produce a critical situation leading to tamponade and death if not recognized. The complication can be minimized by meticulous surgery with good access and visibility.

**Apnoea**

Apnoea is thought to be the result of the sudden discharge of the pent-up carbon dioxide from within the lungs once the obstruction has been suddenly bypassed. A quick way
of resolving this difficulty is to make the patient breathe a mixture of 95% oxygen and 5% carbon dioxide.

**Cardiac arrest**

Cardiac arrest may occur during a tracheostomy. The three most important factors appear to be excessive adrenaline production in the anxious patient; a rapid rise of the pH, consequent upon washing out of retained CO₂; and hyperkalaemia consequent upon respiratory alkalosis.

**Local damage**

In a short chubby neck great difficulty can be experienced with placing the tracheal incision in the correct position. It is better that the incision be placed lower than through the cricoid or the first ring as there is an increased risk of subsequent tracheal stenosis. Unilateral or bilateral vocal cord paralysis may arise from inadvertent injury to the recurrent laryngeal nerve during an emergency tracheostomy, particularly if the dissection deviates from the midline.

**Intermediate**

**Dislodgement / displacement of the tube**

The length of the tracheostomy tube and the thickness of the soft tissues of the neck are clearly the most important factors, however, the modern tubes are of sufficient length to obviate accidental withdrawal of the tube. Nevertheless the silver tubes of Negus and Chevalier Jackson are shorter and should be used only in patients with thin necks. Postoperative oedema, haematoma and emphysema will cause a broadening of the distance between the skin surface and the anterior tracheal wall, the process of expansion dragging the tube out of the trachea. The technique of suturing the flanges to the skin will help to minimize the possibility of dislodgement during the early period. In the later period the tracheostomy tapes should be tied with the neck in flexion, in which the girth of the neck is the smallest; if tied in extension the tapes will be loose once the head comes forward.

**Subcutaneous emphysema**

Subcutaneous emphysema can be alarming but is seldom fatal. Many factors may contribute to this complication - an over-large incision in the trachea, depression of the superior flap of the trachea above the incision, obstruction to the egress of air by glottic or pharyngeal obstruction, a tube that is partially obstructed or diverts air into the soft tissues of the neck, too tight closure of the subcutaneous tissues and skin about the tracheostomy tube causing a ball-valve effect, and excessive coughing. The emphysema is most often confined to the neck but can extend to the face and the chest wall. It usually presents within the first day and is self-limiting by the around the seventh day, unless the precipitating factors persist. The patient may develop a low grade pyrexia with localized cellulitis and a feeling of discomfort caused by stretching of the skin. The most frequent causes are tight skin closure and an improperly fitting tracheostomy tube; they should be rectified at once. In this situation
the risk of the tracheostomy tube being dislodged is increased because of the local increase in neck swelling.

**Pneumothorax / Pneumomediastinum**

These conditions may arise after any operation in the root of the neck. Usually this complication occurs in patients who are having surgery under local anaesthetic and are struggling, gasping and coughing. Occasionally the apex of the lung can be high in the neck and may be punctured accidentally. The diagnosis should be considered in all patients after the creation of the tracheostomy if the dyspnoea has not improved. A chest X-ray will confirm the diagnosis. Under severe circumstances, immediate needle aspiration with a 14-16 gauge needle into the upper anterior thorax will confirm the diagnosis and improve the patient's condition. The patient almost always needs aspiration and drainage.

**Scabs and crusts**

A tracheostomy alters the basic physiology of the inspired air from filtered, warm and humidified to dry, cold air coming into direct contact with the trachea. This alteration dries the tracheal and pulmonary secretions which interfere with the ciliary capacity to move the mucus blanket, and thus causes a production of thick, tenacious, mucus scabs and crusts. This basic interference with the movement of the ciliary blanket and the perpetuation of the drying process, is one of the most serious aspects in the postoperative course of tracheostomy. If not corrected, this sequence of events leads to infection, obstruction, atelectasis and pneumonia. If the situation is not controlled the scabs will increase in size, with the result that they are difficult or impossible to cough out or even remove by suction. Therefore the air supplied to the tracheostomy needs to be humidified artificially.

Air saturated with water vapour may be supplied by an old fashioned but cheap and reliable steam tent. Commercially available humidifiers are available in most hospitals nowadays. A simple method of droplet infusion is to introduce, in an adult, 15 drops/minute of saline via a fine bore plastic catheter or to instil 5 mL/h via a syringe directly into the trachea. Suction is applied as necessary with a sterile, disposable, smooth-tipped catheter; the nurse should wear sterile gloves. Many of these patients aspirate their oropharyngeal secretions and thus have an excessively wet trachea. There is a constant slow adaptation process over weeks, and ultimately the trachea adapts to its new dry environment. The patient should be encouraged to regulate and adjust his own humidification before discharge from hospital. In some instances it may be necessary to insert a bronchoscope to clear out the trachea and bronchi.

**Infection**

All tracheostomy wounds become locally contaminated within hours. However, all tracheostomy wounds should be attended with the strictest of local hygiene. Local dressings applied around the tracheostomy wound help to reduce the pressure on the neck skin and avoid necrosis. However, during the early period these dressings need to be changed frequently as secretions and blood accumulate. Barrier creams applied to the skin help to reduce the risk of local skin infections. Some patients develop Pseudomonas infections locally which may progress to fatal septicaemia. Prophylaxis is the best counteraction to infection.
Fortunately infection in the neck wound is usually local, indolent and produces local cellulitis with some granulation tissue. As the wound is open drainage is adequate and seldom are antibiotics necessary.

**Tracheal necrosis**

This complication most frequently follows local pressure secondary to infection. The pressure is derived from over-sized tracheostomy tubes, an improper curve of the tube, impingement of the tip of the tube or the pressure of the balloon on the trachea. The effect of this pressure begins as an ulcer on the wall of the mid or low cervical trachea. Previous irradiation, low grade infection and poor physiological status exaggerate the condition. This may lead to necrosis of the trachea with subsequent stenosis, tracheo-oesophageal or tracheoarterial fistula. It is therefore essential that the regulation of the pressure in the cuffed tubes in the intensive care units or on the ward receives the most careful attention. Any sign of bleeding, pain or obstruction should attract immediate investigation and remedial action by the elimination of the pressure factors, careful inspection of the ulcer, with a decision to allow the ulcer to heal by secondary intent or to excise the ulcer and attempt primary closure. Occasionally in large ulcers, the great vessels are at risk and need to be protected with a muscle flap with withdrawal or change in position of the ventilatory apparatus.

**Tracheoarterial fistula**

This tragic complication occurs in about 0.4% of tracheostomies. It is associated with an improper position of the tracheostomy tube against the vessel, improper curve and length of the tube, or is secondary to pressure from the cuff. It is almost always fatal. One of the essential prophylactic measures in tracheostomy is to evaluate the position of the innominate artery by digital pressure during the procedure. A significant warning sign before exsanguinating haemorrhage is slight bleeding from the trachea any time from 3 days to 3 weeks before the catastrophe.

**Tracheo-oesophageal fistula**

There are two significant factors contributing to the production of a tracheo-oesophageal fistula. A combination of these factors causes necrosis of the posterior wall of the trachea and the anterior wall of the oesophagus, thus creating a fistula. These factors are an overinflated or improperly fitting cuffed tube, causing pressure on the posterior tracheal wall and, usually, an indwelling nasogastric tube in the oesophagus. Positive pressure ventilation is a significant contributing factor. The diagnosis is suspected clinically by violent coughing during eating, chronic coughing associated with the swallowing of saliva and occasionally air escaping into the hypopharynx. Endoscopic examination is the best method for confirming the site and the presence of the fistula. The use of contrast media for diagnosis is often confusing because it is difficult to differentiate between aspiration of the contrast through the fistula and aspiration of the contrast material into the larynx as a result of loss of the swallowing reflex. Once the diagnosis is confirmed the best approach is surgical closure.
**Dysphagia**

Difficulty in swallowing is often encountered for the first few days after tracheostomy. This situation can be managed by feeding the patient through a Ryles tube or by inflating the cuff of the tracheostomy tube during feeds. This difficulty with swallowing may be related to the original indication for tracheostomy but other factors may contribute: tethering of the larynx so that it cannot move upwards during swallowing; the pressure of an inflated cuff on the oesophagus, or very rarely, as a result of ulceration of the tracheo-oesophageal wall producing a fistula (Bonanno, 1971).

**Late**

**Stenosis of the trachea**

Most tracheal stenoses result from the inflatable cuff on the orotracheal or tracheostomy tubes, others from scar contracture caused by improperly placed incisions, repetitive incisions, tracheal resections and trauma, tracheal infections or organic disease of the trachea.

**Difficulty with decannulation**

Most tracheostomies are temporary; the patient is ultimately decannulated and the tracheocutaneous fistula is closed. In the early phase of the tracheostomy the tube can be withdrawn without much difficulty because the wound is clean, no granulations have formed and the skin edges are still raw which leads to rapid closure. When the tube has been in place for weeks, months or even years removal may be difficult - granulations may have formed developing into fibromata resulting in tracheal strictures. Patients with tracheostomy of long duration should be carefully examined before the tube is removed. Lateral neck X-ray or xerograms with or without tomography can show granulations or fibromata gathering at the entrance of the tracheostome. Sometimes the trachea needs to be inspected directly to assess the lumen. Some tracheal narrowing can be demonstrated in more than 90% of patients after tracheostomy, and is most often seen near the site of the stoma (Lulenski, 1981). Functional impairment is rare unless the trachea has been narrowed more than 50% as measured in biplane radiographs. If the airway appears adequate, tube sizes can be decreased until the patient is breathing through the glottis. The smaller tube may be closed over with tape, or a plug can be inserted for several days before final removal of the tube. If the wound is recent it will close in 1-2 days, but if it is of longer duration it may be necessary to close it surgically.

**Tracheocutaneous fistula and scar**

The tracheal wound and the skin incision usually close by secondary intention, but occasionally fistulae persist particularly if the tracheostomy remained for a long period. A persistent fistula causes continual tracheal secretions with skin irritation, disturbed phonation, frequent infections and poor cosmesis. The scar after secondary closure is usually cosmetically unacceptable to the patient and family. The skin is usually thin and frequently becomes attached to the trachea by fibrous tissue so that the scar moves up and down when the person swallows and causes a tug on the trachea. Most fistulae heal spontaneously if they have been
present for less than 16 weeks, but if they have been present for longer most will need to be closed. Surgery is best performed with endotracheal anaesthesia; the old scar is excised and the strap muscles mobilized. The wound should be closed in layers with a small corrugated drain to avoid the risk of haematoma formation or surgical emphysema (Kulber and Passey, 1972).