SURGICAL TRACHEOSTOMY VERSUS PERCUTANEOUS TRACHEOSTOMY - A HANDBOOK

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INDEX

PREFACE .................................................................................................................................................................................. 6
ACKNOWLEDGEMENT .................................................................................................................................................................... 7
  - INTRODUCTION ........................................................................................................................................................................... 8
  - RELEVANT SURGICAL ANATOMY AND PHYSIOLOGY ........................................................................................................ 9
    - THE INFRAHYOID DEEP STRUCTURES .................................................................................................................................. 9
    - PHYSIOLOGY .................................................................................................................................................................................... 12
  - TRACHEOSTOMY ........................................................................................................................................................................... 15
    - HISTORY .......................................................................................................................................................................................... 15
    - METHODS OF SECURING A SAFE AIRWAY ................................................................................................................................... 17
  - SURGICAL TRACHEOSTOMY VERSUS PERCUTANEOUS TRACHEOSTOMY ........................................................................... 20
    - CHOICE OF TRACHEOSTOMY .................................................................................................................................................... 20
    - SURGICAL TECHNIQUES ............................................................................................................................................................... 25
    - COMPLICATIONS OF TRACHEOSTOMY ....................................................................................................................................... 34
    - TYPES OF TRACHEOSTOMY TUBES ......................................................................................................................................... 36
  - TRACHEOSTOMY MANAGEMENT .................................................................................................................................................. 42
  - APPENDIX ..................................................................................................................................................................................... 47
    APPENDIX-I: ALGORITHM FOR DISLODGED TRACHEOSTOMY TUBE .................................................................................. 47
REFERENCES .................................................................................................................................................................................. 48
PREFACE

The primary objective of airway management is to secure unobstructed gas exchange and protect the lungs from aspiration. Compromise of upper-airway patency is a life-threatening emergency. There are many alternatives to managing the difficult airway. Tracheostomy is considered to be a safe technique to achieve adequate ventilation for patients who suffer from an obstruction of the upper airway or need long-term ventilation.

Even though tracheostomy was performed in ancient times, modern approaches to open tracheostomy are still based on the classic descriptions of tracheostomy by Chevalier Jackson in 1909. Later, cricothyrotomy and percutaneous tracheostomy emerged as alternative techniques. Whatever the technique be, a sound procedural knowledge of tracheostomy along with tracheostomy care and techniques of decannulation are essential.

The objective of this handbook on surgical tracheostomy versus percutaneous tracheostomy is to provide a brief overview regarding the techniques, indications, contraindications and complications of both surgical and percutaneous tracheostomy. Further, we have attempted to discuss the aspects of tracheostomy management.

We hope that otorhinolaryngologists, anesthetists and residents will find this handbook informative, clinically relevant, and a substantive guide for airway management.

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Dr. Mutlaq Al-Sihan
INTRODUCTION

A tracheostomy is usually done to bypass an obstructed upper airway, to clean and remove secretions from the airway or to more easily, and usually more safely, deliver oxygen to the lungs. Tracheostomy is one of the oldest surgical procedures documented by Asclepiades, the Greek physician in 100 BC. It became widely used in the 19th century during the diphtheria epidemics in Europe, and then in the 20th century following a series of devastating poliomyelitis epidemics in the 1950s.

Tracheostomy is considered to be a safe technique to achieve adequate ventilation for patients who suffer from an obstruction of the upper airway or need long-term ventilation. Standard operative technique for tracheostomy described by Chevalier Jackson has remained unchanged for over more than a hundred years. Alternative procedures like cricothyrotomy and different techniques for percutaneous tracheostomy have evolved recently due to advances in technology and interest in minimally invasive procedures.

Among the different strategies for formation of a tracheostoma, the following techniques were widely used: open surgical tracheostomy (ST), first described in 1909, and predominantly performed by surgeons, and the interventional strategy of percutaneous tracheostomy (PT), initially described in 1985 & performed by surgeons, internists, and anesthetists. Nevertheless, the adoption of one or the other method is usually done based on surgeon's preference or experience, patient's clinical condition, availability of surgeon, theater & staff, etc.
RELEVANT SURGICAL ANATOMY AND PHYSIOLOGY

The lower respiratory tract begins at the level of the vocal cords. Inferior to the vocal cords, the rigid cricoid cartilage encases a 1.5–2.0-cm region known as the subglottic space. Access to this space is possible via the cricothyroid ligament, a membrane that runs from the thyroid cartilage inferiorly to the cricoid cartilage.

Inferior to the cricoid cartilage begins the trachea, opposite to the lower border of C6 Vertebra. The trachea is a cylindrical tube that extends inferiorly and slightly posteriorly, following the curvature of spine. It is made up of 18 to 22 C-shaped rings, with rigidity and flexibility provided by rigid cartilaginous portions anteriorly and laterally maintaining its patency and a soft membranous portion posteriorly, permitting expansion of esophagus during deglutition. In adults, the average distance from the cricoid cartilage to the carina is approximately 10 to 13 cm.

If the neck is extended roughly about half this length, the trachea will be within the confines of the neck making surgery easy. On average, the trachea is 2.3 cm wide and 1.8 cm deep in the anterior-posterior direction. The trachea is generally wider in men than in women.\(^{(5)}\)

THE INFRAHYOID DEEP STRUCTURES:
The infrahyoid structures in the anterior median region of neck are grouped into three planes: a superficial plane of infrahyoid muscles that include sternohyoid, sternothyroid, thyrohyoid and superior belly of omohyoid; a middle plane of pretracheal fascia enclosing thyroid gland; and a deep plane of larynx and trachea with their associated structures. (Fig.1)
**A) Superficial plane:**
Beneath the skin are the superficial fascia with platysma and the deep fascia. The sternohyoid and sternothyroid muscles meet at the midline of the neck and are fused together by an avascular fascia that must be incised and retracted laterally to reach the trachea. Motor nerves (ansa cervicalis-C1, C2, and C3) run deep and enter in the lower half of sternohyoid and sternothyroid muscles, and if additional retraction is needed, it should be done superiorly in the upper half to avoid damage to these nerves.

**B) Middle plane:**
The thyroid gland is encased in the middle layer of the deep cervical fascia and is suspended in the anterior neck by a suspensory ligament (Berry) from the cricoid cartilage. Inferior thyroid veins lie within this fascia.

The posterior portion of the gland is attached to the sides of the cricoid cartilage and first and second tracheal rings by the posterior suspensory ligament. The thyroid gland is found anterior to the trachea, with an isthmus crossing the trachea at the level of second or third tracheal rings. This tissue is vascular and should be divided and ligated for adequate homeostasis during this surgical procedure.

The blood supply relevant to surgical tracheotomy is the associated minor arterial and venous supply to the thyroid gland and the brachiophecalic trunk (innominate artery) in the superior outlet of the mediastinum. The superior thyroid artery is the first branch of the external carotid artery, and it descends laterally to the larynx and sternohyoid. It becomes superficial on the anterior part of the gland, supplying the isthmus and anastomoses with the contralateral superior thyroid artery. The inferior thyroid artery arises from the thyrocervical trunk, a branch of the subclavian artery. It is normally found in the tracheoesophageal groove and enters the larynx near the inferior part of the cricoid cartilage.

The great vessels (i.e., carotid arteries and internal jugular veins) may be damaged if the dissection is carried too far laterally. The innominate artery or brachiophecalic trunk crosses from left to right in the anterior superior portion of the thoracic inlet, anterior to the trachea, and it is found under the sternum. This vessel can create significant life-threatening hemorrhage if it is damaged during surgical tracheotomy. Occasionally, a single vessel called the thyroid ima artery originates from the arch of the aorta or the innominate artery and enters the thyroid gland near the isthmus.
Venous drainage of the area is provided by the superior thyroid and middle thyroid veins, which drain into the internal jugular veins bilaterally. The inferior thyroid veins follow a different pathway on each side. On the right, the vein passes anterior to the innominate artery to the right brachiocephalic vein or anterior to the trachea to the left brachiocephalic vein. On the left, the vein drains into the left brachiocephalic vein.

If bilateral inferior thyroid veins anastomose in the middle, they form the thyroid ima vein, which also drains into the left brachiocephalic vein. The anterior jugular vein begins just below the chin through the union of several small veins. It is found superficially and close to the midline of the neck as it descends over the isthmus of the thyroid. It may be encountered during the surgical approach in the midline of the neck.

C) Deep plane:
The deep plane comprise of thyrohyoid membrane deep to thyrohyoid muscle, thyroid cartilage, cricothyroid membrane, arch of the cricoid cartilage, cricothyroid muscle, trachea, carotid sheaths & occasionally left brachiocephalic vessels which may lie in front of the trachea in the suprasternal notch. The thyrohyoid membrane is pierced by internal laryngeal nerve and superior laryngeal vessels. Injury to the internal laryngeal nerve can result in anesthesia of the mucous membrane in the supraglottic part of larynx. Superior laryngeal nerve is found along the superior thyroid artery, and inadvertent damage to this nerve creates dysphonia by altering the pitch regulation.

The recurrent laryngeal nerves travel in the tracheoesophageal grooves and may be damaged if dissection strays too far laterally. Damage to recurrent laryngeal nerves may result in hoarseness, aphonia, and an increased risk of aspiration. (6)
**PHYSIOLOGY**

Although the primary function of the respiratory system is exchange of gas between the air and blood stream, it also provides pathway for movement of air during inspiration and expiration, protect the body from dehydration, temperature fluctuations and entrance of pollutants or pathogens and aids in vocalization.

The upper respiratory tract includes the nose and nasal cavity, pharynx and the part of larynx above the vocal folds. The nose and nasal cavity aids in olfaction and filters the air using cilia and mucus. Further, along with the sinuses help regulate the temperature and humidity of the air we breathe. The oral cavity also acts as an opening to the respiratory tract but does not provide filtration, humidification or temperature regulation.

The pharynx is the muscular tube behind the nasal and oral cavity which connects them to the larynx and esophagus.

The lower respiratory tract begins from the part of larynx below the vocal folds and includes trachea, bronchi, bronchioles and alveoli. Air passing through the glottis vibrates the vocal folds and produce sound waves. The bronchi and bronchioles lead to alveoli within the lungs. Every alveolar bundle is surrounded by a capillary network to have effective diffusion. Low airway resistance and a high elasticity allow for a very efficient system.

**Lung volumes**

At rest, an adult breathes in about 500 mL of air (7–8 ml/kg body weight) with each breath. This is referred to as the tidal volume. Hence 5–6 L of air is breathed in and out each minute. This is enough to meet the needs of the cells of the body at rest, which require around 250 mL per minute. During exercise, oxygen requirements may reach as much as 4 L per minute. To keep up with demand, the volume of air inspired per minute may reach as high as 80 L per minute. However even at rest, we can consciously increase the volume breathed in, or further deflate the lung. Thus there are inspiratory and expiratory reserve volumes.

In addition, the lung contains a volume of gas even after maximal expiration has occurred, as deflation of the alveoli is incomplete and some gas fills the dead space, i.e. there is a residual volume of gas within the lungs which in adults about 1.5 L.
Consequently, the gases within the lung into which inspired air will pass when we breathe in will be the volume represented by the expiratory reserve plus the residual volume; this is the functional residual capacity (FRC) which is around 2.5 L in an adult.

This is equal approximately to half the maximum capacity of the lungs called the total lung capacity. If we inflate the lungs maximally and then breathe out maximally, the volume of gas expired from the lungs represents the maximum volume of gas that can possibly be expelled from the lung in a single breath; this is called the vital capacity which is around 4 L in an adult. If we add the vital capacity to the residual volume, then this gives the total lung capacity which is around 5–6 L in an adult.

The anatomic dead space is the volume of respiratory tract that does not exchange gas. This includes the nose, pharynx, trachea and bronchi. This is about 2mL/kg in the spontaneously breathing individual. Alveolar dead space is the volume of gas that reaches the alveoli but does not take part in gas exchange because the alveoli are not perfused. In healthy individuals, alveolar dead space is negligible. Physiologic dead space is the sum of anatomic and alveolar dead space.

Insertion of a tracheostomy tube alters the airway physiology. Some of the physiological changes are advantageous in treating these patients. Others necessitate extra vigilance and care. Bypassing the nasal airway not only impairs olfaction and taste but disturbs the normal humidification, filtering and warming of inspired air. In the absence of adequate humidification,
the trachea develops squamous metaplasia and chronic inflammatory changes. Dessication of the tracheal mucosa reduces ciliary function.

These factors along with diminished effective cough and overproduction of secretions predispose to respiratory tract infections and blockage of the airway/tracheostomy tube. Furthermore, these tubes also hamper effective swallowing and coughing, thereby predisposing to aspiration.

Vocalization is also affected as airflow bypasses the larynx. Altered body image is an important factor as it can have a major psychological impact. If possible the patient should have careful preoperative explanation. If this is not possible the patient must receive explanation and support postoperatively.

Airflow resistance of the normal upper airway is substantial, constituting up to 80% of total airway resistance during nose breathing and 50% during mouth breathing. Theoretically, tracheostomy tubes should decrease airflow resistance, but in fact this does not occur because of the smaller radius (inner diameter 7–8 mm) of the tubes.

Similarly, the endotracheal tube increases airway resistance and work of breathing, even more than a tracheostomy tube due to its length. Studies suggest that airway resistance, work of breathing, peak inspiratory pressures and intrinsic positive end expiratory pressure (auto-PEEP) decrease after tracheotomy in both ventilated and spontaneously breathing patients. As a result, standard weaning parameters such as the rapid shallow breathing index improve in difficult-to-wean patients following the conversion from endotracheal tube to tracheostomy tube. In addition, ventilator synchrony and triggering may be enhanced, although tidal volume, respiratory rate and dead space ventilation remain unchanged. These benefits, along with other variables such as secretion, clearance and patient comfort may facilitate weaning from mechanical ventilation in a tracheostomised patient.
TRACHEOSTOMY

Tracheostomy is an operative procedure that creates a surgical airway in the cervical trachea. \(^{7,8}\) Although the two terms have been used interchangeably, tracheotomy actually refers to the surgical procedure and tracheostomy, to the stoma created by this surgical procedure.

HISTORY

Tracheostomies have been performed since ancient times and the first known reference can be found in Rig Veda, the sacred Hindu scripture which dates back to (2000 BC). There were obscure references to tracheostomy in the Ebers papyrus (1550 BC) and tracheostomy was first Portrayed on Egyptian tablets in (3600 BC). Asclepiades of Persia was the first person to perform a tracheotomy in (100 BC). Tracheostomy gained popularity in the 19\textsuperscript{th} century, as it became a recognised way of treating patients with Diphtheria. High and low methods were followed in performing the tracheostomy.

Trachea was entered through the larynx by dividing the cricoid cartilage in a high tracheostomy. There were significant problems associated with this method especially laryngeal stenosis and a high mortality rate.

The second way was the ‘low’ tracheostomy in which the trachea was entered directly. This was felt to be very difficult and there were restriction about dividing the thyroid gland in order to gain access to the trachea. Till the end of 19\textsuperscript{th} century, tracheostomy was considered hazardous.

In 1923 Chevalier Jackson established the principles of tracheostomy.

Jackson’s standardization of the surgical tracheostomy technique is credited with reducing the operative mortality associated with tracheotomy at that time from 25\% to 1\%. Because of the continued modern track record of safety associated with surgical tracheostomy along with the widespread use of positive pressure ventilation in the 1950s, there was considerable effort focused on the development of tracheostomy tubes as a means of providing long-term ventilatory support. \(^{9}\)

Procedures, techniques, anesthesia and devices have evolved significantly since 1952.
The origin of percutaneous tracheostomy (PT) is not certain, although the Italian surgeon Sanctorius was probably the first to describe the technique in the 16th century. Sheldon et al \citep{10} used the term percutaneous tracheotomy in 1955 and described the method as an alternative to the surgical route.

Toye and Weinstein \citep{11} introduced the technique using the Seldinger guidewire & it has since been refined with various modifications. The percutaneous tracheostomy (PT) introduced by Ciaglia et al. \citep{3} in 1985, which involves progressive dilatation with blunt-tipped dilators, is the most frequently used and evaluated in the literature.

In 1989, Schachner et al \citep{12} introduced a rapid PT technique, Rapitrac, which did not get considerable acceptance because of complications associated with, and reservations towards, the sharp edges of the dilating forceps. In 1990, Griggs et al \citep{13} reported on a PT technique using a modified Howard-Kelly forceps with a blunt edge and Fantoni et al \citep{14} reported the translaryngeal tracheostomy technique (TLT).
**METHODS OF SECURING A SAFE AIRWAY**

**A) Non-invasive positive pressure ventilation (NPPV):**
This is where a tight fitting face mask is applied over the nose and mouth and the patient’s respiration is assisted by a ventilator. This method is only possible in patients who have normal upper airways. In appropriately selected patients with acute respiratory failure (e.g. COPD), this method is effective for short periods of time (≤24 h). This method avoids the potential risks, including possible mortality, from a surgical airway. However, dealing with bronchial secretions while the face mask is applied is problematic and difficulties with swallowing are encountered with this method. It is quite often uncomfortable for the patient and may not be tolerated for long periods.

**B) Laryngeal mask airway (LMA):**
The LMA consists of a tube connected to a miniature inflatable mask. This is inserted into the patient’s pharynx and the mask is inflated. The epiglottis is pushed forwards and the oropharyngeal airway is opened up and a low pressure seal is formed around the larynx. This method is not suitable for emergency airway management as the patient is at risk of aspiration of stomach contents.

**C) Endotracheal intubation:**
Securing an airway by passing an endotracheal (ET) tube via the oro- or nasotracheal route is the most commonly used method and is the treatment of choice in the vast majority of patients with airway/breathing problems, even those with a degree of upper airway obstruction. The intubated patient is unable to speak, or swallow properly and the tube is very uncomfortable in a patient who is awake. They therefore require a degree of sedation in order to keep them comfortable. The ET tubes cause trauma to the upper airways and larynx and in up to 80% of patients there is visible tissue injury immediately after extubation. This is largely due to pressure, causing ulceration of the delicate laryngeal mucosa. These ulcerated areas can become infected and this may lead to perichondritis and ultimately to stenosis. In the majority of cases the injury is minor and does not lead to any long-term problems for the patient. However, in prolonged intubation (>2–3 weeks), there may be serious complications, with long-term laryngeal injuries.

**D) Transtracheal needle ventilation:**
This method is used to rapidly obtain a surgical airway after failed mask ventilation and endotracheal intubation. A 12- to 14-gauge (16- to 18-gauge in children), plastic sheathed intravenous cannula is pushed into the tracheal lumen via the cricothyroid ligament. In the midline, the cricothyroid ligament is a very safe route...
to the airway as there are usually no structures between the skin and the ligament. This area is therefore referred to as a bloodless field.

The cannula is then connected to an oxygen supply at 15 L/min, with either a Y-connector or a side hole cut in the tubing attached to the cannula. Intermittent insufflation can then be achieved by placing the thumb over the open end of the Y-connector or the hole in the tubing. Commercially available kits are now available in most A&E Departments or operating theatres. This method of ventilation can be used for up to 45 min; buying sufficient time to convert to a more definitive surgical airway. This technique is hazardous for patients with total upper airway obstruction as the lack of air exit may result in pneumothorax.

E) Cricothyroidotomy (minitracheostomy, laryngotomy):

In this procedure a scalpel blade is used to incise the cricothyroid ligament and the blade is then turned through 90 degrees to hold the wound open while a small ET or minitracheostomy tube is inserted into the trachea. This is extremely effective in the emergency situation and the patient can be ventilated for up to 24–48 h with this tube in situ. If ventilation is needed for longer than the cricothyroidotomy should be converted to a formal tracheostomy as there is an increased risk of subglottic laryngeal stenosis and voice problems. The procedure is contraindicated in children less than 12 years because of the risk of damage to the cricoid cartilage in younger children.

F) Tracheostomy:

This is the definitive surgical airway. Patients with tracheotomies tend to have fewer days of mechanical ventilation because of the improvements in the respiratory physiology, as alluded to earlier. This is especially true in trauma patients. They have a lower risk of laryngotracheal injury than patients with ET tubes, largely because of anatomical factors. They have improved secretion clearance as suction is easy and less strength is required for expectoration. This may be linked to the lower incidence of pneumonia and respiratory infections seen, especially in trauma victims.

The airway is more secure than with an ET tube, less sedation is required as the tube is more comfortable than an ET tube. The patients may also be able to swallow, so may be started on oral feeding sooner and mouth care is easier compared with an ET tube. The most significant benefit from a patient’s point of view is that they can communicate more easily, either by articulating or by using a speaking valve and/or fenestrated tube.
G) Percutaneous Tracheotomy (PT):

It is an alternative technique to conventional open tracheotomy for intubated ICU patients. Through a small skin incision anterior to trachea, dissection done down to tracheal wall; under bronchoscopic guidance, a small needle is inserted into tracheal lumen, and through the needle trachea is cannulated with flexible wire; using Seldinger technique, serial dilators are passed over the wire to progressively dilate to an appropriately sized tract so that a tracheostomy tube can be introduced.

It can be done when anterior neck anatomy is easily palpable, intubated patients and with ability to extend the neck.

Initially, percutaneous tracheostomy was contraindicated in pediatric cases due to their small and mobile airway with associated complications.

Recent studies to determine the safety and efficacy of percutaneous tracheostomy in pediatric population still demand an operating room setting and under rigid bronchoscopic guidance (18).

The classical surgical tracheostomy and percutaneous techniques in adult population will be discussed in this handbook.
SURGICAL TRACHEOSTOMY VERSUS PERCUTANEOUS TRACHEOSTOMY

CHOICE OF TRACHEOSTOMY

Indications for tracheostomy in adults

The classical indication for a tracheostomy is upper airway obstruction and this is why the first recorded tracheostomies were performed. However, in modern medical practice, the indications have widened both for temporary and permanent tracheostomy. Indications can be considered as:

1. To secure and maintain a patent airway in upper airway obstruction (actual or potential).
2. To secure and maintain a safe airway in patients with injuries to the face, head or neck & following certain types of surgery to the head and neck. (Elective tracheostomy)
3. To facilitate the removal of bronchial secretions where there is poor cough effort with sputum retention.
4. In an attempt to protect the airway of patients who are at high risk of aspiration, that is patients with incompetent laryngeal and tongue movement on swallowing e.g. neuromuscular disorders, unconsciousness, head injuries, stroke etc.
5. To enable long-term mechanical ventilation of patients, either in an acute ICU setting or sometimes chronically in hospitals or in the community (Respiratory failure)
6. To facilitate weaning from artificial ventilation in acute respiratory failure and prolonged ventilation.

There is no convincing data that can guide clinicians as to optimize the timing of tracheostomy. Based on available evidence from randomized controlled trials (8,19-21) there is no mortality benefit for early tracheostomy (≤ 10 days) as compared to the late tracheostomy (> 10days). However early tracheostomy was associated with more ventilator-free days, early weaning from mechanical ventilation and a shorter ICU length of stay. For specific circumstances such as extensive elective head and neck surgery, the decision is straight forward. In addition, recent trauma guidelines suggest early tracheostomy for patients with severe traumatic brain injury (22).

In other respects, clinical judgment taking into account factors such as the etiology of respiratory failure, predicted duration of mechanical ventilation, the number of daily weaning attempts, the risk of prolonged ETT ventilation, and the inherent risks of tracheostomy itself have to be considered on an individual basis.
Disadvantages of prolonged translaryngeal intubation:

- Unpleasant to tolerate
- Prolonged sedation required to tolerate the tube
- The possibility of accidental extubation or misplacement into a main bronchus.
- Difficult to re-institute respiratory support without re-intubation
- Upper airway trauma and damage to laryngeal structures
- Breaches larynx, swallowing difficulties risks aspiration
- Communication difficulties
- Difficulties in mouth care
- Blockage and displacement

Potential advantages with tracheostomy compared to prolonged translaryngeal intubation:

- Increased patient comfort (easier mobilization, Phonation, oral hygiene)
- Less sedation needed for tube acceptance
- Effective succioning of trachea-bronchial secretions along with more efficient cough (easier mobilization, Phonation, oral hygiene)
- Reduced risk of laryngeal damage in long-term intubation
- Reduced risk of accidental extubation
- Facilitate oral nutrition with less risk of aspiration
- Decreases dead space (airway resistance) and work of breathing
- Easier tube changes without sedatives or laryngoscopy
- Faster weaning from assisted ventilation
- Earlier discharge from critical care unit

Disadvantages of tracheostomy:

- Invasive procedure
- Bleeding and airway loss during procedure
- Stoma infection or breakdown
- Scarring, tracheomalacia, stenosis
- Blockage and displacement
- Damage to adjacent structures
- The larynx is bypassed and so the patient is unable to phonate
- A foreign body reaction can occur causing local inflammation

There is no absolute contraindication to performing a tracheostomy when required as it is a life-saving procedure. A strong relative contraindication is when the airway obstruction is due to laryngeal carcinoma. Prior insult to the tumor by performing a tracheostomy may lead to increased incidence of stomal recurrence. Temporary tracheostomy may be performed just under the first tracheal ring in anticipation of the definitive procedure of laryngectomy at a later time.
**Percutaneous tracheostomy (PT)**

Since 1985, percutaneous tracheostomy (PT) has gained widespread acceptance as a method for creating a surgical airway in patients requiring long-term mechanical ventilation. PT is mostly performed in the intensive care unit (ICU) where the patient is already intubated and sedated. It was proved to be simple, rapid and safe. Furthermore, the technique could be performed at the patient bedside, leading to a new way of viewing surgical access to the airway in the critically ill patient.

Percutaneous tracheostomy is generally not considered as the initial airway of choice. The timing of PT remains controversial with conflicting data regarding early versus late tracheostomy (8, 23-28).

**Benefits of percutaneous tracheostomy over surgical tracheostomy:**

1. Performed in ICU avoiding transfer to theatre
2. Shorter operative time
3. Fewer intra- and early postoperative problems
4. Improved cosmetic results
5. Reduced incidence of wound infection

**The indications of percutaneous tracheostomy are similar to surgical tracheostomy:**

1. Need for airway permeation
2. Prevention of laryngotracheal damage caused by prolonged intubation
3. Maintenance of adequate tracheobronchial hygiene, facilitating the aspiration of secretions in patients with spontaneous secretion clearing problems.
4. Minimization of sedation

**The classical contraindications of percutaneous tracheostomy are:**

- Emergency airway access
- Known or anticipated difficult endotracheal intubation.
- Cricoid cartilage not identified
- Severe local infection of the anterior neck
- Uncontrollable coagulopathy
- Unstable fractures of the cervical spine
Relative contraindications for PT:
- Children (because of their small mobile and compressible airway)
- Infection at insertion site
- Cases requiring urgent airway patency
- Anterior neck anatomical problems
- Thyroid goiter or cervical innominate artery
- Failure to palpate cricoid cartilage
- Obesity or short thick neck
- Spinal cord injury
- Previous tracheostomy application/neck surgeries
- Previous radiotherapy to the neck
- Proximity to extensive wounds or surgical wounds
- Severe thrombocytopenia and uncorrectable coagulopathy
- Operator inexperience
- High PEEP or FiO2 requirements (FiO2 >70%, PEEP >10 cm of H2O)

Even though studies show that PT is safer in older children, the characteristics of the trachea in children may make them more susceptible to certain serious complications. Guidelines or recommendations warranting its application in children are yet to be derived.

Although obesity is currently not an absolute contraindication to PT, it is a condition that does require a number of precautions. Anatomical localization may prove more difficult in some cases, and longer tracheostomy cannulas are probably required in the last step of the technique. Previous tracheostomy has been a classical contraindication to PT.

Acute respiratory failure with high FiO2 and PEEP levels is not anymore considered as a contraindication to PT. Relative contraindications for PT include but are not limited to uncorrectable coagulopathy, inability to extend the neck, c-spine instability, aberrant neck vasculature, distortion of the anterior tracheal anatomy, and overlying cellulitis. Scarce literature exists regarding the cost effectiveness of bedside performed PT versus surgical tracheostomy. Data are insufficient to draw any conclusion regarding this.\(^{(29)}\)

It is however worth keeping in mind that surgical tracheostomy may be safer if anatomical landmarks are difficult to palpate, or there is a malignancy at the site of insertion, and if emergency, tracheostomy placement is required\(^{(30)}\). Needless to say, these relative contraindications are subject to the experience and clinical judgment of the operator and are not set in stone.
Types of tracheostomy

Tracheostomy may be temporary or permanent (long term) and may be formed electively or as an emergency procedure. They may also be classified by their method of initial insertion – either surgical or percutaneous.

Temporary – will be formed when patients require long/short term respiratory support or cannot maintain the patency of their own airway. They can also provide a degree of ‘protection’ of the airways against aspiration if the swallowing or neurological control mechanisms of the larynx or pharynx are damaged (commonly in head injuries or neurological diseases).

Certain maxillofacial or ENT surgical procedures require a temporary tracheostomy to facilitate the procedure. These tubes will be removed if and when the patient recovers.

Long term/permanent – are used when the underlying condition is chronic, permanent or progressive. This includes carcinoma of the nasopharynx or oropharynx or larynx.

Dependent on the stage of the disease either a tracheostomy or a laryngectomy will be performed. Some patients need chronic respiratory support or long term airway protection and this requires a long-term/permanent tracheostomy.

Tracheostomy can also be high, mid or low. A high tracheostomy is done above the level of thyroid isthmus, violating the 1st ring of trachea. This can also induce perichondritis of cricoid cartilage and eventually lead to subglottic stenosis. This is only indicated in carcinoma of larynx, where total larynx would be removed ultimately followed by a fresh tracheostome in a clean area lower down.

A mid tracheostomy is the preferred one and is done through the 2nd or 3rd tracheal rings and would entail division of the thyroid isthmus or its retraction to expose this part of trachea.

A low tracheostomy is done below the level of thyroid istmus. This is done rarely in situations like recurrent laryngeal papillomatosis to avoid implantation. The trachea is deep at this level and in close proximity to several large vessels.
SURGICAL TECHNIQUES

Both the surgical tracheostomy and the PT require similar anesthesia, analgesia, positioning and sterile preparation. Surgical tracheostomy refers to placement of a tracheostomy cannula under direct vision after dissection of pretracheal tissues and incision of tracheal wall. PT involves blunt dissection of pretracheal tissues followed by dilatation of trachea over the guidewire and insertion of tracheal cannula using Seldinger technique.

The patient is positioned supine with a bolster placed transversely behind the shoulders to extend the neck and provide optimal exposure (unless the patient requires cervical spine precautions). The head of the bed is typically elevated $15^\circ$–$20^\circ$ to decrease venous engorgement.

Tracheostomy may be performed under local anaesthesia alone. This usually includes a vasoconstrictor such as adrenaline to reduce bleeding. If the patient is already ventilated, then some form of airway management will have occurred already, although this may not be definitive. A suitable intravenous sedative and analgesic combination should be administered and a neuromuscular blocking agent is usual. Tracheostomy is stimulating and significant doses of short acting opiates & hypnotics are often required. These should be titrated carefully in the critically ill.

Patient preparation before tracheostomy:

- Informed consent, ideally with documented discussions about the risks and benefits of tracheostomy.
- Clotting indices adjusted to acceptable limits.
- Anticoagulation stopped
- Nasogastric feed withheld
- A standard chest radiograph to assess tracheal air column; both antero-posterior and lateral soft tissue views of the neck to assess glottic and subglottic air columns.
For Patient Preparation For PT:

- Consider ultrasound scan of neck (to evaluate anatomy of major vessels and thyroid gland, in relation to tracheostomy site; localize level of tracheal rings and identify midline, puncture, depth etc.)
- Increase sedation to anesthesia levels
- Neuromuscular block with neuromuscular blocking agent
- Ventilate with 100% oxygen and adequate positive end expiratory pressure. Optimize neck position for access (a pillow beneath the shoulders will help extend the head)
- Standby difficult airway trolley in close proximity to the procedure area.
- Check airway with a direct laryngoscope, clear secretions within the oropharynx with suction, and make an assessment of ease of intubation
- Pull back the tracheal tube under direct vision or with the bronchoscope when operator is ready and re-secure so the tip of the tube lies superior to the operative site (cuff lies within or above the larynx)
- Insert bronchoscope through angle piece and orientate the view so that the operator can identify the desired entry point.
- To establish an algorithm in case of displaced tracheostomy.

A) Surgical tracheostomy:

A 2-3 cm horizontal line is marked half way between the cricoid cartilage and the suprasternal notch. This area is then infiltrated with 2% lidocaine with 1:100,000 parts epinephrine. A horizontal skin incision is made. (At the level of second tracheal ring approximately)\[^{31}\]. After division of the skin and underlying platysma, blunt dissection is continued longitudinally. The platysma muscle is then incised to identify the midline raphae between the strap muscles.

The surgeon should periodically feel for the trachea deep within the surgical field to stay midline and avoid lateral dissection. Separation of the strap muscles (i.e., sternothyroid, sternohyoid) & lateral retraction exposes the trachea & overlying thyroid isthmus.

The isthmus may be mobilized and retracted superiorly or divided\[^{32}\]. Nearby vessels can bleed substantially, and hemostasis is achieved with electrocautery or suture ligation. Pretracheal fascia and fibro fatty tissue are cleared bluntly and the second to fifth anterior tracheal rings can be visualized. A cricoid hook can provide upward traction on the trachea, thereby improving exposure. Lateral tracheal stay sutures at the third or fourth tracheal rings can provide lateral traction and stabilization and help to define the stoma\[^{33}\].
Once hemostasis and exposure are optimized, the trachea is opened vertically or transversely with a scalpel. Pole retractors in the stoma maintain patency, and the endotracheal tube is withdrawn under direct vision. A suction catheter placed into the open airway can be used as a guide for tracheostomy tube insertion. Correct placement is confirmed by parameters like direct visualization, end-tidal CO2, ease of ventilation and adequate oxygen saturation. Flexible video bronchoscopy offers adjunctive confirmation and helps bronchial clearance.

The incision in the anterior tracheal wall may be one of the following:

1. Horizontal slit tracheal opening through the membrane between the second and third or third and fourth tracheal rings (Fig 7). With this incision, a silk stay suture can be placed through the tracheal wall on each side and taped to the neck skin on either side. This facilitates tube replacement by pulling the trachea anteriorly and widening the opening should the tube dislodge in the immediate postoperative period. These sutures are removed after the first tracheostomy tube change, usually 5-7 days postoperatively once the newly formed tract from the skin to the trachea becomes more established. One disadvantage of this method is tracheal stenosis after tracheostomy closure.

2. Vertical slit tracheal opening can be made and the tracheal flaps can be tacked to skin edges with absorbable sutures to create a semi-permanent stoma (Fig 8). Sutures can be placed in each tracheal flap and taped to the chest and neck skin, facilitating replacement of a displaced tube in postoperative care. Pulling on these sutures widens the tracheal opening. Most modern adult surgical tracheostomies will be performed in this way, with the sutures remaining for approximately 1 week until the tract is formed.
Integrity of the tube cuff must be checked by inflating and deflating it. The surgeon should next ask the anesthesiologist to slowly retract the endotracheal tube above the level of the entry into the airway. The endotracheal tube should not be completely withdrawn until the placement of the tracheostomy tube into the trachea has been confirmed. With the aid of the obturator placed and locked into the tracheostomy tube, the tube is slid down into the trachea to follow the normal anatomical curvature of the trachea. Next, the obturator is removed; the inner cannula is placed, and the anesthesia circuit is connected to the tracheostomy tube; ventilation is confirmed by positive evidence of end-tidal CO2 and bilateral breath sounds by auscultation.
Using interrupted 4-0 Prolene sutures, the tracheostomy tube flange is secured to the outer edge of the neck incision. A tracheostomy neck collar-tie is used to additionally secure the flange to the neck, taking care not fasten the device too tightly. This allows some air leak from the periphery of the incision and does not create any pressure sores on the patient’s neck. To avoid the risk of subcutaneous emphysema and pneumomediastinum, the skin incision is not closed. A 4 x 4 inch sponge around the flange of the tube helps absorb minor oozing in the first 24 hours postoperatively. The laterally placed stay sutures are taped to the chest and labeled. Pulling the stay sutures up and out will apply traction to the stoma opening to assist with insertion of the replacement tube latter. They should remain in situ & securely attached to chest wall until the first or second successful tube change. A portable chest radiograph is obtained in the post-operative unit to confirm position of the tracheostomy tube and to evaluate the lung fields for presence of pneumothorax.

**B) Percutaneous tracheotomy:**

This is the most commonly used technique in critical care as it is simple, relatively quick and can be performed at the bedside using anaesthetic sedation and local anaesthetic. Several techniques and kits exist, but all employ a modified Seldinger technique. Concomitant bronchoscopy can be used to identify the point of needle insertion into the trachea and confirm correct guide-wire placement.

Many studies compared the risks and benefits of using bronchoscopy during PT. Use of bronchoscope during the procedure has certain obvious advantages such as real-time confirmation of needle placement, midline position of the needle, tube placement, and avoidance of posterior tracheal wall injury. There have however been concerns regarding its routine use. It has been found to be associated with measurable increases in intracranial pressure and alveolar derecruitment related fall in oxygen saturation.
It should be thus used with caution in patients with acute neurological condition and high ventilator requirements. Most of the guidelines do not recommend routine use of bronchoscope as there are insufficient data at present. However, it is usually considered essential if operator is inexperienced and if there is a difficult neck anatomy.

The operator should first check the open kit. The cricoid and laryngeal cartilages are palpated and a horizontal line of 2-3 cm is marked mid way between the cricoid cartilage and the suprasternal notch. This area is then infiltrated with 2% lidocaine with 1:100,000 parts epinephrine. A 2-cm transverse skin incision is made at the level of the second tracheal ring. Blunt vertical dissection is done with forceps until tracheal rings are felt. Cannulation of the trachea can then be performed using the 14G needle and cannula provided in the kit. This may be confirmed by the ability to aspirate air through the needle. This leads to guidewire insertion followed by needle removal. Subtle differences now distinguish the ways of creating a stoma.

The guidewire should be able to move freely through the cannula. Depending upon the kit being used, there may be an intermediate rigid dilator, which is passed over the guidewire.

Next, the curved dilator is passed over the guidewire, into the trachea, as far as the thick black line, in one smooth movement. An example of a curved dilator is the Blue Rhino (Cook Medical). Such dilators are coated in a lubricant that is activated by contact with saline or sterile water. The curved dilator is then removed and the tracheostomy tube, complete with introducer, is then inserted into the trachea over the guidewire.

The introducer is removed, the tube cuff is inflated and the ventilation circuit is connected. Confirmation of correct placement is achieved by assessment of chest movement, auscultation and the use of capnography. The tube should be placed preferentially between the 2nd and 3rd rings, or failing this the 1st and 2nd rings. A tracheostomy performed between the cricoid cartilage and the first tracheal ring may fracture the cricoid and may be associated with long term sequelae. The tracheostomy tube is secured meticulously with tapes and surgical stitches. The ETT should not be removed until the tracheostomy tube has been secured.
1. The Ciaglia serial dilatational technique:
After inserting the needle or cannula in the trachea, a guide wire is then passed in a caudal direction before a primary dilator is passed over the wire to begin dilatation of the tract. The Ciaglia technique uses sequential tracheal dilators (Cook Critical Care Inc.) over the guidewire. Once the tract is sufficiently dilated, a tracheostomy tube loaded onto the appropriately sized dilator is passed over the guide wire into the trachea.

![Image of Cook dilator set](Figure 11: Cook dilator set)

2. Single tapered dilatational technique:
The Blue Rhino technique (Cook Critical Care Inc.) employs a single, hydrophilically coated large tapered flexible rubber dilator. This is a modification of the Ciaglia technique and is faster. It allows progressive dilatation of the tracheal stoma in a single step, reducing the risk of posterior tracheal wall injury, intraoperative bleeding and the adverse effect on oxygenation during repeated airway obstruction by sequential dilators. Variations of this include the Per-fit percutaneous tracheostomy introducer set (Smiths Medical).

![Image of Portex and Blue Rhino dilators](Figure 12: Portex and Blue Rhino single stage dilator (Cook Medical)/Percutaneous Tracheostomy)
3. **PercuTwist:**

PercuTwist is a new technique for percutaneous tracheostomy in that stoma dilation is achieved with a unique screw like dilating device, utilizing controlled rotating dilatation method. The device has technical limitations in particular in the presence of a wide tracheo-cutaneous distance.

![Figure 13: Percu-Twist (Meteko Instrument)](image)

4. **Balloon dilatational technique:**

This method involves the same initial stages as the single tapered dilatational technique, but instead of a curved dilator a pressurized balloon is used to dilate the trachea to allow passage of the tracheostomy tube (Fig. 14).

![Figure 14: The Blue dolphin balloon dilatation percutaneous tracheostomy. (Permission for use granted by Cook Medical Incorporated, Bloomington, IN, USA.)](image)

It is thought to reduce the incidence of posterior tracheal wall injury because of the radial rather than co-axial forces generated. However, a recent study comparing the two techniques found that the Balloon Dilatational technique took longer to complete with increased intra-tracheal bleeding\(^{(35)}\). The authors hypothesized that the technique may be indicated in the presence of conditions of the trachea and oesophagus where co-axial forces are undesirable, such as cervical spine injuries or recent spinal surgery.
5. **Guide wire forceps (Griggs technique):**
The Portex Griggs guidewire dilating forceps technique (Smiths Medical) uses dilating forceps over the guidewire. These forceps are then opened splitting the tracheal membrane to the desired diameter to allow insertion of the tracheostomy tube.

![Griggs wire forceps set with modified Howard-Kelly forceps for blunt dilatation of the pretracheal and intercartilaginous tissue](image)

6. **Translaryngeal tracheostomy (Fantoni technique):**
The Fantoni translaryngeal technique (Mallinckrodt) though not technically a percutaneous method, should also be mentioned. In this technique, after insertion of the cannula or needle into the tracheal lumen the guide wire is directed cranially, parallel to the endo tracheal tube and out through the mouth. The endo tracheal tube is replaced by a narrower tube to maintain ventilation. A special tracheostomy device is introduced orally to the guide wire and drawn back internally through the airway and out to the surface of the neck through the opening formed by the introducer needle.

The tracheostomy tube is separated from the device and rotated 180° so the open end faces down towards the carina. This technique is not widely practiced and there is limited evidence to suggest that it is superior to PT or ST. \(^{(36)}\)
**COMPLICATIONS OF TRACHEOSTOMY**

Complication rates range between 4% and 31% for percutaneous tracheostomy and 6% to 66% for surgical tracheostomy.[37]

*Complications of tracheostomy (both PT and surgical tracheostomy):*

<table>
<thead>
<tr>
<th>Immediate/early</th>
<th>Late</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Bleeding</td>
<td>- Stomal infection</td>
</tr>
<tr>
<td>- Hypoxia/ loss of airway</td>
<td>- Displaced tracheal tube (false passage)</td>
</tr>
<tr>
<td>- Tracheal lesion; posterior wall perforation or tracheal ring fracture</td>
<td>- Bleeding from erosion into blood vessels (including innominate artery)</td>
</tr>
<tr>
<td>- Oesophageal lesion</td>
<td>- Subglottic or tracheal stenosis</td>
</tr>
<tr>
<td>- Displaced tracheal tube / via false passage</td>
<td>- Delayed healing after decannulation</td>
</tr>
<tr>
<td>- Obstruction of tracheal tube by blood clot</td>
<td>- Tracheo-oesophageal fistula</td>
</tr>
<tr>
<td>- Hypercapnia</td>
<td>- Permanent voice changes</td>
</tr>
<tr>
<td>- Raised intracranial pressure</td>
<td>- Scarring of the neck</td>
</tr>
<tr>
<td>- Simple or tension pneumothorax</td>
<td>- Tracheo-arterial fistula</td>
</tr>
<tr>
<td>- Pneumomediastinum</td>
<td>- Dysphagia</td>
</tr>
<tr>
<td>- Surgical emphysema</td>
<td>- Tracheo cutaneous fistula</td>
</tr>
<tr>
<td>- Atelectasis</td>
<td></td>
</tr>
<tr>
<td>- Needle damage to fibre bronchoscope (PDT)</td>
<td></td>
</tr>
<tr>
<td>- Failure of procedure</td>
<td></td>
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</tbody>
</table>

Bleeding is the most common and the most commonly fatal complication of tracheostomy. The incidence is higher with an emergency procedure.

Intraoperative bleeding is commonly due to cut edges of the vascular thyroid gland, anterior jugular vessels or inferior thyroid vessels. There is less dissection & cutting in PT than with a surgical technique and this may cause less tissue trauma & bleeding. The tissues are stretched or dilated. However, the only way to stop any bleeding if it does occur is via the tamponading effect of the tube in the stretched tract.

Surgical tracheostomy can be opted if a patient has bleeding problems or a large vessel near the puncture site as this allows more options for controlling potential bleeding (diathermy, ligation).
Other early, recognised complications include pneumothorax, which may result from direct injury to pleura, pneumomediastinum & injury to local structures like recurrent laryngeal nerve, cartilages & oesophagus.

Malposition of the tracheostomy is always possible but should, in theory, be minimized by the use of fibre-optic bronchoscopy for percutaneous insertions.

A big difference with percutaneous tracheostomies in the first few days after the stoma is created is that the tract will take 7-10 days to mature, compared with 2-4 days for a surgical tracheostomy. If a tracheostomy tube becomes displaced in this early period, the tissues are likely to ‘spring’ back into their original places making reininsertion difficult whereas the cut and sutured surgical tract is more likely to remain patent.

Tracheal stenosis may occur at the level of the stoma due to collapse of the cartilaginous ring or at the level of the tube cuff due to mucosal necrosis & fibrosis. Modern high-volume, low-pressure cuffs have reduced the incidence of tracheal stenosis.

A tracheal granuloma may develop or healing may be delayed leading to a persistent tracheo-cutaneous fistula or sinus. Sometimes, patients fail plugging trials or even decannulation for no apparent reason. Possibilities to consider include an obstructing granuloma previously held out of the way with the tube, bilateral vocal cord paralysis, fractured cartilage and anxiety. Evaluation should include fibreoptic laryngoscopy and bronchoscopy through the stoma.

**Emergency management of a displaced or blocked tracheostomy tube**

This complication can be fatal and it is important that those caring for patients with tracheostomies are alert to its clinical presentation and are familiar with a plan for its management.

Displaced tracheostomy, and to a lesser extent displaced tracheal tubes, were the greatest cause of major morbidity and mortality in ICU. Obese patients were at particular risk of such events and adverse outcome from them. All patients on ICU should have an emergency re-intubation plan.

An example of an emergency management plan is illustrated in (Appendix 1).

Recognizing that this can become a rapidly fatal complication, emphasis is placed on immediate intervention. Protocol is given on how and when to attempt to replace the tracheostomy tube but if in any doubt, the tube should be removed and attempts should be made to maintain and secure the airway from above using a facemask, supraglottic airway devices and ultimately, oral endotracheal intubation.
Types of tracheostomy tubes

The different types of tubes available can seem confusing. Essentially tubes can be described
- by the presence or absence of a cuff at the end
- by the presence or absence of an inner cannula, or
- by the presence or absence of a hole or ‘fenestration.’

Tubes can finally be made of different materials and be different diameters and lengths. Most modern tubes are made from medical grade polyvinyl chloride, polyurethane, silicone or a combination of these materials. Some are lined with special films to reduce the ‘biofilm’ that may develop inside the lumen.

1- Cuffed and Uncuffed Tubes:

Cuffed tubes have a soft balloon around the distal end of the tube which inflates to seal the airway. Cuffed tubes are necessary when positive pressure ventilation is required or in situations where airway protection is essential to minimize aspiration of oral or gastric secretions (although all cuffs are not an absolute barrier to secretions). If the tracheostomy tube lumen is occluded when the cuff is inflated, the patient will not be able to breathe around the tube, assuming the cuff is correctly positioned and inflated within the trachea.

Un-cuffed tubes do not have a cuff that can be inflated inside the trachea and tend to be used in longer-term patients who require on-going suction to clear secretions. These tubes will not allow sustained effective positive pressure ventilation as the gas will escape above the tracheostomy tube. It is essential that patients have an effective cough and gag reflex to protect them from aspiration, as there is no cough to ‘protect’ the airway. Un-cuffed tubes are rarely used in acute care.

The tracheostomy tube has an inner and an outer diameter. The size of the tracheostomy tube refers to the internal diameter (ID) and ranges from 5.0mm to 9.0mm in adult practice. The size quoted is for the outer tube, for single lumen devices, and the inner tube, for double lumen devices but only if the internal cannula is required for connection to a breathing circuit.
The inner tube has the safety advantage of being easily and quickly removed to relieve life threatening obstruction due to blood clots or secretions. This is balanced by the slight reduction in internal diameter, which can result in an increased work of breathing and lengthened weaning. It is recommended that dual cannula tubes should be used whenever possible because of the safety advantage. Regular care of the inner tube will prevent build up of secretions and reduce the risk of tube blockage. The inner tube should be removed and cleaned in sterile water every 6-8 hours or more frequently if heavy secretions load.

A spare inner tube should be kept in a clean container at the patient bedside when not in use.

2- Fenestrated Tubes:
Fenestrations maybe be single or multiple and are sited at the site of maximum curvature of the tracheostomy tube. Fenestrated tubes have an opening(s) on the outer cannula. A fenestrated inner cannula can line up with the fenestration in the outer tube & allows air to pass through the patient’s oral/nasal pharynx as well as the tracheal opening. The air movement allows the patient to speak and produces a more effective cough.

However, the fenestrations increase the risk of oral or gastric contents entering the lungs. It is therefore essential that patients who are at high risk of aspiration or on positive pressure ventilation do not have a fenestrated tube, unless a non-fenestrated inner cannula is used to block off the fenestrations.

Suctioning with a fenestrated tube should only be performed with the non fenestrated inner cannula in situ; to ensure correct guidance of the suction catheter into the trachea. Simply deflating a cuff may be an alternative approach in patients who do not require positive pressure respiratory support.
3- Tubes with sub-glottic suction:
Some newer tracheostomy tubes include a subglottic suction port, the aim of which is to try and reduce the incidence of ventilator-associated pneumonia occurring in those patients who require mechanical ventilation via a tracheostomy tube. These tubes allow continuous or intermittent suction of material that accumulates above the inflated cuff of a tracheostomy tube. Again, when the patient leaves the specialist environment, these tubes should be changed for more simple devices to avoid confusion for the carers.

4- Adjustable Flange Tracheostomy Tubes:
These tubes are used in patients who have an abnormally large distance from their skin to their trachea, and a standard tube would not fit properly. This is useful in obese patients or those with local tissue swelling, where the soft tissue depth is increased.
5- **Single Cannula Tubes:**
Single cannula tubes are traditionally the first tube to be sited in a critical care area. The system is less complicated than a double cannula tube and is usually for temporary use only. These tubes can be cuffed or uncuffed.

The larger inner diameter of the single cannula tube allows lower inflation pressures to be used when the patient is ventilated, as the larger diameter offers lower resistance to gas flow. These tubes are not used routinely in critical care owing mainly to concerns about them becoming occluded with secretions, and the difficulty in cleaning this type of tube. Indeed, without a removable inner cannula, if these tubes do become blocked, often the only way to unblock them is to change the whole tube.

6- **Double Cannula Tubes:**
Double cannula tubes have an outer cannula to keep the airway open and an inner cannula which acts as a removable liner to facilitate cleaning of impacted secretions.

7- **Speaking valve:**
Speaking valves (like the Passy Muir valve or Tracoe modular valve) are one-way small plastic device that are designed to be used with fenestrated tracheostomy tubes or unfenestrated tubes (with the cuff deflated).

They allow inspiration but not expiration. Hence the expired air is forced through the larynx allowing the patient to phonate.

![Speaking valve](image)

Figure 22: Speaking valve
Contraindications for one-way speaking valve assessment

- Severe airway obstruction
- Vocal cord paralysis - adducted position
- Severe neurological deficit
- Tracheostomy tube with inflated cuff (any kind)
- Foam-filled cuff (even if deflated)
- Severe risk for aspiration
- Less than 7 days post-operative tracheostomy tube insertion

Tracheostomy tube dimensions

The length and the diameter of the trachea are roughly proportional to the size of the individual.

A tracheostomy tube should be selected according to the outer diameter, the inner diameter and the length of the tube, rather than the manufacturer’s “size”, which is not standardized between models or manufacturers. I.e. a “size 8” from one manufacturer is likely to have different dimensions to a “size 8” from another (see table 1).

Table 1: Tracheostomy tube dimensions

Following are the dimensions of certain brands of size 8 standard length, cuffed, non-fenestrated tracheostomy tubes. Note the difference in inner diameter (ID), outer diameter (OD) and length.

<table>
<thead>
<tr>
<th>Tracheostomy tubes</th>
<th>ID Without inner cannula</th>
<th>ID With inner cannula</th>
<th>Outside Diameter</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shiley LPC</td>
<td>n/a</td>
<td>7.6mm</td>
<td>12.2mm</td>
<td>81mm</td>
</tr>
<tr>
<td>Shiley DCT</td>
<td>n/a</td>
<td>7.6mm</td>
<td>12.2mm</td>
<td>79mm</td>
</tr>
<tr>
<td>Kapitex Tracheotwist</td>
<td>n/a</td>
<td>8.0mm</td>
<td>11.4mm</td>
<td>76mm</td>
</tr>
<tr>
<td>Portex Blue Line Ultra</td>
<td>8.0mm</td>
<td>6.5mm</td>
<td>11.9mm</td>
<td>75.5mm</td>
</tr>
</tbody>
</table>

The outer diameter of the tracheostomy tube should be about $\frac{2}{3}$ to $\frac{3}{4}$ of the tracheal diameter. As a general rule, most adult females can accommodate a tube with an outer diameter of 10mm, whilst an outer diameter of 11mm is suitable for most adult males.$^{(38)}$
A tube should be no wider than necessary in order to minimize trauma to the tracheal wall and long term complications. The inner diameter of the tracheostomy tube will influence the work of breathing in a spontaneously breathing patient and in turn the course of weaning from the ventilator.

Special care is needed when checking the inner diameter of a tracheostomy tube. In the case of a dual cannula tube with the inner cannula in place, the quoted inner diameter on the packaging may or may not reflect this and may be much smaller than anticipated. In accordance with the International Standards Organization System for size designation, when the 15mm connector is part of the outer cannula, the manufacturer is not obliged to quote the inner diameter of the inner cannula, of which use is optional.

The ideal length of a tracheostomy tube is such that the tube tip lies a few centimeters above the carina. A tube which is too short carries a higher risk of accidental decannulation or partial airway obstruction due to poor positioning. A tube which is too long may impinge on the carina leading to discomfort and coughing. The tracheostomy tube should be fastened securely to the patient’s neck. Ventilator tubing should be supported to reduce leverage on the tube with risk of tracheal injury and accidental decannulation.
TRACHEOSTOMY MANAGEMENT

There should be a detailed plan of care for all patients with a tracheostomy which should be reviewed on a daily basis and updated if there is any change.

A) Patient assessment:
At the start of each shift the Staff Nurse caring for the patient with a tracheostomy should carry out a full assessment of the patient, which should include:
• Indication for tracheostomy
• Date of tracheostomy performed.
• Whether surgical or percutaneous tracheostomy.
• Type and size of tracheostomy tube & availability of spare & emergency equipment
• Cough effort
• Swallowing assessment.
• Sputum characteristics (Colour, Volume, Consistency, Odour)
• Check and change inner cannula for any buildup of secretions (see later)
• Check tracheostomy holder is secure and clean
• Check stoma dressing is clean
• Routine observations

This assessment should be documented on the care plan at the start of every shift.

B) Stoma care:
Care of the stoma is commenced in the immediate post-operative period. Daily inspection of stoma is done to ensure the skin is clean and dry to maintain skin integrity and avoid breakdown. Daily cleaning of stoma with 0.9% sterile saline solution followed by dressing is recommended.

Non-adhesive hydro cellular foam dressing is used if there is redness or excessive exudates. If visible signs of infection are present, a swab specimen for culture and sensitivity is taken. Over granulation at the site of the tracheostomy can be caused by an ill-fitting tube, excessive movement of the tube and/or in response to an infection at the wound site. A polyurethane dressing significantly reduces the rate of hyper granulation. Treatment may include local application of silver nitrate.
C) Changing tracheostomy tubes:

Whilst changing a tracheostomy tube can be hazardous, failing to change one when required also carries risks. Guidance from the Intensive Care Society points out that recommendation regarding the timing of tube changes is inconsistent and not evidence based\(^\text{(39)}\). It is recommended that tracheostomies without inner tubes be changed every 7-14 days, with the frequency decreasing as the stoma becomes better-formed and pulmonary secretions decrease. EEC guidance, from 1993, states that tracheostomies with inner tubes may be left in place for up to thirty days.

A tracheostomy tube inserted percutaneously fits more tightly within the stoma than does a tube that was inserted through a surgical incision. A big difference with percutaneous tracheostomies in the first few days after the stoma is created is that the tract will take 7-10 days to mature, compared with 2-4 days for a surgical tracheostomy.

If a tracheostomy tube becomes displaced in this early period, the tissues are likely to ‘spring’ back into their original places. The first change should not occur within 72 hours of the tracheostomy being sited and ideally not for 7 days after a percutaneous insertion. This is to allow for the formation of a more reliable ‘track’ for the new tube to pass through. Emergency airway equipment, including a smaller tracheostomy tube, & emergency drugs should be immediately available during the change.

In addition, Mitchell et al\(^\text{(7)}\) recommend that patients should not be discharged from the hospital with the tracheostomy tube sutured in place because the first tracheostomy tube change should be done before discharge.

Changing tracheostomy tubes can correct problems that cause ventilator asynchrony, improve comfort by reducing tube size, and correct a cuff leak due to tracheomalacia or Malposition or fracture of the tracheostomy tube or flange\(^\text{(40)}\). Most manufacturers recommend changing the tubes every 1 to 2 months.
D) Humidification:
Cold and unfiltered air is an irritant when inhaled and can lead to increased production and viscosity of secretions. This can be uncomfortable for the patient as well as causing tracheal mucosal keratinisation. The increasingly viscous secretions will be difficult to clear, causing sputum retention, atelectasis, impaired gas exchange and even life threatening blockage of the tracheostomy tube. It is therefore essential that inhaled oxygen is appropriately humidified using conventional techniques such as heat & moisture exchange (HME) filters or heated water baths.

E) Nutrition:
It is conventional to feed intubated, ventilated patients enterally unless there is a good reason not to. This is usually via a nasogastric or nasojejunal tube but it may be possible for patients’ with tracheostomies to be fed orally. However, swallowing is still adversely affected by the presence of a tracheostomy tube, which has a tendency to limit normal movement of the larynx. In addition, the inflated cuff causes a sense of pressure in the upper oesophagus and the difficulty that occurs with swallowing may result in an increased risk of aspiration of food into the lungs. Patients may be fed orally, with the cuff inflated or partially deflated, but staff must be alert to signs of aspiration, such as coughing, increased secretions and impaired gas exchange. It is prudent to commence with sips of water and some form of swallowing assessment.

F) Suctioning:
Suctioning the airway is an essential part of routine care of the tracheostomy patient as it is necessary to remove mucous, maintain a patent airway and avoid tracheostomy tube blockages. Tracheal damage may be caused by suctioning. This can be minimized by using the appropriate sized suction catheter, appropriate suction pressures & limiting suctioning within the tracheostomy tube. The pressure setting for tracheal suctioning is 80-120mmHg (10-16kpa). To avoid tracheal damage, the suction pressure setting should not exceed 120mmHg. Also the duration of suctioning, from passing the catheter and suctioning the tracheostomy tube should be completed within 5-10 seconds. A rough guide to choosing the correct size of suction catheter was proposed by Odell and others (1993):

\[(\text{Size of endotracheal or tracheostomy tube} - 2) \times 2 = \text{Correct French gauge}\]
**G) Cuff management:**

It is usual that the initial tracheostomy tube to be inserted will be a cuffed tube. The cuff provides a sealed airway. A cuffed tube is usually a temporary measure until a patient is weaned from a ventilator and the patient can control their own secretions, but may be required long term if the underlying condition does not improve sufficiently. The purpose of the cuff is to provide a closed system to allow effective ventilation and/or airway protection.

Management of the cuffed tracheostomy tube focuses on the appropriate management of the distal cuff. Tracheal capillary pressure lies between 20-30mmHg and an impairment of this blood flow will be caused by an obstruction between 22-37mm Hg. Monitoring cuff pressure is important because underinflation of the cuff promotes leakage of secretions around the cuff, a situation that can contribute to ventilator-associated pneumonia. However, over inflation of the cuff can cause numerous long-term complications, including tracheomalacia, tracheo innominate artery fistula, tracheal ulcerations, fibrosis, tracheal stenosis, and tracheoesophageal fistula.

In addition a patient with an inflated cuff may experience de-sensitization of the larynx, a reduced cough reflex and loss of voice or sound production. The accepted pressure is the minimum pressure required to prevent a leak but which must not exceed 35cmH2O. Recommendations suggest that the cuff pressure should be kept between 15-25cmH2O (10-18mm Hg).

**H) Decannulation:**

Need to continue with tracheostomy tube should be assessed on a daily basis. Decannulation should be attempted as soon as possible. Decannulation is a planned intervention for the permanent removal of the tracheostomy tube once the underlying indication for the tracheostomy has been resolved or corrected. Decannulation should be considered if patient has effective cough effort, is able to protect upper airway, has reasonably low FiO2 requirement, has low suction requirement and mechanical ventilation has not been needed for at least 24–36 h. It should be deferred if patient is delirious or agitated to avoid airway compromise.
There are several methods available to attempt weaning from tracheostomy tube such as progressively decreasing the size of tracheostomy tube, using a tracheostomy plug (known as tracheostomy button), or progressive capping of fenestrated tracheostomy tube until tolerated for about 48 h \cite{41-45}.

\textbf{I) Post-decannulation:}

Following the removal of the tracheostomy tube, the patient is left with an opening into their trachea. This needs protection from entry of water or foreign bodies and needs assistance to close. An airtight dressing is required to prevent the ongoing passage of air through the tract (tracheo-cutaneous fistula) which will delay wound healing. Where possible, the patient should be encouraged to apply gentle pressure to the dressing whilst coughing or speaking. This will reduce the air pressure through the fistula to the underside of the dressing, which will loosen the dressing’s contact with the skin, necessitating frequent dressing changes.

The wound should be airtight for at least two weeks. Tissue forming along the fistula may require specialist assessment and treatment.

The use of a standardized weaning procedure should reduce the risk of patients ‘failing’ a decannulation attempt. However, a patient’s condition can alter which may necessitate consideration for re-insertion of the tracheostomy.

The emergency tracheostomy equipment should be left at the patient’s bedside for 48 hours following decannulation to enable access to tracheostomy equipment for this period of post decannulation. This is particularly important to maintain for those patients transferred to other clinical settings within 48 hours post decannulation.
APPENDIX

Critical Care Algorithm for Dislodged Tracheostomy Tube

1. Dislodged tracheostomy?
   - Call Consultant if Tracheostomy type is Surgical

2. Does the patient require immediate action?
   - Yes / Wait for consultant help.

3. Tracheostomy type
   - Surgical
   - Percutaneous

   **AS FOR PERCUTANEOUS**
   - If performed using Bjork flap, consider the following
     - Remove the tracheostomy tube
     - Use stay suture to open tracheal window and reinsert tracheostomy tube (consider downsizing)
     - Extending neck may help re-insertion
   - ONE ATTEMPT ONLY - check ETCO2 waveform
   - CALL CONSULTANT IF FAILS

   **Old > 14 days**
   - Spontaneous breathing
     - Deflate tracheostomy cuff
     - Allow patient to breathe through mouth
     - Give 100% oxygen
     - Consider jaw thrust or use an oro pharyngeal airway to improve tidal volumes.
   - Ventilated
     - Remove tracheostomy tube
     - Cover wound with adhesive dressing
     - Re-establish airway from above using an ETT
     - If this fails use LMA / proceed LMA

   **New < 14 days**
   - Remove tracheostomy tube
   - Cover wound with adhesive dressing
   - Re-establish airway from above using an ETT
   - If this fails use LMA / proceed LMA

4. Consider malpositioned tube if:
   - Respiratory distress, high RR, decreased O2 saturation
   - Sudden decrease in tidal volume on pressure control or pressure support
   - Loss of end tidal CO2 trace
   - Change in waveform to sawtooth/ steep upstroke
   - Surgical emphysema

Re-inserting a tracheostomy tube into a false passage and ventilating through it will lead to surgical emphysema and may make laryngoscopy impossible. Avoid multiple attempts. Consider establishing an airway from above early rather than late.

The Bjork flap is a U-Shaped flap sutured to the lower skin edge producing a well-defined tract. Upward and lateral traction on stay sutures placed through the tracheal wall on either side of the tracheostomy will facilitate replacement of the tracheostomy.

Fig 7. An algorithm for managing a displaced tracheostomy tube. Reproduced with kind permission of Dr Peter Ford, Dept of Anaesthesia, Royal Devon & Exeter NHS Foundation trust, UK.
REFERENCES

The following references were reviewed and used when constructing this document.


38) ICS TICS. Standards for the care of adult patients with a temporary tracheostomy Standards and Guidelines 2008


