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Tracheostomy in critically ill patients

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Introduction

Tracheostomy has been traditionally performed to bypass upper airway obstruction [1]. In the ICU, 10-24% of patients require tracheostomy for prolonged respiratory support or weaning [2]. Most critically ill patients tolerate short-term tracheal intubation with minimal complications. Prolonged (longer than 1-2 weeks) tracheal intubation and mechanical ventilation are associated with adverse outcomes [3]. Patients requiring prolonged mechanical ventilation often need a tracheostomy for airway toilet, to aid respiratory weaning and for airway protection.

Surgical tracheostomy is generally performed in the operating theatre. In 1985, Ciaglia and colleagues [4] introduced bedside percutaneous dilatational tracheostomy (PDT). This avoided the need to transport the critically ill patient to the operating theatre. PDT has since become a popular choice and in many countries the majority of tracheostomies are performed in this way [5]. Surgical tracheostomy is reserved for difficult cases, when PDT is contra-indicated or has failed. This lecture will outline the recent advances in timing, techniques and safety of PDT.

Indications for tracheostomy

In the ICU tracheostomy is indicated in patients who requires prolonged weaning, have failed extubation, are unable to protect their airway or require prolonged tracheo-bronchial toilet [6] (Table 1). Tracheostomy is also considered in patients predicted to require prolonged mechanical ventilation to minimise or avoid laryngeal injury secondary to an extended period of translaryngeal intubation [7]. This can also avoid the undesirable side-effects of ongoing sedation allowing for increased patient comfort, cough, respiratory drive, mobility and gut function. Emergency tracheostomy is required for critical upper airway obstruction or the lost airway in the 'can't ventilate, can't intubate' scenario.

Table 1

Indications for tracheostomy

• Failed trials of extubation / failed weaning attempts from assisted ventilation
• Prolonged mechanical ventilation
• Tracheal access to remove thick pulmonary secretions (easier suction than with trans-laryngeal intubation)
• Airway protection and prevention of pulmonary aspiration (for example, patients with laryngeal incompetence, bulbar dysfunction such as cerebrovascular accidents, severe brain injury, spinal cord injury)
• Bypass of upper airway obstruction (for example, patients with trauma, infection, malignancy, laryngeal or subglottic stenosis, bilateral recurrent laryngeal nerve palsy, severe sleep apnoea)
• Trauma or surgery in the face/neck region

Translaryngeal and tracheostomy tubes provide the same functions - namely a patent artificial airway for ventilation, access for removal of secretions and a partially sealed system to limit pulmonary aspiration. Both methods bypass the normal protective mechanisms of an intact upper airway with a propensity to increase the risk of ventilator-associated pneumonia (VAP). Each technique will have specific advantages and disadvantages (Tables 2 and 3).

Table 2

Benefits of tracheostomy

- Easier mouth care
- Speeds enteral nutrition
- Earlier mobilisation of patients
- More comfortable than translaryngeal tubes
- Reduces need for sedative or analgesic drugs
- More effective cough and better co-operation with physiotherapy
- Reduced frequency of accidental extubation and endobronchial intubation
- Reduced complications of long-term translaryngeal intubation (such as, laryngeal damage, subglottic stenosis)
- Lower airway resistance, smaller dead space, reduced work of breathing-
  improved weaning from assisted ventilation
- Fenestrated tracheostomy tube or cuff deflation allows phonation and better communication.
- Potential earlier discharge from the ICU to a level II care unit or suitable ward
- Seamless transition between IPPV and CPAP, NIV and other modes of respiratory support

Table 3

Disadvantages of tracheostomy

- Invasive operative procedure
- Scarring in neck, heals by granulation often infected/colonised
  (PCT better than ST in this respect)
- May be unnecessary if patient improves quickly
- Procedural costs
- May be left in-situ too long
- Occasional severe long term complications including tracheomalacia, blocked tubes, haemorrhage and tracheal stenosis
- Portal for infection

The main complications of prolonged translaryngeal intubation are injury to the upper airway, VAP and adverse effects associated with sedation required for tube tolerance. Serious airway complications including subglottic stenosis are more likely if tracheal intubation is continued for more than two weeks. This has been demonstrated with 86% of patients developing subglottic stenosis after 17 days (mean duration) of translaryngeal intubation [8].

Why perform a tracheostomy

The suggested benefits of tracheostomy include protection from direct laryngeal injury and facilitation of nursing care such as airway suctioning, mouth hygiene and increased patient comfort. It has been claimed that tracheostomy decreases sedation/analgesic requirements and allows earlier patient mobilisation, feeding and physical therapy. Tracheostomy appears to facilitate weaning by decreasing the work of breathing especially in patients with limited respiratory reserve [9]. Other suggested benefits include fewer ventilator days and a reduced incidence of VAP [10, 11]. Patients with tracheostomy who need prolonged ventilatory support can be transferred onto a BiPAP machine. These patients are more likely to be accepted for Level II care. The benefits of tracheostomy are summarised in Table 2. Although tracheostomy has several advantages over standard intubation, having a tracheostomy is also associated with numerous short and long-term complications [12]. It may prove unnecessary, especially in cases where decannulation occurs soon after the procedure, but there is also an opposite tendency to prolong the time to decannulation. The disadvantages are summarised in Table 3.

The timing of tracheostomy

The timing of tracheostomy in critically patients is difficult and subjective. This has recently become an area of investigation. The decision to perform a tracheostomy remains one of professional judgement and physicians use their clinical expertise to determine who will require a tracheostomy and when. It is important to define objective criteria to identify patients most likely to benefit from this procedure. However, the current trend seems to be 'early' tracheostomy - within the first week of tracheal intubation [13, 14.] This is partly because PDT has lowered the threshold for performing the procedure.

In 1981 a prospective study compared the complication rates of prolonged tracheal intubation with tracheostomy. Patients who underwent tracheostomy had a high rate of complications [7]. This study concluded that tracheostomy should not be recommended during the first three weeks of tracheal intubation. This practice continued for some years because there was insufficient evidence to support the hypothesis that the timing of tracheostomy alters the duration of mechanical ventilation or the extent of tracheal injury [15]. Since that time no other study has found such a high complication rate, suggesting an improvement in standards of care.

Recently, several studies [13, 16-18] have supported the use of 'early' tracheostomy in ICU patients. The definition of 'early' remains unclear, with no consensus in the literature; definitions vary between two and 10 days. Tracheostomies performed before day 10 are associated with lower cost of hospitalisation and shorter duration of mechanical ventilation [10]. Tracheostomy performed within 48 h of tracheal intubation are associated with a reduced length of ICU stay, reduced ventilator days and lower mortality [13]. Reduced sedation requirements and increased patient mobility are potential explanations for this improved outcome. Another reason may be that physicians reserve this procedure for patients more likely to survive ICU. However, these studies are underpowered and have design weaknesses. A systematic review recently compared 'early' with 'late' tracheostomy and failed to show any significant difference in either mortality or risk of developing nosocomial pneumonia [14].

A recently published trial comparing early (within 4 days) and late (after 14 days) tracheostomy failed to show a difference in mortality, duration of mechanical ventilation, length of ICU stay or major infectious complications [19]. A multi-centre UK trial (TRACMAN) is nearing completion and its results may add to the debate.

The main barrier to 'early' tracheostomy appears to be the inability of clinicians to predict accurately the need for prolonged mechanical ventilation [20, 21]. If an 'early' strategy for tracheostomy is pursued, it is anticipated that this procedure would inevitably be performed on some patients who would otherwise have been successfully extubated. Those centres geared towards early tracheostomy may also lose a degree of expertise in effective patient weaning from mechanical ventilation and strategies employed to prevent re-intubation.

There are cohorts of patients with end-stage neuromuscular or cardiorespiratory disease who may be better served by removal of the translaryngeal tube and palliative care rather than performing a tracheostomy. A tracheostomy in terminally ill patients may only serve to prolong dying with all the problems related to ethical principles of futility and resource allocation.

In certain patient populations early tracheostomy appears to be particularly beneficial - including those patients with severe trauma [22], burns to the face, neck and airway, those with a neurological injury who are unable to protect their airway because of bulbar dysfunction and reduced level of consciousness, and those with neuromuscular weakness (such as myasthenia gravis or Guillain-Barre syndrome).

Tracheostomy techniques

Tracheostomy can be performed by conventional surgical tracheostomy in the operating theatre or at the bedside. The increased popularity of the PDT has made surgical tracheostomy the back-up technique in many centres for patients that have failed PDT, predicted difficult PDT, abnormal anatomy and for emergency situations. Irrespective of the technique used, tracheostomy carries the inherent risks of bleeding, airway obstruction, hypoxia, hypercarbia, pneumothorax and other life threatening complications. In an already critically ill patient there is little margin for error and all procedures should be performed or directly supervised by competent operators.

Surgical tracheostomy

Open techniques are usually performed by ENT or head and neck surgeons. A transverse skin incision is made between the lower border of the cricoid cartilage and suprasternal notch. The strap muscles are retracted laterally to expose the underlying thyroid isthmus and the trachea. The thyroid isthmus is either retracted cephalad or divided exposing the tracheal rings. A transverse incision is made between the second and third tracheal rings and the tracheostomy tube placed under direct vision. If performed at the bedside this procedure is more difficult because of suboptimal operating conditions such as lighting and operating on a wide bed.

Percutaneous tracheostomy

PDT had been found safe in terms of immediate and late complications. Many percutaneous techniques have been developed over the last decade using either multiple or single dilators to form a tracheal stoma. The anterior tracheal wall can be dilated inside out or from outside in, after bronchoscopically-guided midline placement of an introducer needle and a guide wire [23]. A tracheostomy tube is then inserted through the stoma with the help of a loading dilator. The single dilator technique is by far the most popular (see below) [5].

Multiple dilator technique

The classical Ciaglia technique has provided the most experience. The inward force produced during dilatation of the tracheal stoma using multiple dilators and tracheostomy tube placement has been reported to be associated with posterior tracheal wall tears and tracheal ring fractures [24].

Single dilator techniques

In an attempt to avoid or minimise tracheal damage single-step dilators, made up of softer materials with hydrophilic surfaces, have been introduced (Blue Rhino kit, Cook; Ultraperc kit, Portex, and the Percutan kit, Tracoe). The single dilator technique claims the following advantages over the multiple dilator technique:

- The single dilator has a hydrophilic coating which, when wet, reduces friction and thus allows smooth dilatation of the tracheal stoma. The stomal dilatation appears to be quicker and less traumatic.
- The faster technique reduces the time during which dilators and bronchoscope obstruct the airway, reducing the risk of hypercarbia and hypoxia.
- The single-step dilator is flexible, tapering to a soft malleable tip, which will bend to the required angle to follow the direction of the guide wire down the trachea.
- It avoids aerolisation of blood and secretions as dilators are changed. The continuous tamponade effect reduces bleeding during the procedure.

There are a number of other kits commercially available including Fantoni's translaryngeal technique [25], guidewire forceps dilator technique [26], Percutwist single threaded dilator [27] and the balloon dilation technique [28]. Several clinical trials have compared these techniques without any method being shown to be superior [29]. Operator experience and patient selection are crucial determinants of complications. For the reasons stated above the single dilator technique is currently the most popular in the UK [5].

Emergency PDT

Until recently PDT has been considered an elective procedure. Increasingly, however it has been used in emergency situations where orotracheal intubation has failed [30, 31]. Further studies will be required to confirm whether this method is preferable to surgical tracheostomy. We have recently used the Blue Rhino method for emergency tracheostomy with good results.

With the reduction in numbers of surgical tracheostomies in the UK [5] there is an issue with training of surgeons and their competence in this technique. This could have an impact on their ability to perform the procedure, especially in an emergency setting.

Contra-indications to PDT

Morbid obesity, unusual anatomy, repeated tracheostomy, poor gas exchange, high positive end- expiratory pressure (PEEP), severe coagulopathy and other conditions as shown in the Table 4 have been cited as relative contra-indications to PDT. Absolute contra-indications include the need for an emergency airway in the presence of a tracheal tumour and children < 12 yr because of the risk of damage to the softer cartilaginous airway. The number of relative contra-indications to PDT reduces with increasing experience of the operator, the use of fibreoptic bronchoscopy [5] and ultrasound imaging of the neck [32].

Table 4

Relative contra-indications to PDT

- Children < 12 years old
- Uncorrectable coagulopathy
- Active infection over the anterior neck
- Local malignancy in trachea
- Unstable cervical spine fracture
- Morbid obesity (BMI >35)
- Gross anatomical distortion of the neck
- Previous neck surgery or tracheostomy
- Previous radiotherapy to the neck
- Extensive burns to the neck
- Requirement of high PEEP (> 15cm H2O) or FiO2 (>0.6)
- Haemodynamic instability
- Raised intracranial pressure
- Patient unlikely to survive >48h

Ultrasound scanning of the neck and bronchoscopy

Two trained operators are required for PDT: one to perform the procedure and one to manage the airway. Ideally the procedure should be performed during normal working hours to ensure supervision and support from senior staff members and other specialists, if required.

Ultrasound scanning of the neck prior to PDT allows visualisation of the anterior neck structures, particularly blood vessels and the depth and angulation of the trachea [32]. Useful information about adjacent structures helps with the risk-benefit analysis of surgical tracheostomy vs PDT. Imaging can also guide needles and dilators away from at-risk structures.

Bronchoscopy, using a fibreoptic scope passed through the tracheal tube, should be used to guide the correct placement of the introducer needle, guidewire and tracheostomy tube [23]. Direct visualisation reduces posterior tracheal wall damage and tube misplacement. Many authors have advocated bronchoscopy during PDT, citing a decreased rate of operative complications [33, 34]. However, the presence of a fibreoptic scope may hinder ventilation, increasing the risk of hypoxia and hypercarbia with an associated rise in intracranial pressure in susceptible patients [35]. It should be appreciated that bleeding, distortion of structures and obstruction of the visual field with larger dilators may prevent endoscopic visualisation of damage until after it has occurred. An alternative approach includes the use of a rigid, small-diameter scope, such as a Bonfil's laryngoscope, which interferes less with ventilation and avoids potential expensive damage to the flexible scope by needle puncture [35].

Complications

Tracheostomy is not without risk. Complications can be classified into immediate, early and late (Table 5). Bleeding, hypoxia, pneumothorax, trauma to the trachea and surrounding structures and technical failure are common immediate complications. Most complications are reported only as case reports and their frequency appears to be inversely proportional to the experience of the operator.

Table 5

Complications after tracheostomy

Immediate
• Bleeding
• Puncture of the tracheal tube cuff
• Needle damage to the fibreoptic bronchoscope
• Dislodgement of the tracheal tube
• Anaesthetic awareness
• Hypoxia
• Hypercapnia
• Increased intracranial pressure
• Damage to the trachea
• Damage to the oesophagus
• False passage of tracheostomy tube
• Pneumothorax/ pneumomediastinum
• Airway obstruction due to blood clot
Early
• Collapsed lung
• Surgical emphysema
• Dislodgement of the tracheostomy tube
• Tension pneumothorax
Late
• Minor bleeding erosion into small local vessels
• Major bleeding (for example, erosion into innominate artery/ vein)
• Local stomal infection
• Subglottic / tracheal stenosis
• Tracheo-oesophageal fistula
• Persistent tracheocutaneous fistula
• Permanent voice changes
• Difficulty in swallowing
• Scarring and tethering of the trachea

Major complications are rare but can be devastating. Limited soft tissue dissection in PDT results in less tissue damage and lowers the risk of bleeding and wound infection compared with surgical tracheostomy. There is always a risk of tracheal damage including rupture and displacement of the tracheal rings, tear of the posterior tracheal wall and formation of a tracheo-oesophageal fistula. All of these may be associated with bleeding and the formation of false passages as well as major air leaks. Modifications in the equipment (single dilator) and improvements in the technique of insertion (routine use of endoscopic guidance) appear to reduce the incidence of immediate peri-operative complications [36]. The use of ultrasound scanning to examine the vasculature of the neck in relation to the stoma site may further reduce the incidence of complications [32]. A choice in size and length of a tracheostomy tube is essential to prevent early tube-related complications [37].

A number of meta-analyses have compared surgical tracheostomy with PDT in terms of wound infection, bleeding, and overall mortality, as well as major peri- operative complications [38, 39]. The incidence of clinically important wound infection and bleeding is 5-6% [40]. The majority of the meta-analyses suggest that PDT reduces the overall incidence of clinically relevant bleeding, wound infection, procedural mortality and there is a trend towards shorter duration of translaryngeal intubation prior to the procedure being performed [38]. PDT also gives a better cosmetic result following decannulation. Studies demonstrate a procedural mortality rate approaching zero and morbidity rates around 6-7% with no fatalities attributable to complications, although two procedural fatalities have recently been reported involving intractable bleeding [41, 42].

While long-term complications appear uncommon, incomplete follow-up and lack of consistent definitions make conclusions difficult. Uncontrolled studies, however, have found that clinically relevant tracheal stenosis was uncommon after PDT [43, 44]. Tracheal stenosis can occur at or either side of the stoma, at the level of cuff, or at the tip of the tube. The main cause of the stenosis appears to be mucosal ischaemia. Most stenoses tend to be asymptomatic unless they reduce the tracheal lumen by > 50%. The incidence of clinically significant stenosis has been variably reported in studies, ranging from 2.5-10% [45, 46]. Tracheal stenosis caused by PDT may be significantly closer to the vocal cords compared with surgical trachesotomy, making tracheal resection and end-to-end anastomosis very difficult [47]. This provides a strong argument for ensuring appropriate levels of stoma formation by passing the introducer needle between the second or third tracheal rings, or one space lower under direct bronchoscopic visualisation. However, needle insertion below the fourth tracheal ring poses a risk of tube erosion into adjacent blood vessels. Suprastomal tracheal ring fracture is a common finding in PDT, reported in up to 87% of cases. This may encourage local tissue granulation and formation of stenosis and tracheomalacia [48].

Tracheo-innominate artery fistula is an uncommon but life threatening complication [49]. It is usually fatal unless treatment is instituted immediately. Many reasons have been suggested including pressure necrosis from a high cuff pressure, tracheal wall trauma and perforation from a malpositioned tube tip, low tracheal incision and prolonged tracheostomy. Post-tracheostomy bleeding occurring from 3 days to 6 weeks after insertion should be considered to be from a tracheo-innominate artery fistula unless proven otherwise.

Decannulation

Tracheostomy tubes should be removed as soon as possible to regain the normal physiological functions of active coughing, upper airway warming, humidification and filtering of air. Decannulation should be considered when patients demonstrate a satisfactory respiratory drive, a good cough and the ability to protect their own airway. Patients who show no signs of tiring on continuous positive airway pressure (CPAP) or a T-piece with low flow oxygen therapy are candidates for decannulation. Coughing secretions up into the tracheostomy tube is a good sign, whereas generalised weakness and inability to hold the head up are predictors of unsuccessful decannulation. An impaired conscious level also reduces the chances of success. There is a common tendency to leave tubes in too long whilst clinicians await the perfect time to decannulate, and time consuming referrals to speech therapy or physiotherapy are made. If left too long it can stimulate mucous production. It should be appreciated that an effective cough relies on the build up of positive pressure within the trachea against a closed glottis and then sudden release to generate a cough. This cannot be achieved with a large bore cannula open within the trachea. You may be doing your patient a disservice by leaving the tube in-situ. It has recently been reported that an intensivist-led team performing a post-ICU tracheostomy round has resulted in timely decannulation of tracheostomies, reducing hospital length of stay [50].

Following decannulation, most tracheostomy stomas are allowed to granulate without suturing. They achieve a functional seal within 2-3 days. These partially healed wounds can be quickly re-opened with artery forceps in the first few days after closure, if necessary. Occasional patients will require ENT referral for tethered scars or a sinus. At long term follow-up, clinicians should be aware of the rare but significant complication of tracheal stenosis giving rise to respiratory symptoms of stridor, persistent cough and voice changes.

Key Learning Points

- Certain patients in the ICU require a tracheostomy for prolonged airway toilet, to aid respiratory weaning and for airway protection. Tracheostomy appears to facilitate weaning, nursing care and allows earlier patient mobilisation.
- Intensivists should exercise clinical judgement to determine who will benefit from early (first week) or late (second week or later) tracheostomy.
- Prior ultrasound scanning of the neck and bronchoscopic visualisation throughout the procedure can improve the safety of percutaneous tracheostomy.
- There are numerous percutaneous tracheostomy techniques. The single dilator technique is the most widely used.
- Tracheostomy decannulation is often delayed and should be considered when patients demonstrate a satisfactory respiratory drive, a good cough and the ability to protect their own airway.

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